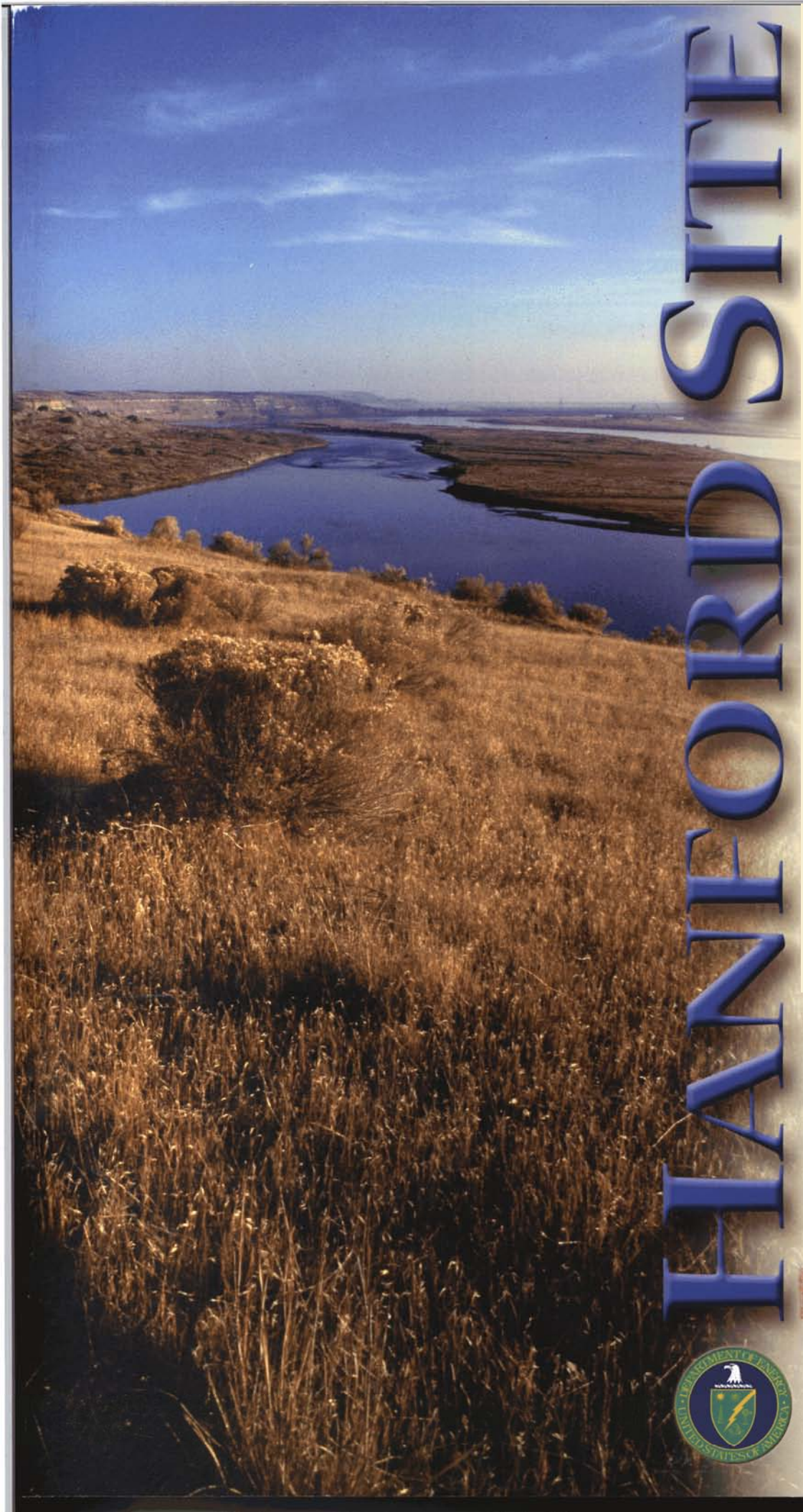

HANFORD SITE

Environmental Report 2000

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

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The cover photo is by L. E. Bowman and is used with permission. The photo is looking south from the Wahluke Slope over the Columbia River. The land in the immediate foreground of the photo is part of the Hanford Reach National Monument. The 100-F Area of the Hanford Site is in the distance on the west side of the river.

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01-OSS-274

Addressees:

THE HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR (CY) 2000 (PNNL-13487), RICHLAND, WASHINGTON, SEPTEMBER 2001

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

This report includes information for CY 2000 (including some historical and early 2001 information) and contains sections summarizing the results of environmental monitoring efforts on and around the site, information on the Hanford Site's conformance to environmental permits, the status of the site's compliance with federal, state, and local regulations, and discusses important issues and actions.

The report was prepared for DOE by the Pacific Northwest National Laboratory (PNNL) with the support of other site contractors and describes programs conducted by PNNL, the research and development contractor; Fluor Hanford, Inc., the prime contractor for the nuclear legacy cleanup; Bechtel Hanford, Inc., the environmental restoration contractor; CH2M HILL Hanford Group, Inc., the contractor responsible for nuclear and chemical waste stored in Hanford's 177 underground storage tanks; MACTEC-ERS, a prime contractor to DOE's office in Grand Junction, Colorado, which is performing vadose zone work at Hanford; and numerous subcontractors and affiliate companies at the Hanford Site.

If you have any questions or comments about this report, you may contact us, or Dana Ward, DOE Richland Operations Office, Office of Site Services, on (509) 372-1261 or by e-mail at Dana_C_Ward@rl.gov.

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Attachment:
Hanford Site Environmental Report

PNNL-13487

Hanford Site Environmental Report for Calendar Year 2000

(Including some historical and early 2001 information)

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September 2001

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under contract DE-AC06-76RL01830, with
contributions from CH2M HILL Hanford
Group, Inc.; MACTEC-ERS; Fluor Hanford, Inc.
and its affiliate companies; and Bechtel Hanford, Inc.
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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, its primary intent is to provide useful summary information to members of the public, public officials, regulators, Hanford Site contractors, and elected representatives. Appendix A lists acronyms, abbreviations, conversion information, and nomenclature that may be useful for understanding the report.

This report is produced for the DOE Richland Operations Office, Office of Site Services, 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 and Fluor Hanford, Inc. and its affiliate companies. Bechtel Hanford, Inc.; CH2M HILL Hanford Group; 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 at the Consolidated Information Center on the campus of Washington State University at 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 is issued in two hard-copy formats and two electronic formats. 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-site.pnl.gov/envreport or http://www.hanford.gov/docs/annualrp00/index.htm. The large report is also available on computer CD. NOTE: The Internet address published in previous reports in this series is no longer valid. For technical reasons, the file server supporting the old Internet address was removed from service in 2000 and was not replaced. Past reports are now available at the Internet address provided above.

Inquiries regarding this report may be directed to Mr. D. C. (Dana) Ward, DOE Richland Operations Office, Office of Site Services, P.O. Box 550, MS A2-15, Richland, Washington 99352 (Dana_C_Ward@apimc01.rl.gov) or to Mr. R. L. (Roger) Dirkes, Pacific Northwest National Laboratory, P.O. Box 999, MS K6-75, Richland, Washington 99352 (rl.dirkes@pnl.gov).

Summary

L. F. Morasch

Each year, the U.S. Department of Energy (DOE) publishes this integrated environmental report on the Hanford Site to summarize environmental data and information, describe environmental management performance, demonstrate the status of compliance with environmental regulations, and highlight major environmental programs and efforts. 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 radiation exposure to the public from 2000 Hanford Site activities
- present effluent monitoring, environmental surveillance, and groundwater protection and monitoring information
- discuss activities to ensure quality.

DOE's current mission at the Hanford Site is twofold: environmental management and science and technology. It is the policy of DOE that all activities be carried out to comply with applicable federal, state, and local laws and regulations, DOE Orders, Secretary of Energy Notices, and directives, policies, and guidelines from DOE Headquarters and site operations.

Compliance with Environmental Regulations in 2000

Activities at the Hanford Site in 2000 were conducted in compliance with DOE directives, federal environmental protection statutes, and related state and local environmental protection regulations. A key element in Hanford's compliance program is the Tri-Party Agreement. The Tri-Party Agreement is an agreement among the Washington State Department of Ecology, EPA, and DOE to achieve compliance with the remedial action provisions of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) and with treatment, storage, and disposal unit regulation and corrective action provisions of the *Resource Conservation and Recovery Act* (RCRA). In 2000, 45 of 48 specific Tri-Party Agreement cleanup milestones were completed on or before their required due dates. Two milestones were delayed because of programmatic issues, and one remained at issue at the time of this report.

Cleanup activities on the Hanford Site generate radioactive, hazardous, and mixed waste. This waste is handled and prepared for safe storage on the site or shipped to offsite facilities for treatment and disposal. In 2000, cleanup activities generated 441,000 kilograms (973,000 pounds) of solid mixed waste and 700,000 kilograms (1.5 million pounds) of radioactive waste on the Hanford Site. There were also 1,381 kilograms (3,045 pounds) of mixed waste and 6.9 million kilograms (15.3 million pounds) of radioactive waste received at Hanford from offsite.

In addition to newly generated waste, significant quantities of legacy waste remain from years of nuclear material production and waste management activities. Most legacy waste from past operations at the Hanford Site resides in RCRA-compliant waste sites or is stored in several places

awaiting cleanup and ultimate safe storage or disposal. Examples include high-level radioactive waste stored in single- and double-shell tanks and transuranic waste stored in vaults and on storage pads (see Section 2.5 for details).

The site's compliance with federal acts in 2000 is summarized in Table S.1. For a detailed discussion of the site's compliance with environmental regulations during 2000, refer to Chapter 2 of this report.

Table S.1. Compliance with Federal Acts at the Hanford Site in 2000

Regulation	What it Covers	2000 Status
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	Sites already contaminated by hazardous materials	Work on these sites was in compliance with CERCLA requirements and met the schedules established by the Tri-Party Agreement.
Emergency Planning and Community Right-to-Know Act	The public's right to information about hazardous chemicals in the community and establishes emergency planning procedures	The Hanford Site was in compliance with the reporting and notification requirements contained in this act.
Resource Conservation and Recovery Act (RCRA)	Hazardous waste being generated, transported, stored, treated, or disposed. The act primarily covers ongoing waste management at active facilities.	The Washington State Department of Ecology identified several violations during 2000. The violations identified RCRA-regulated waste that was shipped offsite and violations of the management agreement. Another violation identified 26 drums of dangerous and/or mixed waste collected more than 20 years ago that were improperly labeled, and a drum of flocculent that was not properly designated as required by WAC 173-303. Other violations included an inspection matter and the application of regulations to determine the integrity of the double-shell tank system. All problems identified have been, or are being, corrected.
Clean Air Act	Air quality, including emissions from facilities and diffuse and unmonitored sources	According to the Washington State Department of Health, air emissions from Hanford Site facilities were well below state and federal standards. However, the calibration of some air monitoring equipment needed to be corrected, and in one instance, proper permits were not obtained.
Clean Water Act	Discharges to U.S. waters	Copper, manganese, and zinc were detected at levels higher than permits allow at one discharge line near the 300 Area shoreline. Also, some 300 Area procedures had to be corrected and equipment at the 100-N Sewage Lagoon had to be repaired. In addition, the permit limits for pH and total suspended solids were exceeded at the 100-N Sewage Lagoon, though the cause was believed to be an algae bloom caused by warm weather.

Regulation	What it Covers	2000 Status
Safe Drinking Water Act	Drinking water supplies operated by DOE	All Hanford drinking water systems were in compliance with guidelines according to the Washington State Department of Health. There was one exception on February 3, 2000, when sampling results showed the maximum contaminant level of coliform bacteria was exceeded at the 200-East Area, but no *E.coli* were found.
Toxic Substances Control Act	Primarily chemicals called poly-chlorinated biphenyls	Hanford was in compliance with the requirements of this act.
Federal Insecticide, Fungicide, and Rodenticide Act	Storage and use of pesticides	Hanford was in compliance with the requirements of this act.
Endangered Species Act	Rare species of plants and animals	Hanford activities complied with the requirements of this act. The Hanford Site has eight plant species, two fish species, and five bird species on the federal or state list of threatened or endangered species.
American Indian Religious Freedom Act, Antiquities Act, Archaeological and Historic Preservation Act, Archaeological Resources Protection Act, Historic Sites Buildings and Antiquities Act, National Historic Preservation Act, and Native American Graves Protection and Repatriation Act	Cultural resources	Hanford was in compliance with the requirements of these acts.
National Environmental Policy Act	Environmental impact statements for federal projects	Hanford was in compliance with the requirements of this act.
Migratory Bird Treaty Act	Migratory birds or their feathers, eggs, or nests	Hanford was in compliance with the requirements of this act. There are over 100 species of birds that occur on the Hanford Site that are protected by this act.

Environmental Monitoring

Environmental monitoring at the Hanford Site includes effluent monitoring, near-facility environmental monitoring, surface environmental surveillance, groundwater monitoring, and vadose zone monitoring. Facility operators perform effluent monitoring by analyzing samples collected near points of release to the environment. Near-facility monitoring includes the analysis of environmental samples collected near major nuclear-related installations, waste storage and disposal units, and remediation sites. Surface environmental surveillance consists of sampling and analyzing various media on and around the site (including the Columbia River) to detect potential contaminants and to assess their significance to environmental and human health. Groundwater sampling is conducted on the site to determine the distribution of

radiological and chemical constituents in groundwater. The strategy for managing and protecting groundwater resources at the Hanford Site focuses on protection of the Columbia River, human health, the environment, treatment of groundwater contamination, and limitation of groundwater migration. Vadose monitoring activities were conducted to better understand and alleviate the spread of subsurface contamination.

The overall objectives of these 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.

Environmental monitoring and surveillance results for 2000 are summarized in Table S.2. For detailed discussions of results, refer to the appropriate sections of this report.

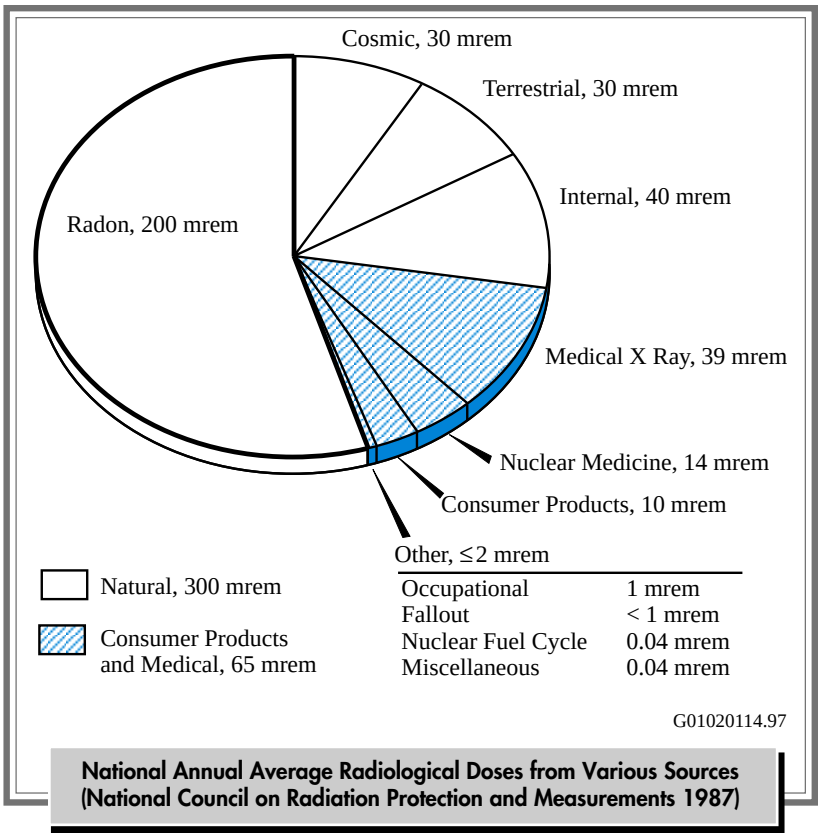
Table S.2. Hanford Site Monitoring Results for 2000

	What was Monitored?	The Bottom Line
Air	Air sampling equipment collected particles and gases, which were analyzed for radioactive and non-radioactive materials. Air was sampled at 110 locations on Hanford, 11 perimeter locations, 8 nearby communities, and 2 distant communities.	All measurements of radioactive and non-radioactive materials in air were below recommended guidelines.
Columbia River Water	Columbia River water was collected from 15 locations throughout the year. Water samples were analyzed for radioactive and chemical materials. Water in the Columbia River continues to be designated Class A (Excellent) by the state of Washington. This designation means that the water is usable for substantially all needs.	As in past years, small amounts of radioactive materials were detected downriver from Hanford. However, the amounts were all far below federal and state limits. During 2000, there was no indication of any deterioration of Columbia River water quality resulting from site operations along the Hanford Reach.
Columbia River Shoreline Springs	Groundwater discharges to the Columbia River via surface and subsurface locations. Discharges above the water level of the river are identified as riverbank springs. Samples of spring water were collected at seven locations along the Columbia River shoreline.	Samples collected at the springs contained contaminants at levels above drinking water standards. However, concentrations in river water downstream of the shoreline springs remained far below federal and state limits.
Groundwater	Groundwater samples were collected from 694 wells to analyze water quality. Water levels were measured in several hundred wells on the site to map groundwater movement.	Groundwater monitoring is focused on preventing the spread of contamination. Samples show that groundwater contaminant plumes are moving slowly from beneath former waste sites toward the Columbia River. Contaminant concentrations are declining in the largest plumes because of spreading and radioactive decay.

	What was Monitored?	The Bottom Line
Vadose Zone	The vadose zone is the region between the ground surface and the top of the water table. Vadose zone characterization and monitoring are conducted to better understand and alleviate the spread of subsurface contamination.	Vadose zone characterization was conducted at four sites in the 200 Areas and at one site in the 100-DR Area. Vadose zone monitoring occurred at four sites in 2000. Technical demonstrations are designed to result in new, innovative methods for environmental monitoring and cleanup on the Hanford Site. A small-diameter, passive neutron tool and a small diameter spectral gamma logging tool were demonstrated in 2000. Both tools could result in substantial cost savings over conventional methods of characterization and monitoring. In addition, the first of four field tests to evaluate how contaminant plumes move in the vadose zone were completed.
Drinking Water	The quality of the drinking water supplied by 11 DOE-owned systems on the Hanford Site was analyzed.	All DOE-owned drinking water systems on the Hanford Site were in compliance with Washington State and EPA regulations. The concentrations of radiological contaminants in all samples were below state and federal standards.
Food and Farm Products	Samples of milk, leafy vegetables, vegetables, fruit, and wine were collected from 15 locations around the Hanford Site.	Radionuclide levels in samples of apples, beet tops, cabbages, tomatoes, potatoes, hops, wines, and milk were at or near normal environmental levels.
Fish and Wildlife	Game animals on the site and along the Hanford Reach and fish from the Columbia River were monitored at 14 locations. Carcass, bone, and muscle samples were analyzed to evaluate radionuclide levels.	Samples of elk, pheasant, quail, deer, and Columbia River fish were collected and analyzed. Strontium-90 was the only radionuclide, possibly of Hanford origin, detected in 2000 and was found only in bone samples. Radionuclide levels in edible tissues were all below DOE detection limits with the exception of potassium-40, which is a naturally occurring radionuclide.
Effluent Monitoring	Liquid effluents and airborne emissions that may contain radioactive or hazardous constituents are continually monitored on the Hanford Site.	Some quantities of radionuclides were released to the environment at state and federally permitted release points. Tritium above natural background levels is released to the ground at the State-Approved Land Disposal facility in the 200 Areas under a state-approved discharge permit.
Hanford Wildfire, June 2000	Samples of air, soil, ash, farm products and natural vegetation were collected on or around the Hanford Site.	Although the fire may have resulted in the spread of small amounts of Hanford contaminants, all samples collected were well below regulatory limits.

Potential Radiological Doses from 2000 Hanford Operations

During 2000, potential radiological doses to the public and biota from Hanford operations 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 GENII computer code and Hanford-specific parameters. The potential dose to the maximally exposed individual in 2000 from site operations was 0.014 mrem compared to 0.008 mrem in 1999. To put this value into perspective, the national average dose from background sources, according to the National Council on Radiation Protection, is ~300 mrem/yr (3 mSv/yr), and the current DOE radiological dose limit for a member of the public is 100 mrem/yr (1 mSv/yr).



National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

Other Hanford Environmental Programs

Climate and Meteorology

Meteorological measurements are taken to support Hanford Site emergency preparedness, site operations, and atmospheric dispersion calculations. Weather forecasting and maintenance and distribution of climatological data are provided. The data are provided by the Hanford Meteorology Station, which is located on the 200 Areas plateau.

Cultural Resources

Management of archaeological, historical, and traditional cultural resources at the Hanford Site complies with the requirements of various federal laws. During 2000, 113 cultural resource reviews were requested and conducted on the Hanford Site to comply with Section 106 of the *National Historic Preservation Act*.

Monitoring conducted during 2000 focused on four sites: Locke Island erosion, archaeological sites affected by visitors or nature, historic buildings, and places with Native American burials. A total of 96 archaeological sites, a building, and cemetery or burial locations were monitoring during 2000.

Public involvement is an important component of cultural resource management. To accomplish this goal, DOE developed mechanisms that allow the public access to cultural resources information and the ability to comment and make recommendations concerning the management of cultural resources on the Hanford Site. Native American involvement included the completion of several surveys, construction monitoring, and monthly meetings on cultural resource issues.

Community Operated Surveillance Program

This program was initiated in 1990 to increase the public's involvement in and awareness of Hanford's surveillance program. During 2000, nine radiological air sampling stations were operated by local teachers at selected locations around the site perimeter.

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 crosscheck 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.

Acknowledgments

The production of this report was managed by the Pacific Northwest National Laboratory's Public Safety and Resource Protection Program under the direction of R. L. Dirkes.

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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Basin City Elementary School, Basin City: C. L. Stevenson, Manager, and K. McEachen, Alternate Manager

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

The authors appreciate the comprehensive reviews of the draft report by A. L. Bunn, P. S. Stansburg, D. J. Strom, and K. R. Price (Pacific Northwest National Laboratory), and M. F. Jarvis (U.S. Department of Energy, Richland Operations Office).

A review of the compliance sections was coordinated by P. J. Krupin, and conducted by P.F.X. Dunigan, Jr., R. F. Guercia, B. D. Williamson, C. V. Smith, D. W. Templeton, L. Guillen, and C. A. Rodriguez (all with the U.S. Department of Energy, Richland Operations Office).

Additional contributors to the chapter discussing the June 2000 Hanford Site Wildfire (Section 5.0) included C. J. Perkins, D. J. Hoitink, L. L. Hale, W. H. Rickard, B. L. Tiller, A. R. Johnson, B. M. Gillespie, and K. R. Price.

The report was prepared by Pacific Northwest National Laboratory staff: L. F. Morasch, text editor, and K. R. Neiderhiser, text processor. Graphics were prepared by D. L. Liddell (Lockheed Martin Services, Inc.), M. A. Chamness, C. A. Newbill, D. C. Lanigan, J. T. Rieger, W. D. Webber, and R. K. Zufelt (Pacific Northwest National Laboratory), P. Call (U.S. Fish and Wildlife Service), and Hanford Site Central Mapping Services. J. Winslow (WinSome Design, Richland, Washington) designed the report cover and layout. Duplicating and printing arrangements were managed by S. J. Kophs, who was supported by G. A. Rowlette. This report was produced using Adobe® PageMaker and formatted for the Internet by J. C. Melland and others in Pacific Northwest National Laboratory's Scientific and Technical Information Department.

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.

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Contents

Figures

Tables

1.0 Introduction

R. W. Hanf and K. R. Price

This Hanford Site environmental report is produced through the joint efforts of the principal site contractors (CH2M HILL Hanford Group, Inc.; MACTEC-ERS; Pacific Northwest National Laboratory; Fluor Hanford, Inc. and its affiliate companies; and Bechtel Hanford, Inc. and its preselected subcontractors). 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, this report provides a short introduction to the Hanford Site and its history; discusses the site mission; and briefly highlights the site's various waste management, waste remediation, environmental restoration, effluent monitoring, environmental surveillance, and environmental compliance programs and projects. Included are summary data and descriptions for the Hanford Site Groundwater/Vadose Zone Integration Project, the Environmental Restoration Project, the Effluent and Near-Facility Environmental Monitoring Program, the Surface Environmental Surveillance Project, the Hanford Groundwater Monitoring Project, the Hanford Cultural Resources Laboratory, Ecosystem Monitoring and Ecological Compliance, the Meteorological and Climatological Services Project, and information about other programs and projects. Also included are sections discussing environmental occurrences, current issues and actions, environmental cleanup and restoration activities, compliance issues, and descriptions of major operations and activities. This year's report also includes a brief discussion about a wildfire that occurred on the Hanford Site in June 2000. Readers interested in more detail than that provided in this report should consult the technical documents cited in the text and listed in the reference sections. 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).

1.1 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 waste. 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 Hanford Site has two major missions: 1) environmental management and 2) science and technology. The environmental management mission includes the following activities:

- **managing waste** and the handling, storage, treatment, recycling, and disposal of radioactive, hazardous, mixed, or sanitary waste 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 costs 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 proceeding to permanent deactivation and shutdown of the facility
- **maintaining and cleaning up** several hundred inactive radioactive, hazardous, and mixed waste disposal sites; **remediating** contaminated groundwater; and **surveillance**, **maintenance**, **and decommissioning** of inactive facilities.

The science and technology mission includes the following activities:

- **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's goal is to clean up Hanford Site waste and ensure that its facilities are always in compliance with federal, state, and local environmental laws.

The highest priority of the DOE's Hanford Site offices 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's Richland Operations Office and Office of River Protection provide safe and healthful workplaces and protect the environment across the Hanford Site. Fundamental to the attainment of this policy are personal commitment and accountability, mutual trust, open communication, continuous improvement, worker involvement, and full participation of all interested parties. Consistent with the strategic plan for the site (DOE/RL-96-92), both DOE offices on the site will reduce accidents, radiological and toxicological exposures, and regulatory non-compliances.

1.2 Overview of the Hanford Site

The Hanford Site lies within the semiarid Pasco Basin of the Columbia Plateau in southeastern Washington State (Figure 1.1). The site occupies an area of ~1,517 square kilometers (~586 square miles) located north of the city of Richland and the confluence of the Yakima and Columbia Rivers (DOE/EIS-0222). This large area has restricted public access and provides a buffer for the smaller areas on the site that historically were used for production of nuclear materials, waste storage, and waste disposal. 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 at the city of Richland. The U.S. Fish and Wildlife Service administers ~66,775 hectares (165,000 acres) of the Hanford Site.

1.2.1 Site Description

The major areas on the Hanford Site (see Figure 1.1) 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 (in the 100-N Area)

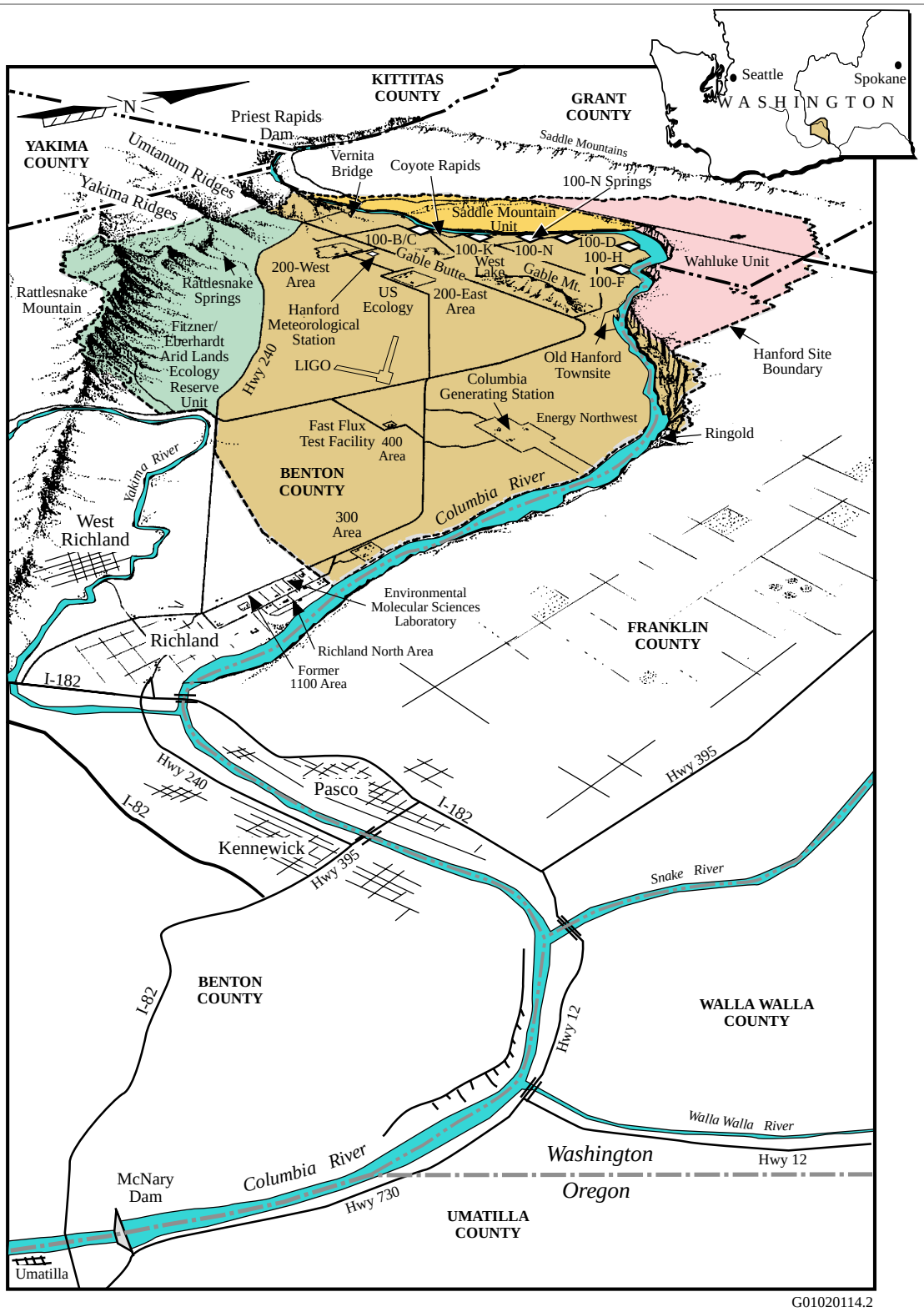

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Figure 1.1. The Hanford Site and Surrounding Area

(see Section 1.3.2). The 100 Areas occupy ~11 square kilometers (4 square miles).

- The 200-West and 200-East Areas are centrally located on a plateau and are ~8 and 11 kilometers (5 and 7 miles), respectively, south and west of the Columbia River (see Section 1.3.3). The 200 Areas cover ~16 square kilometers (6 square miles).
- The 300 Area is located just north of the city of Richland (see Section 1.3.1). This area covers 1.5 square kilometers (0.6 square mile).
- The 400 Area is ~8 kilometers (5 miles) northwest of the 300 Area (see Section 1.3.4).
- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas.
- The former 311-hectare (768-acre) 1100 Area is located generally between the 300 Area and the city of Richland and included site support services such as general stores and transportation maintenance. On October 1, 1998, this area was transferred to the Port of Benton as a part of the U.S. Department of Energy's (DOE's) Richland Operations Office economic diversification efforts and is no longer part of the Hanford Site. However, DOE contractors continue to lease facilities in this area.
- The Richland North Area (off the site) includes DOE and contractor facilities, mostly leased office buildings, generally located in the northern part of the city of Richland.

Other site related facilities (office buildings) are located within the Tri-City area.

The 78,900-hectare (195,000-acre) Hanford Reach National Monument (Figure 1.2) was established by Presidential Proclamation in June 2000 (65 FR 144) to protect the nation's only free-flowing stretch of the Columbia River above Bonneville Dam and the largest remnant of the shrub-steppe ecosystem once blanketing the Columbia River Basin. DOE and the U.S. Fish and Wildlife Service are joint stewards of the monument. The U.S. Fish and Wildlife Service administers three major management units of the monument: 1) Fitzner/Eberhardt Arid Lands Ecology Reserve Unit, a 312 square kilometer (120 square mile) tract of land in the southwestern portion of the Hanford Site; 2) Saddle Mountain Unit, a 130 square kilometer (50 square mile) tract of land located north-northwest of the Columbia River and generally south and east of State Highway 24; and 3) Wahluke Unit, a 225 square kilometer (87 square mile) tract of land located north and east of both the Columbia River and the Saddle Mountain Unit (see Figure 1.1). The portion of the monument administered only by DOE includes the McGee/Riverlands area (west of the Vernita Bridge rest stop and north of State Highway 24), the Columbia River islands of Benton County, the Columbia River corridor (one-fourth mile inland from the river shoreline) on the Hanford (Benton County) side of the river, and the sand dunes area located along the Columbia River north of Energy Northwest. A piece of land (~162 hectares [400 acres]) north of the Vernita Bridge and south of State Highway 243 is managed by the Washington State Department of Fish and Wildlife. All of these lands have served as a safety and security buffer zone for Hanford Site operations since 1943, resulting in an ecosystem that has been relatively untouched.

Non-DOE operations and activities on Hanford Site leased land or in leased facilities include commercial power production by Energy Northwest (4.4 square kilometers [1.6 square miles]) and operation of a commercial low-level radioactive waste burial site by US Ecology, Inc. (0.4 square kilometer [0.2 square mile]). 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 has built the Laser Interferometer Gravitational-Wave Observatory facility for gravitational wave studies. R. H. Smith Distributing operates vehicle-fueling stations in the former

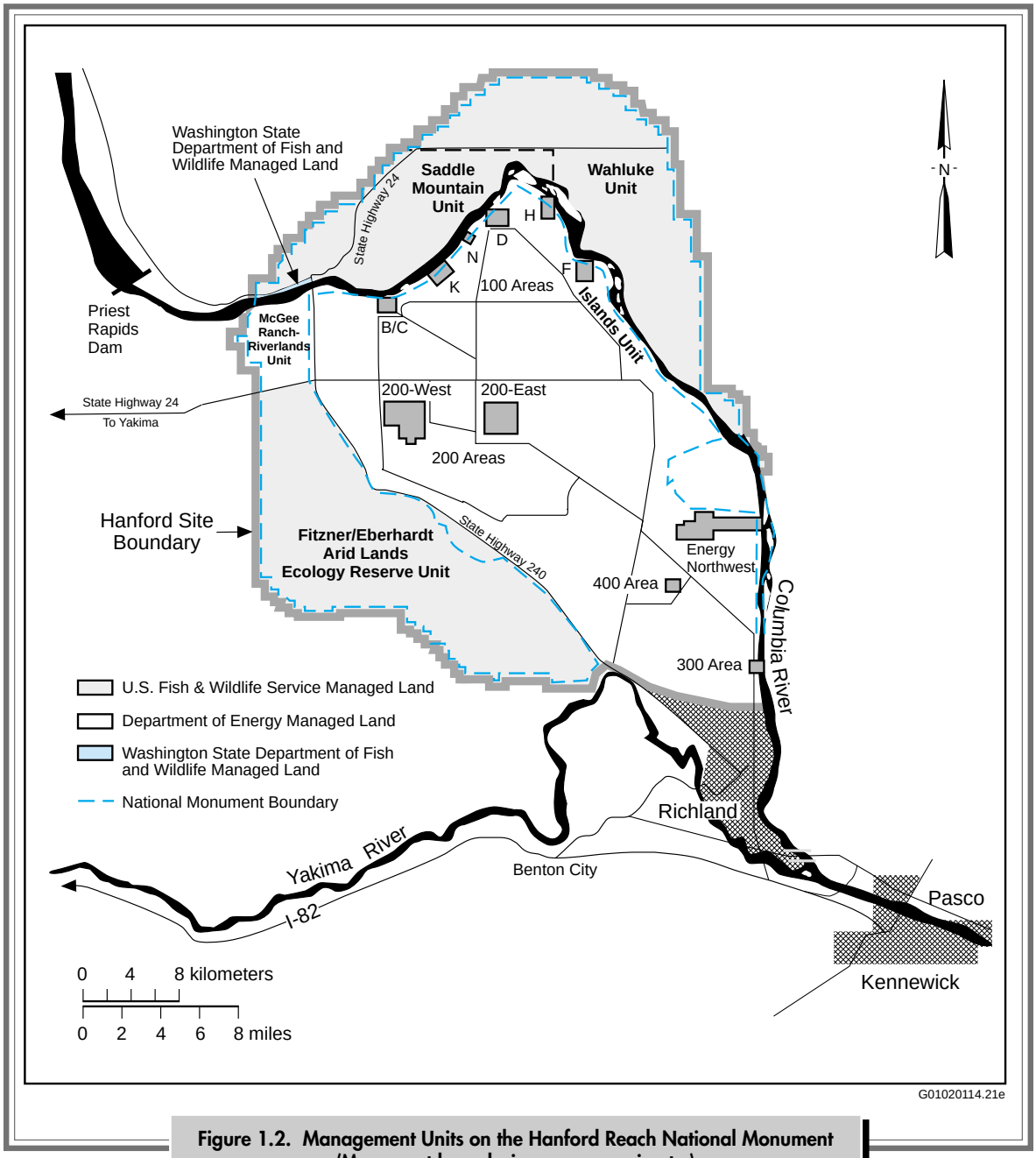

Figure 1.2. Management Units on the Hanford Reach National Monument (Monument boundaries are approximate.)

1100 Area and in the 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 former 1100 Area, to rebuild train locomotives. Johnson Controls, Inc. operates 42 diesel and natural gas package boilers to produce steam in the 200 and 300 Areas (replacing the old coal-fired steam plants) and also has compressors supplying compressed air to the site.

Near the city of Richland, immediately adjacent to the southern boundary of the Hanford Site, Framatome ANP, Inc. (formerly 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.

1.3 Historical Site Operations

This section discusses the historic operational mission of the Hanford Site. Sections 1.1 and 2.3 summarize current activities at the Hanford Site.

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 to construct large concrete structures. For security, safety, and functional reasons, the site was divided into numbered areas (see Figure 1.1).

Hanford Site operations have produced liquid, solid, and gaseous waste. Most waste resulting from site operations had at least the potential to contain radioactive materials. From an operational standpoint, radioactive waste was originally categorized (see Table 10.3 in Fitzgerald 1970) 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 waste, consisting of tools, machinery, paper, or wood, was placed into covered trenches at storage and disposal sites known as "burial grounds." Beginning in 1970, solid waste was segregated according to the makeup of the waste material. Solids contaminated with plutonium and other transuranic materials were packaged in special containers and stored in trenches covered with soil for possible later retrieval.

High-level liquid waste was stored in large underground tanks. Intermediate-level liquid waste streams were usually routed to underground structures of various types called "cribs." Occasionally, trenches (specific retention 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 waste was 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 receives waste.

All unrestricted discharges of radioactive liquid waste to the ground were discontinued in 1997. The 616-A crib (a state permitted facility also known as the State-Approved Land Disposal Site) receives radioactive (tritium) liquid waste from the 200 Areas Effluent Treatment Facility. This effluent is the only discharge of radioactive liquid waste to the ground at Hanford. All liquids discharged to the ground are approved by separate permits from the state of Washington. Current liquid effluent treatment facilities are discussed in Section 2.3.9. Efforts to cleanup (remediate) former liquid waste disposal sites are discussed in Sections 2.3.11 and 7.2.2.

National Pollutant Discharge Elimination System permits issued by the U.S. Environmental Protection Agency (EPA) govern liquid discharges to the Columbia River (40 CFR 122). Permits from EPA, the Washington State Department of Health, and the Washington State Department of Ecology govern the discharge of gaseous effluents to the atmosphere. See Section 2.2 for details. The status of the high-level waste tanks is discussed in Section 2.3.7.

1.3.1 The 300 Area

From the early 1940s until the advent of the cleanup mission, most research and development 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 waste was sent to process trenches or shipped to a solar evaporation facility in the 100-H Area (183-H solar evaporation basins). This practice was discontinued in December 1994. At this time, all liquid process waste generated in the 300 Area is treated at the 300 Area Treated Effluent Disposal Facility and released to the Columbia River according to the requirements of a National Pollutant Discharge Elimination System permit (see Section 2.3.4.3). Efforts in 2000 to clean up former waste disposal sites in the 300 Area are briefly discussed in Section 2.3.11.2. Sewage waste is released into the city of Richland sanitary water treatment system.

Former fuel fabrication buildings and facilities are now used for other purposes or are in various stages of cleanup or restoration. For example, the 313 Building that houses a very large and unique extrusion press is leased by DOE to Kaiser Aluminum and Chemical Corporation.

1.3.2 The 100 Areas

The fabricated fuel elements were shipped by rail from the 300 Area to the 100 Areas. The 100 Areas are located along the Columbia River shoreline, where up to nine nuclear reactors were in operation. The main component of the nuclear reactors consisted of a large 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 tubes 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 1943 and 1955, used water from the Columbia River for direct cooling. Large quantities of water were pumped through the pipes in the graphite piles and discharged back into the river. The ninth reactor, N Reactor, was completed in 1963 and was a modified 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 Energy Northwest to generate 860 megawatts of 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 electricity 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 105K-East and 105K-West fuel storage basins (K Basins) in the 100-K Area for temporary storage, where it remains today. This fuel accounts for the majority of the total fuel inventory stored under water in the K Basins. From the early 1980s until its shutdown in 1987, N Reactor operated to produce weapons-grade material. Electricity production continued during this operating period but was actually a by-product 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. See Section 2.3.3 for the status and details regarding the storage of spent fuel.

All of the Hanford production reactors and most of the associated facilities have been shut down, and each 100 Area is in some stage of cleanup, decommissioning, or restoration. For example, C Reactor has been cocooned and placed into interim safe storage as a large-scale demonstration, an economical state that it can safely remain in for many years pending final disposal of the reactor core. Of the 24 facilities associated with the reactor, 23 have been removed. See Section 2.3 for the status of various facilities.

1.3.3 The 200 Areas

The 200-East and 200-West Areas are located on a plateau approximately in the center of the Hanford Site. These areas house facilities that received and dissolved irradiated fuel and then separated out the valuable plutonium (Figure 1.3). These facilities were called "separations plants." Three types of separations plants were used over the years to process irradiated fuel. Each of the plutonium production processes began with the dissolution of the aluminum or zirconium cladding material in solutions containing ammonium hydroxide/ammonium nitrate/ammonium fluoride followed by the dissolution of the irradiated fuel elements in nitric acid. All three separations plants, therefore, produced large quantities of waste nitric acid solutions that contained high levels of radioactive materials. This waste was 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 in the early 1950s.

Both B and T plants 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 specific retention trenches and covered with soil at the BC cribs area south of the 200-East Area.

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

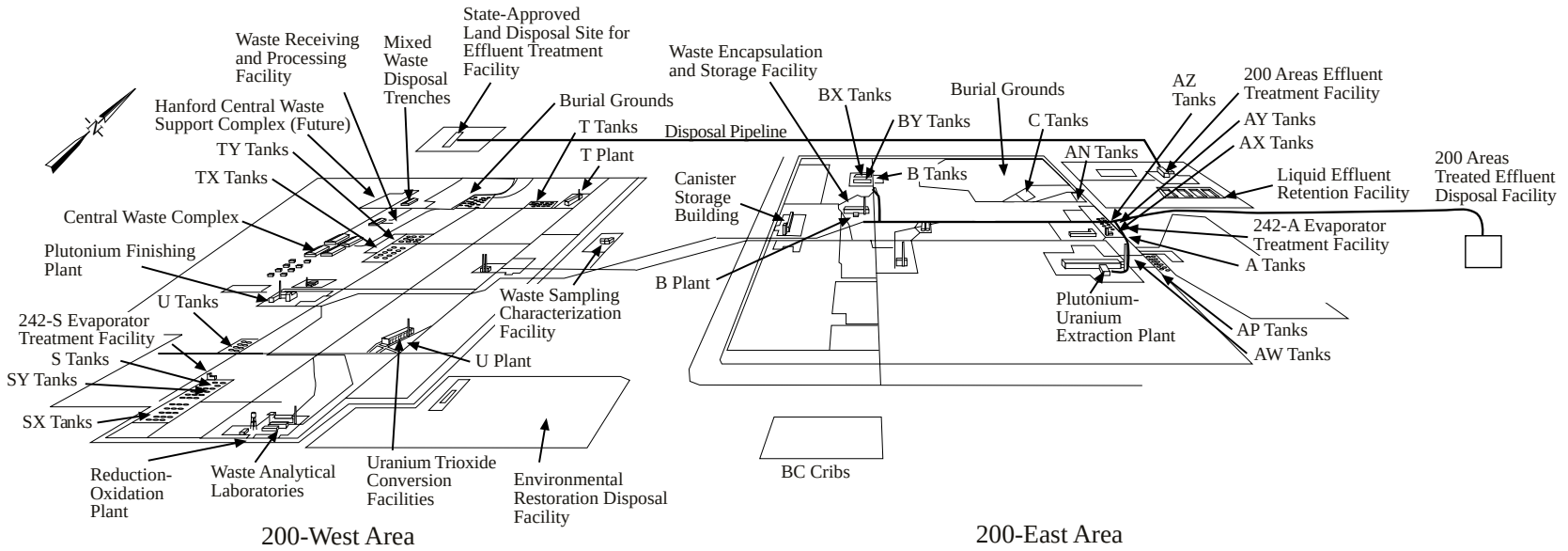

Figure 1.3. Waste Processing, Storage, and Disposal Facilities in the 200 Areas

Canisters of encapsulated strontium and cesium are currently stored in a water storage basin at the encapsulation facility.

In 1952, U Plant in the 200-West Area, built during World War II but not needed as a processing canyon, was retrofitted as the Metal Recovery Plant. Its mission was to use a new tributyl-phosphate/saturated kerosene extraction technique to recover uranium from the waste stored in Hanford's tank farms. The scarcity of high-grade uranium supplies made this mission crucial and much of the United States' supply of uranium was housed in Hanford's tanks. The separated uranium was purified into uranium oxide powder at the adjacent Uranium-TriOxide Plant.

The Reduction-Oxidation and Plutonium-Uranium Extraction Plants used solvent extraction techniques to separate plutonium from leftover uranium and radioactive waste products. Most of the irradiated fuel produced at Hanford was processed at either of these two plants. The solvent extraction method separated chemicals based on their differing solubilities in water and organic solvents (i.e., hexone at the Reduction-Oxidation Plant and tributyl-phosphate at the Plutonium-Uranium Extraction Plant). High-level liquid waste was 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 saltcake 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 waste discharged to the soil from the Reduction-Oxidation and Plutonium-Uranium Extraction Plants typically contained tritium and other radioactive fission products as well as non-radioactive nitrate. Intermediate-level liquid waste 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 216-S-10 ditch. Cooling water from the Plutonium-Uranium Extraction Plant was discharged to the Gable Mountain and 216-B-3 (B Pond) ponds (see Figure 7.1.1).

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 Plutonium Finishing Plant was used to convert the plutonium nitrate into plutonium metal blanks (buttons) that were shipped off the site for manufacture into nuclear 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 waste that were discharged to cribs. Cooling water from the Plutonium Finishing Plant was discharged via open ditch to the 216-U-10 pond (U Pond) (see Figure 7.1.1). High-level solid waste containing plutonium scraps were segregated and packaged for storage in special earth-covered trenches.

All of the former activities in the separations plants and the Plutonium Finishing Plant have

been shut down and the facilities are in various stages of decontamination and decommissioning or alternate use. For example, the former T Plant complex now consists of two operational facilities used for waste sampling and verification, waste repackaging, equipment decontamination, and storage of a small amount of irradiated fuel from the former Shippingport, Pennsylvania, reactor. See Section 2.3.4 for additional information. Untreated low-level liquid waste is no longer released to surface ponds, ditches, or cribs. These facilities are in various states of decommissioning, decontamination, and restoration. See Section 2.2, especially Table 2.2.2, for details.

1.3.4 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 ~8 kilometers (5 miles) northwest of the 300 Area. This special nuclear reactor was designed to test various types of nuclear fuel. The facility operated for ~13 years and was shut down in 1993. The reactor was a unique design that used liquid sodium metal 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 waste was transported to the 200 Areas. With the exception of the spent fuel, no major amounts of radioactive waste were stored or disposed of at the Fast Flux Test Facility site.

1.4 Site Management

The Hanford Site is managed by the DOE's Richland Operations Office and the Office of River Protection through the following contractors and subcontractors. Each contractor is responsible for safe, environmentally sound maintenance and management of its activities or facilities; for waste management; and for monitoring any potential effluents to ensure environmental compliance.

DOE Richland Operations Office. The DOE Richland Operations Office manages legacy cleanup, research, and other programs at the Hanford Site. Hanford supplied plutonium for the United States nuclear weapons defense for more than four decades and is now engaged in the world's largest environmental cleanup project. Three cleanup outcomes are being pursued: restoring the Columbia River corridor, transitioning the central plateau for waste treatment and long-term storage, and putting DOE's assets to work solving regional and global environmental challenges.

In 2000, the principal contractors for the DOE Richland Operations Office, and their respective responsibilities, included the following:

- **Fluor Hanford, Inc.** is the prime contractor for the nuclear legacy cleanup. Fluor Hanford, Inc.'s four principal subcontractors were Numatec Hanford Corporation, Duratek Federal Services of Hanford, Inc., DynCorp Tri-Cities Services, Inc., and Protection Technology Hanford. As part of the commitment to the economic development of the Tri-Cities region, Fluor Hanford, Inc. and its major subcontractors established affiliate companies that were separate businesses with the flexibility to pursue and perform non-Hanford work.
  - Numatec Hanford Corporation provided best-in-class engineering and project management services and technical expertise and implemented relevant technologies to accelerate cleanup.

- DynCorp Tri-Cities Services, Inc. provided essential infrastructure services for the Hanford Site, including utilities, facility maintenance, real estate and site planning, emergency response, property management, fleet and transportation operations, and crane and rigging.
- Protection Technology Hanford provided management, operation, and integration of all safeguards and security services of the Hanford Site, except those of Pacific Northwest National Laboratory. These services included function design, testing and upgrade of safeguards and security systems, material control and accountability, physical security, personnel security, technical security, information security (classified and unclassified), vulnerability assessment, and the Hanford Patrol.

In addition, several affiliate (formerly enterprise) companies were created to provide services to Fluor Hanford, Inc. These subcontractors and their areas of responsibility included the following:

- Fluor Federal Services, Inc. provided project management, engineering, procurement, and construction services to government clients including the Energy, Defense, and State Departments, as well as clients at the Hanford Site.
- Lockheed Martin Services, Inc. provided telecommunications and network engineering, Internet technology integration, software modernization, maintenance and support, engineering computational resources, data center management, imaging and document management, and multimedia services to other Lockheed Martin Corporation companies, government, and commercial industry.
- Duratek Federal Services, Inc., Northwest Operations worked to privatize a select group of capabilities that were developed at Hanford. These transportation, engineering, environmental, and training services capabilities were unique, state-of-the-art, or simply acknowledged as being among the best available.
- COGEMA Engineering Corporation developed and designed waste sampling characterization and retrieval equipment and specialized analytical methods and techniques. COGEMA Engineering Corporation applied its expertise in field screening and sampling to Hanford cleanup, as well as to developing and applying its special welding techniques.

- **Bechtel Hanford, Inc.**, the environmental restoration contractor, planned, managed, executed, and integrated a full range of activities for the cleanup of groundwater, contaminated soil, and inactive nuclear facilities. Bechtel Hanford, Inc.'s preselected subcontractors were CH2M HILL Hanford, Inc. and Eberline, Inc.
- **Hanford Environmental Health Foundation**. Hanford Environmental Health Foundation's Health Risk Management Program worked with the site to identify and analyze the hazards that Hanford personnel faced in the work environment. Hanford Environmental Health Foundation's occupational health services provided occupational medicine and nursing, medical surveillance, ergonomics assessment, exercise physiology, case management, psychology and counseling, fitness for duty evaluations, health education, infection control, immediate health care, industrial hygiene, and health, safety, and risk assessment.
- **Pacific Northwest National Laboratory**. Battelle operated the Pacific Northwest National Laboratory for DOE's national security and energy missions. The core mission was to deliver environmental science and technology in the service of the nation and humanity. Pacific Northwest National

Laboratory services included molecular science research, advanced processing technology, biotechnology, global environmental change research, and energy technology development.

DOE Office of River Protection. The Office of River Protection was established by Congress in 1998, as a DOE field office, to manage DOE's largest, most complex environmental cleanup project—Hanford tank waste retrieval, treatment, and disposal. Sixty percent of the nation's high-level radioactive waste is stored at Hanford in aging, deteriorating tanks. In late spring of 2000, the Office of River Protection conducted an expedited bidding process to complete the design and construction of a waste vitrification facility. The contract was awarded in December 2000.

The principal contractors for the DOE Office of River Protection in 2000, and their respective responsibilities, included the following:

- **Bechtel National, Inc.** was awarded a $4 billion, 10-year contract in December 2000 to design, build, and commission a Waste Treatment Plant to vitrify Hanford's tank waste. The project included a pretreatment facility to separate the tank waste into high-level radioactive and low-activity radioactive streams. Separate vitrification facilities will immobilize the waste in a glass form encased in stainless steel canisters. High-level waste will be stored at the Hanford Site for eventual disposal at a federal repository. Low-activity waste will be disposed of in concrete-lined trenches at the Hanford Site.
- **CH2M HILL Hanford Group, Inc.** was the Office of River Protection's prime contractor with responsibility for storing and retrieving for treatment ~204 million liters (54 million gallons) of highly radioactive and hazardous waste stored in 177 underground tanks. The company's role included characterizing the waste and delivering it to the future waste vitrification facility. In January 2001, the contract for CH2M HILL Hanford Group, Inc. was extended through 2006.
- **MACTEC-ERS** was a prime contractor to the DOE Grand Junction Office and conducted vadose zone characterization and monitoring work beneath single-shell underground waste storage tanks in the 200 Areas.

U.S. Fish and Wildlife Service at the Hanford Site administered much of the site under the National Wildlife Refuge System and managed the land in accordance with the Presidential Proclamation (65 FR 114) establishing the Hanford Reach National Monument. The U.S. Fish and Wildlife Service was a joint steward of portions of the monument with DOE.

1.5 References

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2.0 Environmental and Regulatory Compliance Summary

This section 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 current policy of the U.S. Department of Energy (DOE) that all activities be carried out in compliance with applicable federal, state, and local environmental laws and regulations, DOE Orders, Secretary of Energy Notices, DOE Headquarters and site 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. 1998) and other compliance or consent agreements. Both the Richland Operations Office and the Office of River Protection recognize 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

K. R. Price

Many entities have a role in DOE's mission of environmental restoration, waste management, and protection of the Columbia River at the Hanford Site. Stakeholders include federal, state, and local regulatory agencies; environmental groups; regional communities and governments; and the public. Indian tribes and nations also have a special and unique involvement with the Hanford Site. The following sections describe the roles of the principal agencies, organizations, and public at the Hanford Site.

2.1.1 Regulatory Oversight

K. A. Peterson

Several federal, state, and local regulatory 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 Clean Air Authority. These agencies issue permits and administrative orders, negotiate compliance agreements, review budgets and workscope, review environmental reports and documentation, participate in joint monitoring programs, inspect facilities and operations, and/or oversee compliance with applicable regulations. DOE directs site activities, including environmental compliance, through contractor audits, oversight, and directives.

EPA is the primary federal regulatory agency that develops, promulgates, and enforces environmental regulations and standards as directed in statutes passed by Congress. In some instances, EPA has delegated 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 of 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 to regulate 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 directly enforce federal environmental regulations.

Although Oregon does not have direct regulatory authority at the Hanford Site, DOE recognizes its interest in Hanford Site cleanup because of the state's location along the Columbia River. 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

R. D. Morrison

This order (also known as the Tri-Party Agreement; Ecology et al. 1998) is an agreement among the Washington State Department of Ecology, EPA, and DOE to achieve environmental compliance at the Hanford Site with the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), including the *Superfund Amendments and Reauthorization Act of 1986* remedial action provisions, and with the *Resource Conservation and Recovery Act* (RCRA) treatment, storage, and disposal unit regulations and corrective action provisions. The Tri-Party Agreement 1) defines RCRA and CERCLA cleanup commitments, 2) establishes responsibilities, 3) provides a basis for budgeting, and 4) reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones in an aggressive manner. A companion document to the Tri-Party Agreement is the Community Relations Plan. The plan describes how public information and involvement activities are conducted for Tri-Party Agreement decisions.

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 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 concerns prior to final approvals. Copies of the agreement are publicly available at the DOE's Hanford Reading Room located in the Consolidated Information Center on the campus of Washington State University at Tri-Cities, Richland, Washington, and at information repositories in Seattle and Spokane, Washington, and Portland, Oregon. The Tri-Party Agreement can also be viewed on the Internet at http://www.hanford.gov/tpa/tpahome.htm. 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
Public Involvement, M/S B3-30
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

K. V. Clarke

The Hanford Site is located on land ceded to the United States government by the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation in the Treaties of 1855. These tribes, as well as the Nez Perce Tribe, have treaty fishing rights on portions of the Columbia River. These 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 and unclaimed land. The Wanapum People are not a federally recognized tribe; however, they have historic ties to the Hanford Site as do the Confederated Tribes of the Colville Reservation, whose members

are descendants of people who utilized the area that is known as the Hanford Site.

The Hanford Site environment supports a number of Native American foods and medicines and contains sacred places important to 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.

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. Tribal government representatives from the Yakama Nation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe participate in DOE supported groups such as the State and Tribal Government Working Group, the Hanford Natural Resources Trustee Council, the Hanford Site Groundwater/Vadose Zone Integration Project, the Hanford Cultural Resources Program, and provide review and comments on draft documents. Both the Wanapum People and the Confederated Tribes of the Colville Reservation are also provided an opportunity to comment on documents and participate in cultural resource management activities.

The DOE American Indian and Alaska Native Tribal Government Policy (revised November 2000) guides DOE's interaction with tribes for Hanford plans and activities. The policy states, among other things, "The Department will consult with any American Indian or Alaska Native tribal government with regard to any property to which that tribe attaches religious or cultural importance which might be affected by a DOE action." DOE Order 1230.2 will be changed to reflect the revisions to the former DOE American Indian Policy. In addition to the DOE American Indian and Alaska Native Tribal Government 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, executive orders, 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 Nation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe to support their involvement in environmental management activities of the Hanford Site.

2.1.4 Hanford Natural Resource Trustee Council

J. H. Zeisloft

The President of the United States is required by CERCLA 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. Other designated federal trustees for Hanford natural resources include 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.

CERCLA also authorizes state governors to designate a state lead trustee to coordinate all state trustee responsibilities. CERCLA further states that chairmen (or heads of governing bodies) of Indian

tribes have essentially the same trusteeship over natural resources belonging to or held in trust for the tribe as state trustees. Indian tribes and state organizations have been designated as natural resource trustees for certain natural resources at or near the Hanford Site. Indian tribes include the Yakama Nation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe. State organizations include Washington, represented by the Washington State Department of Ecology and the Washington State Department of Fish and Wildlife, and Oregon represented by the Oregon Department of Energy.

To address their responsibilities, the Hanford trustees have signed a Memorandum of Agreement (1996) 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 to mitigate the impacts to natural resources that result from either hazardous substance releases within the Hanford Site or the remediation of those releases. The Council also adopted bylaws to direct the process of arriving at consensus agreements.

The Natural Resource Trustee Council is performing an ongoing assessment of potential injury to Columbia River aquatic resources from exposure to hazardous substances released within the Hanford 100 Areas. The initial phase of this assessment involved preparation of an aquatic resources assessment plan by the U.S. Fish and Wildlife Service using the natural resource damage assessment regulations in 43 CFR 11 as guidance (Hanford Natural Resource Trustee Council 1999). The plan focused on several contaminants, including chromium that has migrated via groundwater flow to sections of the Columbia River used by fall chinook salmon for spawning. As recommended in the assessment plan, the council is studying the potential for these chromium releases to injure the salmon. The results of this study will aid the trustees, regulators, and DOE to develop, evaluate, and select remedial actions that minimize or eliminate any injury to the salmon.

2.1.5 Public Participation

B. K. Wise

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

A framework for integrated communications and public involvement for the Hanford Site outlines DOE's commitment to plan for involving the public in decisions. The Office of Intergovernmental, Public and Institutional Affairs (DOE Richland Operations Office) is responsible for establishing the planning and scheduling of public participation for the Hanford Site.

The Tri-Party Agreement provides a means for Hanford to become compliant with environmental regulatory requirements. The Community Relations Plan (Ecology et al. 1997), a companion to the Tri-Party Agreement, describes how public information and involvement activities are conducted for Tri-Party Agreement decisions. Washington State Department of Ecology, DOE, and EPA developed and negotiated the plan with input from the public. The plan was approved in 1990. The plan is updated on an as-needed basis; the most recent revision occurred in 1997.

Before each public participation event, 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 ~3,800 individuals who have indicated an interest in participating in Hanford Site decisions is maintained and kept current. The mailing list also is used to send topic-specific information to those people who have requested it.

To inform 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 stakeholders reside 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 Intergovernmental, Public and Institutional Affairs (DOE Richland Operations Office) at (509) 376-7501. Also, a calendar of public involvement opportunities can be found on the Internet at http://www.hanford.gov/calendar/.

2.1.6 Hanford Advisory Board

B. K. Wise

The Hanford Advisory Board was chartered in January 1994 to advise DOE, EPA, and Washington State Department of Ecology on major Hanford Site cleanup policy issues. The Hanford Advisory Board was the first of many such advisory groups created by DOE at weapons production cleanup sites across the national DOE complex. The Hanford Advisory Board consists of 31 members who represent a broad cross section of interests, including environmental, local governments, public health, business, tribal governments, and the public. Each board member has at least one alternate. Todd Martin, public at large, is the chairperson. During 2000 the board undertook an effort to re-examine its processes and procedures. The goal of this restructuring activity was to increase board effectiveness and efficiency. The board identified five standing committees to focus on the following issues: 1) finance and contract management, 2) river corridor/central plateau, 3) human health and safety, 4) Office of River Protection tank issues, and 5) public communication. In addition, a leadership committee was identified to frame policy and address administrative issues for the board.

The board held six 2-day meetings in fiscal year 2000. Members engaged in discussions with representatives from the Tri-Party Agreement agencies on major cleanup issues, plans to treat tank waste, and budget priorities. From October 1999 through September 2000, the board produced 11 new pieces of consensus advice (making a total of 111), engaged in a series of "sounding boards," participated in several workshops and engaged in informational exchanges with each other and representatives from the Tri-Party Agreement agencies. Information about the Hanford Advisory Board, including copies of its advice and responses can be found on the Internet at http://www.hanford.gov/boards/hab/index.htm.

Sections 2.1.6.1 and 2.1.6.2 are the Hanford Advisory Board Statement of Principles (prepared and presented to the Assistant Secretary of Energy for Environmental Management on September 20, 1999).

2.1.6.1 Long-Term Vision

The long-term vision of the Hanford Advisory Board states that the Hanford Site will become a clean, accessible, and healthy environment by

- protecting the health and safety of communities and workers
- protecting the Columbia River and the environment
- moving resolutely forward to site cleanup through use of existing technologies and resources where solutions exist, and through focused research and development of solutions where solutions do not exist
- respecting treaty rights of affected Native American Indian Tribes
- embracing the Tri-Party Agreement, which has widespread and deep public support in the Northwest, as the basic framework and blueprint for the Hanford cleanup
- preparing the site for future productive uses including the transfer from predominantly DOE-funded activities to privately sponsored activities
- fostering economic prosperity through scientific research and innovation in the development and testing of waste management approaches and cleanup technologies that have benefits locally and worldwide.

2.1.6.2 Near-Term Needs

The Hanford Advisory Board has developed a statement of principles regarding the near-term needs of the Hanford Site. The board agreed that DOE should

- reduce the footprint of future stewardship needs by cleanup and waste stabilization
- maintain integrity of the Tri-Party Agreement; meet milestones
- design, construct, and operate a tank waste vitrification plant
- remove spent nuclear fuel and sludge from the K basins
- decontaminate and stabilize the Plutonium Finishing Plant
- complete cleanup along the Columbia River
- protect workers; improve and enhance their morale and productivity.

2.1.7 Hanford Site Technology Coordination Group

L. L. Fassbender

The Hanford Site Technology Coordination Group was established in 1994 and its structure was modified in early 2000. It now consists of a Management Council and five subgroups aligned with the Environmental Management Focus Areas: 1) deactivation and decommissioning, 2) mixed waste, 3) subsurface contaminants, 4) tanks, and 5) nuclear materials. The DOE Headquarters' Office of Environmental Management established the focus areas to develop and deliver solutions to technology needs identified at DOE sites across the nation. Subgroups of the Hanford Site Technology Coordination Group provide detailed documentation of the Hanford Site's technology needs to guide the focus areas' efforts in technology development.

The Management Council focuses on Hanford Site policy issues related to technology development and deployment. Subgroups of the Hanford 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 2000, the subgroups endorsed the science and technology needs developed by the site contractors for submittal to the Environmental Management Focus Areas and the Environmental Management Science Program. The Environmental Management Science Program sponsors basic research on fundamental issues that may be critical to ongoing technology development. This research will decrease public and worker risks, provide major cost reduction opportunities, reduce the time required to achieve DOE's cleanup mission, and address problems considered intractable without new knowledge. Hanford's science and technology needs can be found on the Internet at http://www.pnl.gov/stcg/needs.stm. In addition, the subgroups heard and provided comments on numerous presentations on a variety of new technologies being demonstrated and/or deployed on the Hanford Site.

The DOE Richland Operations Office Associate Manager for Science and Technology now chairs the Management Council. It includes four DOE Richland Operations Office Assistant Managers (Environmental Restoration and Waste Management, Nuclear Materials and Facility Stabilization, Planning and Integration, and Safety and Engineering), as well as representatives from the Office of Spent Nuclear Fuels, the Fast Flux Test Facility Project Office, and the Office of Training Services and Asset Transition. Representatives from the DOE Office of River Protection also participate. The Management Council includes two representatives from EPA, two from the Washington State Department of Ecology, one from the Oregon Department of Energy, three from the Hanford Advisory Board, and three from American Indian tribes (Yakama Nation, Nez Perce Tribe, and Confederated Tribes of the Umatilla Indian Reservation). The Hanford Site contractors also have designated representatives on the Management Council.

The elements of the Hanford Site Technology Coordination Group mission statement are as follows:

- involve user organizations (both DOE and the contractors), technology providers, regulators, American Indian tribes, and stakeholders; promote 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 technology insertion points; 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 effectiveness, schedules, or 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 the Hanford Site 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 contractors and eliminate barriers (e.g., resistance to change and acceptance of technologies developed offsite)
- promote competitive privatization and commercialization by communicating information on Hanford's science and technology needs and technology insertion points, as well as demonstration and deployment opportunities, to commercial technology providers; help break barriers to involvement by companies new to the Hanford Site
- provide input to decision-makers (e.g., DOE Richland Operations Office, Office of River Protection, 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

K. R. Price

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

2.2.1 Hanford Federal Facility Agreement and Consent Order, 2000 Performance

R. D. Morrison

The Tri-Party Agreement (Ecology et al. 1998) commits DOE to achieve compliance with the remedial action provisions of CERCLA and with the treatment, storage, and disposal unit regulations and corrective action provisions of RCRA, including the state's implementing regulations. From 1989 through 2000, a total of 689 milestones and 264 target dates were completed on or ahead of schedule. In 2000, there were 48 specific cleanup milestones and target dates scheduled for completion: 45 were completed on or before their required due dates, 2 were delayed because of programmatic issues, and 1 remained at issue at the time of this report. Highlights of the work accomplished in 2000 are listed in Section 2.3.

2.2.2 Environmental Management Systems

H. T. Tilden II, G. D. Cummins, R. D. Lichfield, and L. M. Dittmer

Major contractors at the Hanford Site have established Integrated Environment, Safety, and Health Management Systems. These systems, contractually mandated by DOE, are intended to protect the worker, public, and environment by integrating environment, safety, and health into the way work is planned, performed, and improved. The international voluntary consensus standard ISO 14001, *Environmental Management Systems – Specifications with Guidance for Use*, and DOE P 450.4, *Safety Management System Policy*, was used in the development of the systems.

In 1998, DOE Headquarters approved the Integrated Environment, Safety, and Health Program Description for the Pacific Northwest National Laboratory (https://sbms.pnl.gov/program/pd03d010.htm). Also in 1998, Fluor Hanford, Inc. issued an Integrated Environmental, Safety, and Health Management System Plan (HNF-MP-003); and Bechtel Hanford, Inc. issued an Integrated Environmental, Safety, and Health Management System Description (BHI-01199). DOE has verified the following Hanford contractors as having adequately implemented an Integrated Environmental, Safety and Heath System: Fluor Hanford, Inc. (August 2000), CH2M HILL Hanford Group (May 2000), Bechtel Hanford, Inc. (May 2000), and Pacific Northwest National Laboratory (1998). Efforts continued in 2000 to implement and improve these environmental, safety, and health programs.

2.2.3 Chemical Management Systems

M. T. Jansky

The Hanford Site, with its numerous contractors, facilities, and processes, uses a variety of approaches for chemical management. The major contractors developed and documented formal systems for the management of chemicals in 1997. These management systems are applicable 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, Appendices A and B). The chemical management systems have been reviewed periodically and improved as needed. Details on the chemical inventories stored at the Hanford Site may be found in Section 2.5.2.

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

L. M. Dittmer

In 1980, CERCLA was enacted to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. The EPA is the federal agency responsible for oversight of DOE's implementation of CERCLA. There is significant overlap between the state RCRA corrective action program (see Section 2.2.6) and CERCLA. Many waste management units are subject to remediation under both programs. The CERCLA program is implemented via 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," which establishes procedures for characterization, evaluation, and remediation. The Tri-Party Agreement addresses CERCLA implementation at Hanford and is generally consistent with the national contingency plan process.

There are several remediation activities under way at Hanford that are accomplished using the CERCLA process (e.g., remedial investigation in the 200 and 300 Areas, cleanup in the 100, 200, and 300 Areas). Specific project activities and accomplishments are described in Sections 2.3.3 and 2.3.11.

2.2.5 Emergency Planning and Community Right-To-Know Act

D. E. Zaloudek

This act requires states to establish a state emergency response commission and local emergency planning committees and to develop a process for the distribution of information on hazardous chemicals present in facilities. These organizations gather information and develop emergency plans for local planning districts. 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 the local emergency planning committee, and periodically provide information to support the emergency planning process. Facilities must also notify the state emergency response commission and the local emergency planning committee immediately after an accidental release of an extremely hazardous substance over the reportable quantity. Extremely hazardous substances are listed in 40 CFR 355 (Appendices A and B) along with the applicable threshold planning quantity.

The Hanford Site provides required 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. The 2000 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory (DOE/RL-2001-0010) was issued in February 2001.

Facilities must also report total annual releases of certain toxic chemicals. The *Pollution Prevention Act* requires additional information with the report, and Executive Order 13148 (65 FR 24595), *Greening the Government Through Leadership in Environmental Management*, extends the requirements to all federal facilities, regardless of the types of activities conducted. Based on evaluation of Hanford Site toxic chemical usage data during 1999 and 2000, no chemicals were used in quantities exceeding applicable thresholds; therefore, reporting was not required for either year.

The Hanford Site was in compliance with the reporting and notification requirements contained in this act. Table 2.2.1 provides an overview of 2000 reporting under the *Emergency Planning and Community Right-To-Know Act*.

2.2.6 Resource Conservation and Recovery Act (RCRA)

M. J. Hartman

RCRA was enacted in 1976 with the objective of protecting human health and the environment. In 1984, the Hazardous and Solid Waste Amendments reauthorized RCRA and imposed new requirements on the management of hazardous waste. The most important aspect of RCRA is its establishment of "cradle-to-grave" management to track hazardous waste from generator to treatment, storage, and disposal. The Washington State Department of Ecology has the authority for enforcing RCRA in the state. At Hanford, RCRA regulates ~70 hazardous waste treatment, storage or disposal units that have received waste since implementation of the act.

Table 2.2.1. Emergency Planning and Community Right-to-Know Act Compliance Reporting, 2000[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	X		
313: Toxic chemical release inventory reporting			X

(a) "Yes" indicates that notifications were provided and/or reports were issued under the applicable provisions. "No" indicates that notifications or reports should have been provided but were not. "Not Required" indicates that no actions were required under the applicable provisions, either because triggering thresholds were not exceeded or no releases occurred.
(b) These notifications apply to the Hanford Site but were completed prior to 2000.

2.2.6.1 Hanford Facility RCRA Permit

J. C. Sonnichsen

The Hanford Facility RCRA Permit (WA7890008967), Dangerous Waste Portion that was issued by the Washington State Department of Ecology has been in effect since late September 1994 (DOE/RL-91-28). The permit provides the foundation for all future RCRA permitting on the Hanford Site in accordance with provisions of the Tri-Party Agreement (Ecology et al. 1998).

2.2.6.2 RCRA/Dangerous Waste Permit Applications and Closure Plans

J. C. Sonnichsen

For purposes of the RCRA and the Washington State dangerous waste regulations (WAC 173-303), the Hanford Site is considered a single facility that encompasses approximately 70 treatment, storage, and disposal units. The Tri-Party Agreement recognized that all of the treatment, storage, and disposal units could not be issued permits simultaneously and a schedule was established for submitting unit-specific Part B dangerous waste permit applications and closure plans to the Washington State Department of Ecology. During 2000, eight Part A, Form 3, revisions were certified and submitted to the Washington State Department of Ecology. In 2000, one Part B permit application for final status was certified and submitted.

2.2.6.3 RCRA Groundwater Monitoring Project Management

B. A. Williams

RCRA groundwater monitoring is part of the Hanford Site Groundwater Monitoring Project. Pacific Northwest National Laboratory conducts the project for the DOE, to detect and characterize groundwater contaminants (see Section 7.1). Table 2.2.2 lists the facilities and units (or waste management areas) that require groundwater monitoring and notes their monitoring status. Samples were collected from 233 RCRA wells sitewide in 2000, five less than during 1999. The decrease was mainly due to wells going dry on the 200 Area plateau as the water table in that area declines. A summary of groundwater monitoring activities and results for these sites during 2000 is provided in Section 7.1.7.

Groundwater samples were analyzed for a variety of dangerous waste constituents and site-specific constituents, including selected radionuclides. The constituent lists meet the minimum RCRA regulatory requirements and are integrated to supplement other groundwater project requirements (e.g., *Atomic Energy Act*, CERCLA) at the Hanford Site.

During 2000, ten new RCRA wells were installed (Table 2.2.3) to fulfill requirements of the Tri-Party Agreement milestone M-24-00L. The installation of these ten wells was successfully completed on December 27, 2000. Of these ten wells, three were installed at Waste Management Area S-SX, four at Waste Management Area T, and three at Waste Management Area TX-TY all located in the 200-West Area. All the wells are completed as shallow (top of the aquifer) monitoring wells. The wells have ~10.7-meter- (35-foot-) long well screens intended to monitor the uppermost portion of the unconfined aquifer. Well data package summaries are being prepared that contain characterization and construction details including detailed geologic and geophysical descriptions and a complete set of sample data results.

At the end of 2000, 11 RCRA waste management areas were monitored under interim status indicator parameter evaluation, 7 were monitored under interim status assessment, 4 were monitored under final status detection evaluation, and 2 were monitored under final status corrective action. All

Table 2.2.2. RCRA Interim and Final Status Groundwater Monitoring Projects, September 2000

TSD Units, date initiated	Interim Status TSD Unit Groundwater Monitoring: Indicator Parameter Evaluation[a]	Interim Status TSD Unit Groundwater Monitoring: Groundwater Quality Assessment, date initiated	Interim Status TSD Unit Groundwater Monitoring: Detection Evaluation	Final Status TSD Unit Groundwater Monitoring: Compliance Evaluation	Final Status TSD Unit Groundwater Monitoring: Corrective Action, date initiated	Regulations	Year Scheduled for Part B or Closure
1301-N LWDF, December 1987			X[b]			40 CFR 265.93(b) WAC 173-303-400	1999[c]
1324-N/NA LWDF, December 1987			X[b]			40 CFR 265.93(b) WAC 173-303-400	1999[c]
1325-N LWDF, December 1987			X[b]			40 CFR 265.93(b) WAC 173-303-400	1999[c]
183-H solar evaporation basins, June 1985					X, 1998	40 CFR 264 WAC 173-303-645(10)	1994[c]
WMA S-SX October 1991		X, 1996				40 CFR 265.93(d) WAC 173-303-400	TBD[c,d]
WMA T, February 1990		X, 1993				40 CFR 265.93(d) WAC 173-303-400	TBD[c,d]
WMA TX-TY, September -October 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	TBD[c,d]
WMA U, October 1990		X, 2000				40 CFR 265.93(b) WAC 173-303-400	TBD[c,d]
216-S-10 pond and ditch, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	2003[c]
216-U-12 crib, September 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	2005[c]
LLWMA 3, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002[e,f]

Table 2.2.2. (contd)

TSD Units, date initiated	Interim Status TSD Unit Groundwater Monitoring: Indicator Parameter Evaluation[a]	Interim Status TSD Unit Groundwater Monitoring: Groundwater Quality Assessment, date initiated	Final Status TSD Unit Groundwater Monitoring: Detection Evaluation	Final Status TSD Unit Groundwater Monitoring: Compliance Evaluation	Final Status TSD Unit Groundwater Monitoring: Corrective Action, date initiated	Year: Regulations	Scheduled for Part B or Closure
LLWMA 4, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002[e,f]
WMA A-AX, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	TBD[c,d]
WMA B-BX-BY, February 1990		X, 1996				40 CFR 265.93(d) WAC 173-303-400	TBD[c,d]
WMA C, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	TBD[c,d]
PUREX cribs[g] 1988		X, 1997				40 CFR 265.93(d) WAC 173-303-400	2005[c]
216-B-3 pond, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2003[c]
216-A-29 ditch, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2003[c]
216-B-63 trench, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	2003[c]
LERF, July 1991			X, 1998[h]			40 CFR 265.93(b) WAC 173-303-400	1998[e]
LLWMA 1, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002[g,h]
LLWMA 2, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002[g,h]

Table 2.2.2. (contd)

TSD Units, date initiated	Interim Status TSD Unit Groundwater Monitoring: Indicator Parameter Evaluation[a]	Interim Status TSD Unit Groundwater Monitoring: Groundwater Quality Assessment, date initiated	Interim Status TSD Unit Groundwater Monitoring: Detection Evaluation	Final Status TSD Unit Groundwater Monitoring: Compliance Evaluation	Final Status TSD Unit Groundwater Monitoring: Corrective Action, date initiated	Regulations	Year Scheduled for Part B or Closure
NRDWL, October 1986	X					40 CFR 265.93(b) WAC 173-303-400	2006[c]
316-5 process trenches, June 1985					X, 1996	40 CFR 264 WAC 173-303-645(10)	1996[c]

(a) 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 assessment column indicates whether an evaluation was needed or an assessment was required.
(b) Monitored according to interim status plan as specified in closure plans.
(c) Closure/postclosure plan; TSD unit will close under WAC 173-303-610.
(d) Unscheduled.
(e) Part B permit; TSD unit scheduled to operate under final status regulations beginning in year indicated.
(f) Facility Part B permit and final status groundwater monitoring plan contingent on completion of solid waste environmental impact statement.
(g) 216-A-10, 216-A-36B, and 216-A-37-1 combined into one RCRA monitoring unit. RCRA monitoring will be performed according to interim status groundwater quality assessment requirements.
(h) Will monitor groundwater under interim status until final status groundwater monitoring plan is approved.

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980.
LERF = Liquid effluent retention facility.
LLWMA = Low-level waste management area.
LWDF = Liquid waste disposal facility.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PUREX = Plutonium-uranium extraction (plant).
RCRA = Resource Conservation and Recovery Act of 1976.
TBD = To be determined.
TSD = Treatment, storage, or disposal (unit).
WMA = Waste management area (single-shell tank farm).

Table 2.2.3. New RCRA Well Installation in the 200-West Area, 2000

Well Number	Location
299-W11-39	WMA T
299-W11-40	WMA T
299-W11-41	WMA T
299-W11-42	WMA T
299-W14-15	WMA TX-TY
299-W14-16	WMA TX-TY
299-W14-17	WMA TX-TY
299-W22-80	WMA S-SX
299-W23-20	WMA S-SX
299-W23-21	WMA S-SX

WMA = Waste management area.

the facilities being monitored under RCRA are scheduled for closure under the Site Part B RCRA Permit except the Liquid Effluent Retention Facility and low-level burial grounds (Low-Level Waste Management Areas 1-4), which are operating facilities. The Liquid Effluent Retention Facility is currently monitored under final status detection evaluation program and the Low-Level Waste Management Areas 1-4 will be added as soon as the Part B permit is approved.

2.2.6.4 RCRA Inspections

R. C. Bowman

DOE and its contractors are working to resolve outstanding notices of violation and warning letters of non-compliance from the Washington State Department of Ecology that were received during 2000. Each of these notices lists specific violations. RCRA non-compliance events for 2000 are detailed below.

- The Washington State Department of Ecology issued a Notice of Correction on May 25, 2000, based on an inspection of a long-term and sitewide practice that had resulted in RCRA regulated waste being shipped offsite for disposal in municipal landfills. The inspection included an investigation into the storage of hazardous and mixed waste from drilling in the 200-West Area. The Notice of Correction identified 2 alleged violations, 2 concerns, and 2 corrective measures. All corrective actions have been completed.
- The Washington State Department of Ecology issued a Notice of Correction on May 26, 2000, following a compliance inspection of the Hexone Storage and Treatment Facility, 200-West Area, on April 25, 2000. The inspection alleged that the facility had not been managed in accordance with formal agreements between the Washington State Department of Ecology and DOE signed on December 6, 1996. In addition the Washington State Department of Ecology believed that the Hexone Storage and Treatment Facility posed a safety hazard to employees because the tanks contained potentially reactive and explosive dangerous waste. The Notice of Correction identified one alleged violation and one corrective measure. Corrective action efforts are ongoing.
- The Washington State Department of Ecology delivered a Notice of Correction for the Waste Encapsulation and Storage Facility on June 12, 2000, following a compliance inspection that was initiated on August 8, 1999. The Waste Encapsulation and Storage Facility is located in the 200-East Area of the Hanford Site. The Notice of Correction alleges 5 violations, 5 corrective measures, and 5 concerns related to compliance with Dangerous Waste Regulations, WAC 173-303, and 40 CFR Part 265 interim status requirements. The Notice of Correction alleged that DOE and Fluor Hanford, Inc. had not completed the actions

necessary to obtain interim status, had not completed a waste analysis plan, did not meet the weekly inspection requirements for the cesium and strontium capsule storage areas, had not properly labeled cesium and strontium capsules, and did not have a written closure plan for the facility. All corrective actions have been completed.

- EPA and Washington State Department of Ecology conducted a RCRA inspection from May through July 1998 as part of a multimedia inspection of the Hanford facility. The inspection identified concerns that resulted in the issuance of a Compliance Order and Notice of Opportunity for Hearing ("Complaint"). The complaint identified three alleged violations of RCRA regulations: 1) storage without a permit, 2) failure to make a hazardous waste determination, and 3) failure to immediately amend a contingency plan. Civil penalties were assessed for these alleged violations in the amount of $367,078. EPA and the DOE Richland Operations Office agreed to settle the multimedia inspection matter as documented in the Consent Agreement and Final Order issued on October 12, 2000. The Consent Agreement and Final Order requires payment of a $25,000 civil penalty, performance of two Supplemental Environmental Projects, and the performance of specified compliance activities. The fine was paid and corrective action efforts are ongoing.
- The Washington State Department of Ecology issued an Administrative Order on June 13, 2000, following a compliance inspection on the M-32-00 Milestone, "Complete Identified Dangerous Waste Tank Corrective Actions." The Administrative Order required DOE and CH2M HILL Hanford Group to comply with WAC 173-303-640 requirements as they apply to determine the integrity of the double-shell tank system. The Administrative Order requires payment of a penalty and the performance of specified compliance activities. Corrective action efforts are ongoing.
- The Washington State Department of Ecology issued a Notice of Correction on October 11, 2000, following a compliance inspection of twenty-six 55-gallon drums currently stored at the T Plant complex in the 200-West Area. The drums contain dangerous and/or mixed waste collected more than 20 years ago. The Notice of Correction alleged 3 violations, 3 corrective measures, and 2 concerns. The Notice of Correction alleged that the drums had not been managed properly because the drums have remained undesignated since the 1970s, two of the drums contained completely unknown waste and had no identification labels on them, and the contents of the drums had never been sampled. All corrective actions have been completed.
- The Washington State Department of Ecology issued a Notice of Correction on August 18, 2000, following a compliance inspection of the 274-E 90-Day Dangerous Waste Storage Pad and associated facilities on June 22, 2000. The inspection alleged that a drum of flocculent stored on the non-regulated waste storage pad in the 200-East Area had exceeded its useful shelf life and had been labeled as a "Non-Regulated Waste." An examination of the manufacturer's Material Safety Data Sheet by the Washington State Department of Ecology revealed that the chemical is designated as a toxic waste in Washington State. It was alleged that the drum contents were not properly designated as required by WAC 173-303-070. The Notice of Correction identified one alleged violation and one corrective measure. All corrective actions have been completed.

2.2.7 Clean Air Act

K. A. Peterson

Federal, state, and local agencies enforce the standards and requirements of the *Clean Air Act* to regulate air emissions at facilities such as the Hanford Site. A summary of the major agency interfaces and applicable regulations for the Hanford Site is provided in the following paragraphs. Section 3.1 discusses air emissions from Hanford facilities.

DOE and EPA signed the *Federal Facility Compliance Agreement for Radionuclides NESHAP* (EPA 1994). The agreement provides a compliance plan and schedule that are being followed to bring the Hanford Site into compliance with *Clean Air Act* requirements under 40 CFR 61, Subpart H, for continuous measurement of emissions from applicable airborne emission sources. All scheduled milestones of the *Federal Facility Compliance Agreement* were met in 2000, and Hanford Site air emissions remained well below the levels that approach the state and EPA offsite emission standard of 10 millirems per year. The 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 in accordance with a schedule approved by EPA and monitored by the Washington State Department of Health.

The Washington State Department of Health's Division of Radiation Protection regulates radioactive air emissions statewide through delegated authority from EPA and Washington State legislative authority. The Washington State Department of Health implements the federal/state requirements under state regulation WAC 246-247. Prior to beginning any work that would result in creating a new or modified source of radioactive airborne emissions, a notice of construction application must be submitted to the Washington State Department of Health and EPA for review and approval. Ensuring adequate emission controls, emissions monitoring/sampling, and/or annual reporting of air emissions are typical requirements for radioactive air emission sources. The Hanford Site operates under state license FF-01 for such emissions. Conditions specified in the FF-01 license will be incorporated into the Hanford Site air operating permit, scheduled to be issued in 2001. The Hanford Site air operating permit will be issued in accordance with Title V of the *Clean Air Act Amendments of 1990*, and will be implemented through federal and state programs under 40 CFR 70 and WAC 173-401. The permit is intended to provide a compilation of applicable *Clean Air Act* requirements both for radioactive emissions and for non-radioactive emissions at the Hanford Site. The permit requires the DOE Richland Operations Office to submit periodic reports and an annual compliance certification to the Washington State Department of Ecology.

The Washington State Department of Ecology Nuclear Waste Program regulates air toxic and criteria pollutant emissions from the Hanford Site. The Department enforces state regulatory controls for air contaminants as allowed under the Washington *Clean Air Act* (RCW 70.94). The Washington State Department of Ecology's implementing requirements (e.g., WAC 173-400, WAC 173-460) specify a review of new source emissions, permitting, applicable controls, reporting, notifications, and provisions of compliance with the general standards for applicable sources of Hanford Site emissions.

EPA regulates other potential air emission sources at the Hanford Site. Under 40 CFR 61, Subpart M, EPA regulations specifically address asbestos management requirements under the *Clean Air Act*. These regulations apply at the Hanford Site with regard to building demolition and/or asbestos renovation and waste disposal operations. Asbestos at Hanford is handled in accordance with federal/local regulations and approved contractor procedures. In addition, Title VI of the *Clean Air*

Act Amendments of 1990 require regulation of the service, maintenance, repair, and disposal of certain systems containing Class I and Class II ozone-depleting substances (refrigerants) through implementation of the requirements in 40 CFR 82. Implementation of the ozone-depleting substance management requirements on the Hanford Site is administered at the facility/project level, as applicable.

At the local level, the Benton Clean Air Authority was designated authority by EPA to establish a local oversight and compliance program for asbestos renovation and/or demolitions, as regulated by EPA under the National Emission Standards for Hazardous Air Pollutants (40 CFR 61, Subpart M). In addition, the Benton Clean Air Authority regulates open burning, as an extension of the Washington State Department of Ecology's open burning requirements (WAC 173-425). In both areas of responsibility, the Benton Clean Air Authority enforces/adopts the federal/ state regulations, respectively by reference, as well as imposes additional requirements on sources within the local agency's jurisdiction.

2.2.7.1 Clean Air Act Enforcement Inspections

R. C. Bowman

DOE and its contractors are working to resolve outstanding compliance findings from the Washington State Department of Health and Washington State Department of Ecology inspections. The non-compliance events in 2000 are listed below.

- The Washington State Department of Health conducted an inspection of all minor emission units at the Plutonium Finishing Plant, 200-West Area, on January 31, 2000. The inspection resulted in the Washington State Department of Health issuing a Notice of Correction for all Plutonium Finishing Plant emission units. The Notice of Correction addressed the calibration/function testing frequencies of differential pressure gauges. All corrective actions have been completed.
- The Washington State Department of Health issued a Notice of Violation and Compliance Order as authorized by WAC 246-247-100(a) and RCW 70.94.332 for actions taken at the 244-AR Vault. The Notice of Violation and Compliance Order alleges that entries into the 244-AR Vault were made without proper Washington State Department of Health approvals and permitting or adequate radiation control measures in place. The 244-AR Vault is located in the 200-East Area and serves as a waste transfer station. The Washington State Department of Health alleged three violations and three compliance orders. All corrective actions have been completed.

DOE and its contractors entered into technical assistance partnering with the Washington State Department of Ecology. On July 1, 2000, the Washington State Department of Ecology initiated a 1-year period of technical assistance visits (versus formal inspections) from the Air Program Office of its Nuclear Waste Program. During that time, the Washington State Department of Ecology agreed to meet with several Hanford facilities/ projects, as requested, to resolve any compliance issues with air monitoring and/or questions pursuant to WAC 173-400 and WAC 173-460. As of December 31, 2000, five technical assistance visits were successfully completed.

The technical assistance program is part of a sitewide criteria/toxic air emissions program review between the Washington State Department of Ecology, DOE, and contractor representatives. The technical assistance visits are to facilities or projects with existing notice of construction approvals and existing facilities that are grandfathered from new source review but comply with the general air requirement standards. The Washington State Department of Ecology conducts the technical assistance visits in accordance with the Revised Code of

Washington (RCW 43.05) in preparation for the Washington State Department of Ecology's initiation of a formal air inspection program at the start of their fiscal year (i.e., July 1, 2001). That formal air inspection program will include coordinated involvement with the Title V, Level II inspections, once the Hanford Site air operating permit is issued.

2.2.8 Clean Water Act

J. A Winterhalder

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. There is one National Pollutant Discharge Elimination System permit, WA-002591-7, for the Hanford Site. The permit covers three active outfalls: one (outfall 001) for the 300 Area Treated Effluent Disposal Facility and two (outfalls 003 and 004) in the 100-K Area. Fluor Hanford, Inc. is the holder of this permit.

There was one non-compliance with Permit WA-002591-7 during 2000. In February, analytical laboratory results indicated that the permit threshold limits for three metals had been exceeded at outfall 001. Copper was detected at 75 ppb; manganese at 110 ppb; and zinc at 115 ppb. The permit threshold limits for copper, manganese, and zinc are 15 ppb, 17 ppb, and 15 ppb, respectively. No other exceedances of the permit occurred throughout the remainder of 2000.

The Hanford Site was covered by two storm water permits in 2000. WAR-10-000F is the storm water general permit for construction activities covering five acres or more. Storm water discharges from the 1908-K Outfall in the 100-K Area are covered under Multi-Sector General Storm Water Permit WAR-05-A45F. The requirements of the National Pollutant Discharge Elimination System Multi-Sector General Storm Water Permit are fulfilled through implementation of the Hanford Site Storm Water Pollution Prevention Plan (HNF-4081). The Pollution Prevention Plan establishes a process to evaluate potential pollution sources at the 100-K Area, and select and implement appropriate measures that are designed to prevent and control the discharge of pollutants in the storm water run-off.

The DOE Richland Operations Office has a pretreatment permit (CR-IU005) from the city of Richland to discharge wastewater from the William R. Wiley Environmental Molecular Sciences Laboratory located in the Richland North Area. Also, there are numerous sanitary waste discharges to the ground throughout the site. Sanitary waste from the 400 Area is discharged to the Energy Northwest treatment facility (see Figure 1.0.1 for Energy Northwest location). Sanitary waste from the 300 Area, the former 1100 Area, and other facilities north of, and in, Richland discharge to the city of Richland treatment facility.

2.2.8.1 State Wastewater Discharge Permit Program

W. E. Toebe

The Washington State Department of Ecology State Wastewater Discharge Permit Program regulates the discharge or disposal of wastewater to surface or ground waters. The program's goal is to maintain the highest purity of public waters by limiting pollutant discharges to the greatest extent possible. The Hanford Site has eight state waste discharge permits issued by the Washington State Department of Ecology. In 2000, there were six non-compliances with three of the eight discharge permits in place at the Hanford Site. Details of the permit non-compliances are listed below.

- Permit No. ST 4508, Hydrotest, Maintenance, Construction Discharges – During a review of water line flushing logs, personnel noted that five water line flushes at various locations in the 300 Area exceeded the instantaneous flow rate limit of 3,785 liters (1,000 gallons) per minute. Flushing procedures and associated blank log sheets were modified to more clearly identify discharge limits.
- Permit No. ST 4500, 200 Areas Effluent Treatment Facility – Tritium tracking data must be reported annually as part of a groundwater monitoring summary for the 200 Areas Effluent Treatment Facility. During an audit of the onsite analytical laboratory's records, it was discovered that the accreditation for tritium analysis had not been renewed. The onsite laboratory, the Waste Sampling and Characterization Facility, is pursuing renewal of its tritium accreditation through the Washington State Department of Ecology for future sample analyses.
- Permit No. ST 4507, 100-N Sewage Lagoon – It was reported that the flow meter which measures the effluent at the 100-N Sewage Lagoon had stopped collecting data. The flow meter in use at the time was a replacement that did not have the same memory capacity as the original monitoring device. Upon discovery, the flow meter was reprogrammed to correct the problem pending repair and re-installation of the original device.
- Permit No. ST 4507, 100-N Sewage Lagoon – Effluent data for March 2000 indicated the permit limits for pH and total suspended solids were exceeded. It was believed that the limits were exceeded because of an algae bloom brought on by warmer weather during the month of March.
- Permit No. ST 4507, 100-N Sewage Lagoon – Effluent data indicated that permit limits for total suspended solids were exceeded during July and September 2000. An algae bloom within the stabilization pond appeared to be contributing to the increase in suspended solids.

2.2.9 Safe Drinking Water Act

D. A. Rohl

There were 11 public water systems on the Hanford Site in 2000. Two of these systems, the Yakima Barricade well and the 100-D Area system, were removed from service to supply potable water for human consumption. All public water systems are required to meet the *Safe Drinking Water Act*, the *Safe Drinking Water Act Amendments of 1986*, and the *Safe Drinking Water Act Amendments of 1996*. Specific performance requirements are defined within the federal regulations (40 CFR 141, EPA-570/9-76-003, EPA 822-R-96-001) and WAC 246-290. The drinking water program has been updated to comply with the changing regulatory requirements. A complete revision of WAC 246-290 was issued on April 9, 1999, and all site water programs have had the necessary changes incorporated.

The compliance monitoring program elements are updated annually with monitoring cycles beginning in January. Drinking water is monitored for radionuclides, inorganics, synthetic and volatile organics, lead, copper, asbestos, disinfectant byproducts, and coliform bacteria. All sampling results for 2000 met the requirements of the Washington State Department of Health with the exception of a non-acute Coliform Maximum Contaminant Level Exceedance (RL-PHMC-S&W-2000-0002) issued by the state for the 200-East Area water system on February 3, 2000. Section 2.4.3 discusses the details of this event where bacteria were present in two samples but no *E. coli* bacteria were found in the system. Sample results for radiological monitoring of drinking water are discussed in Section 4.3.

The 200-East Area water treatment plant remains in standby if needed. The 283-W water treatment plant in the 200-West Area, provides potable water to customers in both 200 Areas as the primary water supply. The 300 Area treatment plant remains in standby if needed. The well that supplied water to the Hanford Patrol Training Academy was taken out of service for potable use in May 1999. The well remains in service for irrigation purposes only. The training academy is now supplied by the city of Richland who will maintain the system and sample the quality of the drinking water.

2.2.10 Toxic Substances Control Act

A. L. Prignano

Requirements in the *Toxic Substances Control Act* that apply to the Hanford Site primarily involve regulation of polychlorinated biphenyls. Federal regulations for use, storage, and disposal of polychlorinated biphenyls are found in 40 CFR 761. The state of Washington also regulates certain classes of polychlorinated biphenyls through the *Dangerous Waste Regulations* in WAC 173-303.

Non-radioactive polychlorinated biphenyl waste is stored and disposed of in accordance with 40 CFR 761. Radioactive polychlorinated biphenyl waste remains in storage onsite, pending the development of adequate treatment and disposal technologies and capacities. Electrical equipment that might contain polychlorinated biphenyls or polychlorinated biphenyl items is maintained and serviced in accordance with 40 CFR 761.

EPA issued a *Federal Facility Notice of Significant Noncompliance* on February 10, 1999, following *Toxic Substances Control Act* inspections conducted as a part of the multimedia inspection on the Hanford Site. DOE Richland Operations Office responded on February 26, 1999. During 1999 and 2000, EPA, DOE, and DOE contractors worked toward resolving all issues associated with this Notice of Significant Noncompliance. DOE and its contractors provided requested information to EPA and assisted in inspections. This issue was closed in January 2001.

EPA, Washington State Department of Ecology, and DOE have discussed the potential for double-shell tank waste to be subject to *Toxic Substances Control Act* requirements. These discussions resulted in the signing of the "Framework Agreement for Management of Polychlorinated Biphenyls in Hanford Tank Waste"[(a)] on August 31, 2000. Per this agreement, some double-shell tank waste might be regulated under the *Toxic Substances Control Act* as polychlorinated biphenyl remediation waste. Through the framework agreement, DOE, EPA, Washington State Department of Ecology, and DOE contractors are working together to resolve the regulatory issues associated with managing polychlorinated biphenyl remediation waste at the proposed waste vitrification plant, in tank farms, and at affected upstream and downstream facilities.

In 2000, work started on a RCRA risk assessment for treatment of tank waste at the proposed waste vitrification plant. This assessment is being performed so that results can be used to evaluate polychlorinated biphenyls regulated by the *Toxic Substances Control Act* as well.

(a) Agreement signed by Washington State Department of Ecology, U.S. Environmental Protection Agency, U.S. Department of Energy, Richland Operations Office and Office of River Protection, Richland, Washington, dated August 31, 2000.

2.2.11 Federal Insecticide, Fungicide, and Rodenticide Act

J. M. Rodriguez

This act is administered by EPA. The standards administered by the Washington State Department of Agriculture to regulate the implementation of the act in Washington State include: *Washington Pesticide Control Act* (RCW 15.58), *Washington Pesticide Application Act* (RCW 17.21), and rules relating to general pesticide use codified in WAC 16-228. At the Hanford Site, pesticides are applied by commercial pesticide operators who are listed on one of two commercial pesticide applicator licenses and by a private commercial applicator. In 2000, the Hanford Site was in compliance with the federal and state standards.

2.2.12 Endangered Species Act

R. K. Zufelt

Many rare species of native plants and animals are known to exist on the Hanford Site. Three species that may occur onsite (the bald eagle, steelhead trout, and spring chinook salmon) are listed by the U.S. Fish and Wildlife Service as either threatened or endangered (50 CFR 17.11). Others are listed by the Washington State Department of Fish and Wildlife as endangered, threatened, or sensitive species (see Appendix G). The bald eagle is currently under review for a change in listing status. The site wildlife monitoring program is discussed in Section 8.2.

Bald eagles are seasonal visitors to the Hanford Site. 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 seasonal 800-meter (2,600-foot) restricted access zones around all active nest sites and five major communal roosting sites. A pair of eagles once again prepared a nest and occupied it for a short time in 2000, but no other nesting activities were observed (see Section 8.2.2).

Steelhead and salmon are regulated as evolutionary significant units by the National Marine Fisheries Service based on their historical geographic spawning areas. The evolutionary significant units for the upper Columbia River steelhead and the upper Columbia River spring-run chinook salmon were listed as endangered in August 1997 and March 1999, respectively. A Hanford Site steelhead management plan (DOE/RL-2000-27) was prepared that will serve as the formal plan for the National Marine Fisheries Service as required under the *Endangered Species Act*. Like the bald eagle management plan, the steelhead management plan discusses mitigation strategies and lists activities that can be conducted without affecting steelhead trout or their habitats.

As part of the *National Environmental Policy Act* review process, an ecological review is conducted on all Hanford Site projects to evaluate their potential to affect federal- and/or state-listed species within the proposed project area (PNNL-6415). The ecological reviews included efforts to quantify the potential impact of project activities and to identify mitigation strategies to minimize or eliminate such effects.

2.2.13 Migratory Bird Treaty Act

M. R. Sackschewsky

The *Migratory Bird Treaty Act* (DOE/RL-96-32) prohibits taking or disturbing specified migratory birds or their feathers, eggs, or nests. There are over 100 species of birds that regularly occur on the Hanford Site that are protected by the *Migratory Bird Treaty Act*.

All Hanford Site projects with a potential to effect federally- or state-listed species of concern complied with the requirements of this act using the ecological review process. The ecological reviews produced recommendations to minimize the adverse impact to migratory birds, such as performing work outside of the nesting season and minimizing the loss of habitat.

2.2.14 Cultural Resources Compliance Legislation

D. W. Harvey

Cultural resources on the Hanford Site are subject to the provisions of the following seven acts and one executive order: *American Indian Religious Freedom Act*; *Antiquities Act*; *Archaeological and Historic Preservation Act*; *Archaeological Resources Protection Act*; Executive Order 11593, *Protection and Enhancement of the Cultural Environment* (36 FR 8921); *Historic Sites, Buildings, and Antiquities Act*; *National Historic Preservation Act*; and *Native American Graves Protection and Repatriation Act*. Compliance with these regulations is accomplished through an active management and monitoring program. Included is the review of all proposed projects to assess their potential impact on cultural resources and the periodic inspection of known archaeological sites and historic buildings to determine their condition and eligibility for listing in the National Register of Historic Places. The effects of land management policies on archaeological sites and buildings, and management of a repository for federally owned archaeological collections and Manhattan Project and Cold War artifacts are also evaluated. Federal agencies, as a matter of policy, are directed by Executive Order 11593 and Section 110 of the *National Historical Preservation Act* to administer the cultural and historic properties under their control in a spirit of stewardship and trusteeship for future generations.

In 2000, 113 cultural resource reviews were requested and conducted on the Hanford Site to comply with Section 106 of the *National Historic Preservation Act*. 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. The regulations of the *Native American Graves Protection and Repatriation Act* provides a process to determine the rights of Indian Tribes "to certain Native American human remains, funerary objects, sacred objects, or objects of cultural patrimony with which they are affiliated" (43 CFR 10). See Section 8.3 for more details regarding the cultural resources program on the Hanford Site.

2.2.15 National Environmental Policy Act

M. T. Jansky

The *National Environmental Policy Act* requires consideration of the effects of federal actions before those actions are taken. The preparation of an environmental impact statement is required for federal actions determined to be major federal actions

with the potential to impact the quality of the human environment. Other *National Environmental Policy Act* documents include an environmental assessment prepared when it is uncertain if a proposed action has the potential to impact the environment significantly and, therefore, would require the preparation of an environmental impact statement. A summary and status of environmental assessments that apply to specific activities and facilities on the Hanford Site may be found in the *National Environmental Policy Act Source Guide for the Hanford Site* (HNF-SP-0903). The report is updated annually. A supplemental analysis is prepared to consider new information developed since issuance of a *National Environmental Policy Act* environmental impact statement and record of decision. The purpose is to consider if the federal action is still bounded by the original environmental impact statement and record of decision or if a supplemental environmental impact statement is required.

Additionally, certain types of actions may fall into typical classes that have already been analyzed by DOE and have been determined not to result in a significant environmental impact. These actions are called categorical exclusions, and, if eligibility criteria are met, they are exempt from *National Environmental Policy Act* environmental assessment or environmental impact statement requirements. Typically, the DOE Richland Operations Office documents more than 20 specific categorical exclusions annually, involving a variety of actions by multiple contractors. In addition, sitewide categorical exclusions are applied to routine, typical actions conducted daily on the Hanford Site. In 2000, there were 20 sitewide categorical exclusions.

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 451.1B. In accordance with the Order, DOE documents prepared for CERCLA 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.

2.2.15.1 Recent Environmental Impact Statements

M. T. Jansky

The potential environmental impact associated with ongoing, major operations at the Hanford Site have been analyzed in environmental impact statements issued in the past several years and the ensuing records of decision. Additional *National Environmental Policy Act* reviews and supplemental analyses 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 stabilization of plutonium-bearing materials at the Plutonium Finishing Plant was issued in May 1996 (DOE/EIS-0244F). The proposed action is to stabilize selected plutonium-bearing materials for interim storage and immobilize some materials for transport to a Hanford Site solid waste management facility. The record of decision was issued in July 1996 (61 FR 36352). In 2000, three supplemental analyses were prepared to provide the basis for determining if a supplemental environmental impact statement would be required. Two previously prepared Supplemental Analyses (DOE/EIS-0244-FS/SA1 and DOE/EIS-0244-FS/SA2) resulted in determinations that no additional NEPA analyses were required.

Supplemental Analysis (DOE/EIS-0244-FS/SA3) was issued on March 9, 2000, and provided the

basis for determining if a supplemental environmental impact statement was required prior to providing enhanced stabilization, packaging, and storage capabilities for plutonium oxides and metals under Project W-460, "Plutonium Finishing Plant Plutonium Stabilization and Packaging System." It was determined that additional *National Environmental Policy Act* analysis was not required.

Supplemental Analysis (DOE/EIS-0244-FS/SA4) was issued on August 18, 2000, and provided the basis for determining if a supplemental environmental impact statement was required prior to starting an alternate method for packaging selected bulk plutonium-bearing materials presently stored at the Plutonium Finishing Plant. It was determined that additional *National Environmental Policy Act* analysis was not required.

Supplemental Analysis (DOE/EIS-0244-FS/SA5) was issued on September 22, 2000, and provided the basis for determining if a supplemental environmental impact statement was required prior to stabilizing all of the plutonium-bearing solutions presently stored at the Plutonium Finishing Plant using a magnesium hydroxide precipitation process. It was determined that additional *National Environmental Policy Act* analysis was not required.

2.2.15.2 Programmatic and Offsite Environmental Impact Statements

M. T. Jansky

The *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* was issued in May 1997 (DOE/EIS-0200F) to evaluate management and national siting alternatives for the treatment, storage, and disposal of five types of radioactive and hazardous waste. The Hanford Site was considered in all alternatives. A record of decision was issued in January 1998 (63 FR 3623) on treatment and storage of transuranic waste. A subsequent record of decision on hazardous waste treatment was issued in August 1998 (63 FR 41810). A record of decision for storage of immobilized high-level waste was issued in August 1999 (64 FR 46661). A record of decision for the treatment and disposal of low-level waste and mixed low-level waste was issued in February 2000 (65 FR 10061).

The draft environmental impact statement, *Idaho High-Level Waste & Facilities Disposition Final Environmental Impact Statement* (DOE/EIS-0287D), was issued by the Idaho National Engineering and Environmental Laboratory in December 1999 for the disposition of Idaho high-level waste and facilities in which Hanford was listed as an alternative disposal site. Public comments were received through April 2000. The final environmental impact statement is expected to be issued in 2001.

The *Final Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility* (DOE/EIS-0310) was issued in December 2000. The final statement evaluated the expanded civilian nuclear energy research and development and isotope production missions in the United States including the role of the Fast Flux Test Facility at the Hanford Site. A record of decision was issued in January 2001 (66 FR 7877) indicating the Fast Flux Test Facility would be permanently deactivated, but the ruling was later postponed pending review. A detailed summary of the status of the Fast Flux Test Facility can be found on the project website at http://www.fftf.org/currstat/.

2.2.15.3 Site-Specific Environmental Impact Statements in Progress

M. T. Jansky

A draft environmental impact statement is being prepared for the Hanford Site Solid (Radioactive and Hazardous) Waste Program.[b] The Yakama Nation is a cooperating agency. The draft environmental impact statement is expected to be issued for public comment in 2002.

US Ecology operates a commercial low-level radioactive waste disposal site near the 200 Area on land leased from the federal government by the State of Washington. The Washington State Department of Health and Washington State Department of Ecology distributed a draft environmental impact statement for the facility for comment in August 2000. This *Washington State Environmental Policy Act* (RCW 43.21C) impact statement considers the renewal of US Ecology's license to operate the waste site, to increase the upper limit for disposal of naturally occurring radioactive materials, and to approve the Site Stabilization and Closure Plan. A final decision is planned for 2001.

2.2.15.4 Recent Environmental Assessments

M. T Jansky

An environmental assessment was prepared to determine whether an environmental impact statement would be required for disposition of surplus Hanford Site uranium (DOE/EA-1319). The environmental assessment analyzed the impact of 1) relocating potentially saleable Hanford Site surplus unirradiated uranium to the DOE's Portsmouth Site near Portsmouth, Ohio, for future beneficial use and 2) providing onsite management of Hanford Site surplus uranium that is not considered readily saleable. The analysis of the anticipated impacts led to a conclusion that no significant impacts were expected. A finding of no significant impact was issued on June 15, 2000, determining that no further review was required under the *National Environmental Policy Act*.

(b) A draft report (DOE/EIS-0286), *Hanford Site Solid (Radioactive and Hazardous) Waste Program*, is being prepared by the U.S. Department of Energy, Richland Operations Office, Richland, Washington.

2.3 Activities, Accomplishments, and Issues

K. R. Price

This section describes DOE's ongoing environmental and regulatory activities. Self-assessments, inspections by regulating agencies, Tri-Party Agreement (Ecology et al. 1998) discussions, and communications with stakeholders provided mechanisms to identify environmental compliance issues. Relevant issues are discussed openly with the regulators and with the public to ensure resolution.

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

R. D. Morrison

The Hanford Federal Facility Agreement and Consent Order, or Tri-Party Agreement, is an agreement for achieving compliance with CERCLA remedial action provisions and with RCRA treatment, storage, and disposal unit regulations and corrective action provisions. The Tri-Party Agreement contains a schedule, utilizing numerous enforceable major and interim milestones and unenforceable target dates, which reflects a concerted goal of achieving full regulatory compliance and remediation in an aggressive manner.

Highlights of accomplishments during 2000 under the terms of the Hanford Federal Facility Agreement and Consent Order include (associated milestone numbers are shown in parenthesis):

- Construction, installation, and acceptance testing of the K West Cask System facility modifications were completed (M-34-14A).
- The installation of RCRA groundwater monitoring wells in accordance with M-24-00L was completed at the following locations
  - three wells in the Single-Shell Tank Waste Management Area S-SX (M-24-46)
  - four wells in the Single-Shell Tank Waste Management Area T (M-24-47)
  - three wells in the Single-Shell Tank Waste Management Area TX-TY (M-24-48)
- The Hanford Tank Waste Treatment Alternatives Report (M-62-02) was completed and submitted to the EPA, the Washington State Department of Ecology, and the public.
- Remediation and backfill of 19 liquid waste sites in the 100-BC-2 Operable Unit (M-16-08B) were completed.
- The biennial assessment of information and data access needs (M-35-09B) was conducted.
- The remedial design report/remedial action work plan for the K Basins interim action (M-34-04) was submitted to EPA and the Washington State Department of Ecology for review and approval.
- The Dangerous Waste Permit Application for the Phase I Tank Waste Treatment Complex (M-20-59) was submitted to the Washington State Department of Ecology for review and approval.
- The 244-AR Vault interim stabilization project plan (M-45-11A) was submitted.
- The Site-Specific Single-Shell Tank Waste Management Area Phase I RCRA Facility Investigation/Corrective Measure Study Work

Plan Addenda for Waste Management Area B-BX-BY (M-45-53) was submitted to the Washington State Department of Ecology for review and approval.

- Complete data packages, including validation, for two cores collected from tank 241-Z-361 (M-15-37B) and a recommended regulatory pathway were provided to EPA for review.
- The B Reactor Phase II Feasibility Study Engineering Design Report was issued for Public Comment (M-93-05).
- The Hanford Site Transuranic/Transuranic Mixed Waste Project Management Plan (M-91-03) was submitted to the Washington State Department of Ecology for review and approval.
- The Waste Information Requirements Document for Fiscal Year 2001 (M-44-13D) was submitted to the Washington State Department of Ecology for review.
- Construction of upgrades in a second tank farm (M-43-13) was started.
- The annual Hanford Land Disposal Restrictions Report (M-26-01J) was submitted to the Washington State Department of Ecology for review and approval.
- Workshops on the content of the Land Disposal Restrictions Report (M-26-01K) were conducted.
- Re-negotiation of "near term" activities (prior to 9/30/2006) for single-shell tank waste retrieval (M-45-00A) was completed.
- The Final Waste Information Requirements Document for Fiscal Year 2001 (M-44-14D) was submitted to the Washington State Department of Ecology.
- The 200-TW-1 and 200-TW-2 Operable Unit work plans (M-13-23, M-13-24) were submitted to EPA and the Washington State Department of Ecology, respectively, for review and approval.
- Remedial action was initiated in the 100-FR-1 Operable Unit (M-16-13A).
- Development of a spectral gamma-logging baseline for the single-shell tank farms (M-45-50) was completed.
- Construction of a small container transuranic/transuranic mixed waste retrieval facility was completed and retrieval of small container transuranic/transuranic mixed waste was initiated from 200 Area burial grounds (M-91-04).
- Double-shell tank space evaluation (M-46-00G) was completed and submitted to the Washington State Department of Ecology and the EPA.
- The annual progress report on the development of waste tank leak monitoring/detection and mitigation activities in support of M-45-08 (M-45-09E) was submitted to the Washington State Department of Ecology for information.
- The 300 Area Special Case Waste Project Management Plan (M-92-13) was submitted to the Washington State Department of Ecology for review and approval.
- Input of characterization information was completed for high-level waste tanks for which sampling and analysis were completed per the Waste Information Requirements Document into the electronic database (M-44-16D).
- Deliverables consistent with the Waste Information Requirements Document developed for fiscal year 2000 were completed (M-44-15D).
- The 105-F Area Interim Safe Storage field activities were initiated (M-93-09).
- K West basin spent nuclear fuel removal was initiated (M-34-16).
- One 200 Area National Priority List Remedial Investigation/Feasibility Study Work Plan (M-13-00K) was submitted to EPA and the Washington State Department of Ecology for review and approval.

- The 100-HR-3 Phase I, In Situ Redox Manipulation barrier emplacement, planning and well installation was completed (M-16-27A).
- The Uranium Rich Process Waste Group (200-PW-2) work plan (M-13-25) was submitted to the Washington State Department of Ecology for review and approval.

Since this annual report was issued last year, negotiated changes to the Tri-Party Agreement established 20 new enforceable milestones. A summary of the significant changes is given in the following sections.

2.3.1.1 Waste Management

There were two change requests related to waste management approved during 2000.

Target Date M-91-11-T01 identified the need to complete and submit to the Washington State Department of Ecology the engineering study/functional design criteria for a low-level mixed waste treatment facility. The volume of waste that will actually require treatment in the conceptual facility is limited. Evaluation of this volume, processing rates, and treatment requirements led to the conclusion that an existing facility, the 2706-T Facility and its adjacent concrete pad, could be used to accomplish the required treatment operations. As a result, Target Date M-91-11-T01 was removed from the Tri-Party Agreement.

The Spent Nuclear Fuel Project in conjunction with Hanford's T Plant Facility developed a new strategy that will accelerate removal of sludge from the K Basins. The sludge will be removed from the basin floors, containerized and shipped to T Plant in accordance with requirements in the *Toxic Substances Control Act* for remote handled, transuranic waste for interim storage awaiting treatment. This will improve operational efficiency in removing spent nuclear fuel and sludge from the K Basins. Because of the importance of T Plant preparations, three new interim milestones and two new target dates were added to the Tri-Party Agreement to ensure T Plant is prepared to receive the sludge.

2.3.1.2 Environmental Restoration

Thirteen change requests related to environmental restoration were approved during 2000.

Minor modifications were made to groundwater sampling and analyses for the 100-BC-5 Operable Unit Groundwater Sampling Project.

The due date for Target Date M-93-06-T01, which requires the submittal of a surveillance and maintenance plan for the B Reactor, was extended from June 30, 2001 to June 30, 2002. This extension was necessary to complete an engineering evaluation/cost analysis to evaluate all hazards and removal action alternatives within the facility, and to accomplish a requisite public comment period.

As required by the 200 Area Remedial Investigation/Feasibility Study Implementation Plan, the annual evaluation of 200 Area operable unit priorities was completed. Based on the evaluation, the Tri-Party Agreement was modified to replace the General Process Waste Group (200-PW-4 Operable Unit) Work Plan with the Plutonium/Organic-Rich Process Waste Group (200-PW-1 Operable Unit) Work Plan under Interim Milestone M-13-26. The existing due date for this milestone was unchanged.

The Tri-Party Agreement requires that DOE specify additional interim milestones to conduct remedial investigations based on submitted operable unit work plans. To meet this requirement, three change requests were approved that established seven new interim milestones to conduct remedial investigations in Operable Units 200-CW-1, 200-CS-1 and 200-CW-5.

One change request was approved that modified four interim milestones requiring remedial actions

at the 100-KR-1, 100-FR-1, and 100-HR-1 Operable Units. Activities at the 100-HR-1 Operable Unit increased due to the discovery of vadose zone plumes at sites that had been excavated. Work in the 100-FR-1 and 100-HR-1 Operable Units was affected because the start of work at these units depended on the completion of work in the 100-HR-1 Operable Unit.

Interim Milestone M-16-07B required the completion of remediation and backfill of 22 liquid waste sites and process effluent pipelines in the 100-DR-1 and 100-DR-2 Operable Units. The continued discovery of contaminated plumes in the vadose zone increased excavation, closeout, and backfill activities at these operable units. Ultimately, the completion date for M-16-07B required an extension due to the increased workload.

In October 1999, a Record of Decision Amendment was approved by DOE, EPA, and Washington State Department of Ecology changing the selected remedial action specified in the Interim Remedial Action Record of Decision for the 100-HR-3 Operable Unit. The change was the deployment of a new and innovative technology, in situ redox manipulation, to remediate the newly characterized chromium groundwater plume while still operating the existing pump-and-treat operations. The technology involves creating a permeable groundwater treatment barrier that reduces the mobility and toxicity of chromium in groundwater. Three new interim milestones were established to track progress of the in situ redox manipulation barrier.

Interim Milestone M-16-03E requires the completion of remediation of the waste sites in the 300-FF-1 Operable Unit. Washington State Department of Ecology, DOE, and EPA began an evaluation of uranium cleanup levels as part of the CERCLA process at the neighboring 300-FF-2 Operable Unit. If a lower uranium cleanup level were chosen as a result of the evaluation, the 300-FF-1 Operable Unit cleanup level would also need to be evaluated to see if further excavation would be warranted. Until evaluation results for the 300-FF-2 Operable Unit became available, it was considered appropriate to defer backfill and re-grading of the remediated waste sites at the 300-FF-1 Operable Unit. On this basis, the due date for Interim Milestone M-16-03E was extended.

Under Major Milestone M-24-00, DOE and Washington State Department of Ecology are annually required to establish the location and number of RCRA groundwater monitoring wells to be installed in the upcoming year. For 2000, it was determined that ten monitoring wells should be installed and that five wells would be installed by April 2001 in partial fulfillment of the 2001 requirements. Five new interim milestones were added to the Tri-Party Agreement requiring the installation of these 15 new monitoring wells.

Tri-Party Agreement Action Plan Appendix C contains the official list of waste management units to be remediated. Two change requests were approved which updated Appendix C to reflect the numerous changes that had occurred as sites were cleaned up, new sites discovered, and information was collected.

2.3.1.3 Office of River Protection

There was one change request approved and one "Directors Determination" issued related to the Office of River Protection during 2000.

A change request was approved which modified the description of Interim Milestones M-44-15D, M-44-15E, and M-44-15F. These interim milestones require the development of characterization information on Hanford high-level waste storage tanks. The change request requires the progress of the milestones to be reported in quarterly reports. The physical field activities identified in each milestone will continue to be completed by the existing September 30 milestone due date. However, the progress and final notification for completion of the

above interim milestones will be documented in quarterly reports and year-end reports that are due on October 31 of each year.

DOE and Washington State Department of Ecology conducted extensive negotiations in 1999 and 2000 to arrive at a set of Tri-Party Agreement commitments related to the retrieval and treatment of tank waste at the Hanford Site. These negotiations did not result in a successful final agreement by the agreed due date of March 29, 2000. Under the terms of the Tri-Party Agreement and associated agreements controlling the negotiations, the Director of the Washington State Department of Ecology issued a final determination on the matters under negotiation. This determination added 26 new milestones and made numerous other adjustments to existing milestones and administrative requirements of the Tri-Party Agreement.

2.3.1.4 Facilities Transition

Two change requests approved during 2000 were related to facility transition, i.e., the transition of a major facility from an expensive high maintenance shutdown/standby condition to a low maintenance, low cost, safe, stable condition to await final decommissioning.

One change request was approved that established two new milestones governing the disposition of "Rocky Flats Ash" mixed waste stored at Hanford's Plutonium Finishing Plant. Specifically, the "Rocky Flats Ash" material will be repackaged and eventually shipped to the Waste Isolation Pilot Plant in New Mexico for final disposition. This change request is also committed to begin negotiations for the transition of the entire Plutonium Finishing Plant to the Environmental Restoration Contractor by June 1, 2001.

Another change request was approved which modified one target date MX-92-06-T01, requiring the disposition of all Hanford Site Unirradiated Uranium by December 31, 2000. The modification extended the due date and established two separate target milestones: MX-92-06-T01 due by December 2001 and MX-92-06-T02 due by September 2006. These modifications were necessary to align these activities with the Hanford Site 300 Area Accelerated Cleanup Plan, the River Corridor Project, and other site priorities.

2.3.1.5 Spent Nuclear Fuel

Spent nuclear fuel from past operations at N Reactor is stored at the two K Basins, 100-K Area (see Section 2.3.3). Currently, under the Tri-Party Agreement, the fuel and sludge are being removed to safer storage facilities in the 200 Area. The Spent Nuclear Fuel Project developed a new strategy that will accelerate removal of sludge from the K Basins and improve operational efficiency in removing spent nuclear fuel from the basins. In implementing the new strategy, three interim milestones were accelerated, three were extended, three target dates were extended, and two target dates were deleted. One change request related to these actions was approved in 2000.

2.3.2 Pollution Prevention Program

D. H. Nichols

Pollution prevention is DOE's preferred approach to environmental management. The Hanford Site Pollution Prevention Program is an organized and continuing effort to reduce the quantity and toxicity of hazardous, radioactive, mixed, and sanitary waste. 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 federal and state 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) is considered only when source reduction and recycling are not possible or practical. Approved disposal to the environment at permitted sites is the last option.

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

Hanford Site pollution prevention efforts in 2000 helped to reduce disposal quantities through source reduction and recycling by an estimated 155,000 m^3 (202,000 yd^3) of radioactive and mixed waste, 26,000 metric tons (28,700 tons) of RCRA hazardous/dangerous waste, 860,000 liters (227,000 gallons) of process wastewater, and 1,800 metric tons (1,984 tons) of sanitary waste. Waste disposal cost savings in 2000 exceeded $46 million for these activities. During 2000, the Hanford Site recycled 430 metric tons (470 tons) of paper products and 510 metric tons (560 tons) of various metals.

2.3.3 Spent Nuclear Fuel Project

D. J. Watson

The Spent Nuclear Fuel Project was established in February 1994 to provide safe, economic, and environmentally sound management of Hanford Site spent (irradiated) nuclear fuel and to prepare the fuel for long-term storage or final disposal. During 2000, the project continued to make progress on an accelerated strategy to move spent fuel stored in the KW Basin and KE Basin, 100-K Area, away from the Columbia River and into the Canister Storage Building in the 200-East Area. The 40-year-old K Basins temporarily store 2,100 metric tons (2,300 tons) of N Reactor spent fuel and a small quantity of slightly irradiated single-pass reactor fuel. The spent fuel is removed from underwater storage in the K Basins and placed in dry interim storage in the 200-East Area. Prior to interim storage, the fuel is cleaned and packaged into containers called "multi-canister over packs." The over packs are vacuum processed to remove any water and then sealed. The vacuum processing and sealing is done at the Cold Vacuum Drying Facility located in the 100-K Area. The dried over packs are then transported to the Canister Storage Building located in the 200-East Area (see Figure 1.3). The multi-canister overpacks will be maintained in dry storage pending a decision by the Secretary of Energy on final disposition. If necessary, the repackaged spent fuel could remain in dry storage for up to 40 years. This strategy supports completion of fuel removal from the K Basins by the Tri-Party Agreement date of July 2004.

The corrosion of fuel and fuel handling operations has led to the accumulation of sludge and debris in old fuel storage canisters and on the floors of the K Basins. The majority of the sludge is in the KE Basin. The sludge, debris, and empty storage canisters will be removed after the spent fuel is removed. Water remaining in the basins will also be removed, treated at the Hanford Site 200 Areas Effluent Treatment Facility and disposed of onsite. Sludge, debris and old fuel canisters will be transported to the Environmental Restoration Disposal Facility for disposal to the extent possible. Sludge and debris that do not meet acceptance criteria for the Environmental Restoration Disposal Facility

will be transferred to the appropriate onsite waste management facility. The K Basins will then be prepared for interim stabilization pending final remediation.

The Spent Nuclear Fuel Project also specifies that other spent nuclear fuel stored on the Hanford Site will be relocated to the 200-East Area Interim Storage Area or to the Canister Storage Building. Other stored spent nuclear fuel and storage locations include

- Fast Flux Test Facility fuel in the 400 Area
- Training, Research, and Isotope Production General Atomics fuel in the 400 Area
- Shippingport, Pennsylvania, reactor fuel at T Plant in the 200-West Area
- miscellaneous special case and research reactor fuels in the 324, 325, and 327 buildings in the 300 Area.

Major accomplishments of the Spent Nuclear Fuel Project in 2000 included the following items:

- completed an Operational Readiness Review to begin startup of the 105-KW Basin Fuel Removal System, Cold Vacuum Drying Facility, and Canister Storage Building
- began removing spent nuclear fuel from the 105-KW Basin on December 7, 2000
- placed the first multi-canister overpack of spent nuclear fuel into dry storage on December 19, 2000
- developed a new strategy to accelerate removal of sludge from the K Basins.

2.3.4 River Corridor Project

The mission of the River Corridor Project is to deactivate contaminated facilities in all areas of the Hanford Site to prepare for decontamination and decommissioning. The project also provides for safe and secure storage of special nuclear material, nuclear material, and nuclear fuel until these materials can be transferred to another facility, sold, or otherwise dispositioned. Within the River Corridor Project are multiple subprojects and facilities, which are discussed in the following sections.

2.3.4.1 Accelerated Deactivation Project

J. M. Barnett

The mission of the Accelerated Deactivation Project is to complete facility deactivation and closure activities while maintaining the facilities in a safe and compliant status until they are turned over to the Environmental Restoration Program.

300 Area Fuel Supply Shutdown Subproject. The Fuel Supply Shutdown subproject includes deactivation of a building dating from 1943 that housed manufacturing equipment to produce uranium fuel for Hanford Site reactors. These processing operations were discontinued in 1987 when N Reactor was shut down. In 2000, 667 metric tons (734 tons) of uranium in the form of uranium trioxide powder were transferred to Portsmouth, Ohio.

2.3.4.2 324 and 327 Facilities Deactivation Project

M. M. *Serkowski*

Construction of the 324 and 327 buildings was completed and operations began in 1966 and 1953, respectively. These buildings contain hot cells that were used for radiological research and development work. Both facilities were transferred to Fluor Hanford, Inc. in 1996 for deactivation and closure.

Significant accomplishments achieved at the 324 Building in 2000 included the following:

- Size reduction activities of B-Cell equipment and storage rack continued as required per Tri-Party Agreement Milestone M-89-02.
- Dispersible materials from the B-Cell floor were collected and containerized.
- Seventeen grout containers and four mixed waste containers were packaged and shipped to the 200-West Area Burial Ground and Central Waste Complex.
- The 300 Area Special Case Waste Management Plan was developed and submitted six months ahead of schedule (Tri-Party Agreement Milestone M-92-13).
- Phase I Special Case Waste materials were packaged and removed from the facility on schedule, meeting Tri-Party Agreement Milestone M-92-14.

Significant accomplishments achieved at the 327 Building in 2000 included the following:

- One hundred three buckets of legacy waste were packaged and shipped to the Central Waste Complex. Only 29 buckets of legacy waste remain to be shipped out of 450 initial buckets.
- Three hundred fourteen grams (10 ounces) of fissile material were removed from the dry storage carousel, leaving just under 100 grams (3 ounces) in storage.
- Two drums of legacy waste were shipped to the burial ground. Only 4 containers remain to be shipped out of 19 initial containers of legacy waste.
- The interim clean out of H Cell was completed and all waste associated with that activity was shipped to the Central Waste Complex.
- All remaining irradiated fuel pin segments (a total of 335.2 grams or 10.8 ounces) were packaged and shipped to the Central Waste Complex.
- Thirty-two cubic meters (42 yd^3) of low-level waste were packaged and shipped to the low-level burial ground.

2.3.4.3 300 Area Treated Effluent Disposal Facility

C. P. Strand

In the past, the 340 Waste Handling Facility provided for the receipt, storage, and shipment of low-level, mixed, liquid waste from the 300 Area to the double-shell tanks. The accumulated waste was pumped into railcars and transported to the 200-East Area for neutralization and transferred to double-shell tanks for storage. Because the 340 Waste Handling Facility does not have a RCRA permit for hazardous waste storage, the facility ceased receiving waste in September 1998. The facility is currently in a standby mode awaiting deactivation.

Currently, industrial wastewater generated throughout the Hanford Site is accepted and treated in the 300 Area Treated Effluent Disposal Facility. Laboratories, research facilities, office buildings, and former fuel fabrication facilities in the 300 Area are the primary sources of wastewater. The wastewater consists of once-through cooling water, steam condensate, and other industrial wastewater. The facility began operation in December 1994.

This facility is designed for continuous receipt of wastewater, with a storage capacity of up to 5 days at the design flow rate of 1,100 liters per minute (300 gallons per minute). The treatment process includes iron coprecipitation to remove heavy metals, 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 in the low-level waste burial grounds. The treated liquid effluent is monitored and discharged through an outfall to the Columbia River under a National Pollutant Discharge Elimination System permit No. WA 002591-7 (see Section 2.2.8).

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. In 2000, ~231 million liters (61 million gallons) of wastewater were treated.

2.3.4.4 Plutonium Finishing Plant

W. J. McKenna

In 1949, the Plutonium Finishing Plant began to process plutonium nitrate solutions into metallic form for shipment to nuclear weapons production facilities. Operation of this plant continued into the late 1980s. 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 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 nuclear materials until final disposition.

Significant accomplishments achieved at the Plutonium Finishing Plant during 2000 include the following:

- Over 650 plutonium material items were heat stabilized in electric muffle furnaces. This is more than a fourfold increase over last year's level.
- Three major stabilization and packaging processes were brought on line, while achieving over a million safe work hours.
- Plutonium stabilization processes were operated in parallel with a special packaging system to prepare metals, oxide powder, solutions, and residues to meet packaging criteria for long-term storage.
- Installation of the special packaging system welding process was begun to prepare for an April 2001 startup.
- Extensive testing confirmed that polycube inventory (small cubes of plutonium in polystyrene) can be stabilized in existing muffle furnaces eliminating the need for new pyrolysis equipment.

2.3.4.5 Plutonium-Uranium Extraction Plant and B Plant

L. M. Dittmer

The Plutonium-Uranium Extraction Plant was transferred to the environmental restoration contractor after deactivation in 1999 and is being maintained in a surveillance and maintenance mode before decommissioning. The plant has a single effluent stack emission point that is a major emission unit as defined in 40 CFR 61. Also, there are 45 RCRA treatment, storage, and disposal vessels within the facility and containment structure. An annual roof inspection is performed from within the facility and from the outside to assess the condition of a facility that no longer has heat or utility service.

The B Plant, excluding the 296-B-1 stack, was transferred to the environmental restoration contractor in 1999. The facility effluent emission point through the 296-B-1 stack was transferred on August 10, 2000. The facility is being maintained in a surveillance and maintenance mode before decommissioning. The plant maintains two stack emission points that are a major emission unit by definition of 40 CFR 61. The plant contains 54 RCRA treatment, storage, and disposal vessels within the facility and containment structure. An annual roof inspection is performed from within the facility and from the outside to assess the condition of a facility that no longer has heat or utility service.

2.3.4.6 Waste Encapsulation and Storage Facility

F. M. Simmons

The mission of the Waste Encapsulation and Storage Facility project is to provide safe interim storage of encapsulated radioactive cesium and strontium. The facility was initially constructed as a portion of the B Plant complex and began service in 1974. In 1998, B Plant was deactivated and disconnected from the Waste Encapsulation and Storage Facility. There are currently 601 strontium fluoride capsules and 1,335 cesium chloride capsules stored at the facility. A RCRA Part A (Form 3) permit for dangerous waste storage was approved by the Washington State Department of Ecology on August 25, 2000. The capsules will be stored at the Waste Encapsulation and Storage Facility until at least 2013. The capsules then will be shipped to the vitrification plant for high-level waste vitrification. The final capsule shipment is scheduled for 2017.

2.3.5 Fast Flux Test Facility

D. A. Gantt

The Fast Flux Test Facility is a 400-megawatt thermal, liquid metal cooled reactor located in the 400 Area. It was built in the late 1970s to test plant equipment and fuel for the Liquid Metal Fast Breeder Reactor Program. The Fast Flux Test Facility operated from April 1982 to April 1992, during which time it successfully tested advanced nuclear fuels, materials, and safety designs and also produced a variety of isotopes for medical research. The reactor has been in a standby mode since December 1993. Fuel has been removed from the reactor vessel and stored in two sodium-filled vessels and in above-ground, dry storage casks. Twenty-three of the facility's 100 plant systems were deactivated.

On December 22, 1998, the Secretary of Energy announced the decision to remove the Fast Flux Test Facility from consideration as a tritium supply source. However, the Secretary asked that a program plan be developed that clearly defined other potential uses of the facility and the roles and responsibilities of potential users. A program plan was prepared and reviewed by the Nuclear Energy Research Advisory Committee. The Committee recommended that DOE proceed toward a record of decision but that a non-proliferation policy review, cost evaluation, and mission assessment be conducted to inform the Record of Decision. The committee also recommended that a comprehensive research and development plan be prepared for DOE that would include the Fast Flux Test Facility.

Based on these recommendations, the Secretary initiated a National Environmental Policy Act review of the environmental impacts associated with the restart and operation of the Fast Flux Test Facility as a nuclear research and medical isotope production facility. The *Final Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility* was issued in December 2000 (DOE/EIS-0310). The Secretary of Energy approved the Record of Decision (66 FR 7877) on January 19, 2001. In this record of decision, the Secretary determined that the Fast Flux Test Facility should be permanently deactivated. However, the ruling was later postponed pending review. A detailed summary of the status of the Fast Flux Test Facility can be found on the project website at http://www.fftf.org/currstat/.

2.3.6 Advanced Reactors Transition Project

D. A. Gantt

The mission of this project is to transition or convert the Plutonium Recycle Test Reactor facility and other nuclear energy legacy facilities into structures that are in a safe and stable condition suitable for transfer to the environmental restoration contractor. Legacy facilities are those used for nuclear research projects conducted in the past at the Hanford Site. Although nuclear energy legacy facilities existed in many areas of the Hanford Site, the only facilities remaining to be transferred to the environmental restoration contractor are in the southeastern part of the 300 Area. The transfer process includes preparation for minimal safe surveillance and maintenance activities. Deactivation of legacy facilities also includes the disposition of nonradioactive sodium and sodium-potassium alloy originally used in the development and testing of components for use in liquid metal-cooled reactors.

At the Plutonium Recycle Test Reactor/309 Building, located in the 300 Area, an above-grade contaminated ion exchange column and associated above grade piping were removed from the facility's transfer waste tank farm area. Inside the facility, contamination below ground level (-9.8 meter [-32 foot]) of the containment building was cleaned up. This included areas known as the A-Cell, B-Cell, C-Cell, and the reactor lower access space. Cleanup consisted of removing steel I-beams, scaffolding, materials, and unattached equipment. In the process, four 4x4x8 foot boxes (512 ft^3) were filled with contaminated debris and shipped to the low-level waste burial ground. Following the removal of the contaminated materials, the floors, sumps, and walls to a height of 2.4 meters (8 feet) were wiped down and painted. About 837 m^2 (9,000 ft^2) were wiped down and 227 liters (60 gallons) of paint were applied. The C-Cell, with a floor area of 74 m^2 (800 ft^2), was downgraded from a Contaminated Area (unpainted surface) to a Fixed Contamination Area (painted surface). The A-Cell, B-Cell, and the reactor lower access space remain as Contaminated Areas because the walls above 2.4 meters (8 feet) and the 8.2-meter (27-foot) high ceilings were not wiped down or painted.

The process of cleaning residual nonradioactive sodium from small tanks, which were previously drained, was completed. Sodium-potassium alloy residuals were also cleaned from the cold trap-cooling loop in the 337 High Bay Building. In 1998, about 510 liters (135 gallons) of bulk sodium-potassium was drained from the loop and shipped offsite. The loop was then sealed under an inert cover gas. Because of an accident involving sodium-potassium alloy at the Oak Ridge, Tennessee, Y-12 Plant, the decision was made in January 2000 to react the residual sodium-potassium alloy remaining in the cold trap cooling loop. A water vapor-nitrogen process was used to convert the sodium-potassium alloy to a mixture of sodium hydroxide and potassium hydroxide, and hydrogen gas. The rinse solution was sent to the onsite Treated Effluent Disposal Facility either in drums or via the process sewer. This was the first use of the Hanford designed and built cleaning station to treat and clean a piping system. Previous work had been to treat sodium residue in empty storage tanks.

2.3.7 Office of River Protection

P. A. Powell, P. D. Henwood and R. G. McCain

Congress established the Office of River Protection in 1998 as a DOE Field Office reporting directly to the DOE Assistant Secretary for Environmental Management. The Office of River Protection is responsible for managing DOE's River

Protection Project to store, retrieve, treat, and dispose of high-level tank waste and close the tank farm facilities at the Hanford Site.

2.3.7.1 Waste Tank Status

The status of the 177 waste tanks as of December 2000 was reported in HNF-EP-0182, *Waste Tank Summary Report for Month Ending December 31, 2000*. This report is published monthly; the December report provided the following information:

- number of high-level waste tanks
  - 149 single-shell tanks
  - 28 double-shell tanks
- number of high-level waste tanks assumed to have leaked
  - 67 single-shell tanks
  - 0 double-shell tanks
- chronology of single-shell tank leaks
  - 1956: first high-level waste tank reported as suspected of leaking (tank 241-U-104)
  - 1973: largest estimated leak reported (tank 241-T-106; 435,000 liters [115,000 gallons])
  - 1988: tanks 241-AX-102, 241-C-201, 241-C-202, 241-C-204, and 241-SX-104 confirmed as having leaked
  - 1992: latest tank (241-T-101) added to list of tanks assumed to have leaked, bringing total to 67 single-shell tanks
  - 1994: tank 241-T-111 was declared to have leaked again.
  - The total estimated volume to date of radioactive waste leakage from single-shell tanks is <2.84 to 3.97 million liters (<750,000 to 1 million gallons).
- number of ferrocyanide tanks on the Watch List (Twenty-four single-shell tanks were previously on the Watch List.)
  - 0 (The ferrocyanide safety issue was closed in 1996, and all remaining tanks were removed from the Watch List.)
- number of flammable gas tanks on the Watch List (As of February 28, 2001, there were 24 tanks on the Watch List; previously there were 25.)
  - 19 single-shell tanks
  - 5 double-shell tanks (The flammable gas safety issue associated with tank 241-SY-101 was closed in January 2001, and the tank was removed from the Watch List.)
- number of organic tanks on the Watch List (Twenty single-shell tanks were previously on the Watch List.)
  - 0 (Eighteen tanks containing organic complexants were removed from the Watch List in December 1998, and two tanks containing organic solvents were removed in August 2000.)
- number of high-heat tanks on the Watch List (One single-shell tank was previously on the Watch List.)
  - 0 (Single-shell tank 241-C-106 was removed from the Watch List in December 1999.)

To date, 125 of the 149 (84%) single-shell tanks have been stabilized and the program is ahead of schedule. At the end of 2000, intrusion prevention work was completed on 108 single-shell tanks. This involved capping off connecting pipes, risers, and pit covers to prevent any liquids from entering the tanks. Partial interim isolation was completed on 40 single-shell tanks. This involved capping off in the same manner as intrusion prevention except risers and piping were required to stabilize the tanks.

During 2000, four tanks (241-S-103, 241-SX-104, 241-SX-106, and 241-U-103) were

declared stabilized. Waste was pumped from 14 single-shell tanks into the double-shell tank system. Portions of the waste in tanks 241-S-102, 241-S-103, 241-S-106, 241-S-109, 241-SX-101, 241-SX-103, 241-SX-105, 241-U-102, 241-U-103, 241-U-105, 241-U-106, 241-U-109, 241-A-101, and 241-AX-101 were removed. This pumping removed 2.3 million liters (600,000 gallons) of waste from the single-shell tanks. The addition of this waste and dilution water to the double-shell tank system required the transfer of 11 million liters (3 million gallons) of waste from the double-shell tank system in the 200-West Area to the double-shell tank system in the 200-East Area, through the new 10.5-kilometer (6.5-mile) cross-site transfer pipeline. The ability to transfer waste safely from 200-West Area to 200-East Area has allowed a significant amount of single-shell tank waste to be transferred to the safer and environmentally compliant double-shell tank system. For the safe and timely removal of waste from the single-shell tank system, temporary transfer piping (above ground and shielded) has been installed. This has enhanced the schedule of single-shell tanks to be pumped, because the old underground lines had a tendency to leak.

To assure safe storage and retrieval, 136 of 177 (76%) tanks have been characterized. Characterization data and resulting safety controls have allowed the safe storage of tank waste and the removal of tanks from the Watch List. Currently, the first 14 tanks for waste feed delivery have been selected. Sampling has been performed in 12 of these tanks, with characterization analysis performed on 11 of them. This characterization information is being used to improve the design and operation of the Waste Treatment Facility.

2.3.7.2 Waste Tank Safety Issues

The Waste Tank Safety Program was established in accordance with the Public Law 101-510, *Defense Authorization Act*, Section 3137, "Safety Measures for Waste Tanks at Hanford Nuclear Reservation" (1990). The focal point of the program is the identification and resolution of safety issues involving high-priority waste tanks. The tasks to resolve safety issues are planned and implemented in the following order: 1) evaluate and define the associated safety issue, 2) identify and close any associated unreviewed safety questions, 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 tasks 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.

The Safety Issue Resolution Project focused on resolution of safety issues involving flammable gas, organic complexants and organic solvents, high-heat, and criticality. The tanks of concern were placed on a Watch List and categorized by safety issue. By 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. In 1998, 18 tanks containing organic complexants were removed from the Watch List, and in August 2000, the remaining tanks containing organic solvents were taken off the Watch List. The high-heat tank (241-C-106) was removed from the Watch List in 1999. At the end of 2000, 25 flammable gas tanks remained on the Watch List, but in January 2001 tank 241-SY-101 was removed after DOE, Defense Nuclear Facility Safety Board, and other stakeholders agreed the safety issue for that tank had been resolved. Currently, 24 flammable gas tanks remain on the Watch List.

2.3.7.3 Watch List Tanks

In early 1991, all Hanford Site high-level waste tanks were evaluated and organized into categories to ensure increased attention and monitoring. Other safety concerns, including flammability,

uncontrolled reactions, and the possibility of nuclear criticality in a waste tank are discussed below.

Flammable Gas. The Flammable Gas Safety Issue involves the generation, retention, and potential release of flammable gases by tank waste. Twenty-five tanks were identified and placed on the Watch List. In prior years, work controls were instituted to prevent introduction of spark sources into these tanks, and evaluations were completed to ensure that installed equipment was intrinsically safe.

Conditions within tank 241-SY-101 changed in 1997, which led to a continuous rise in the waste level. In February 1998, the DOE Richland Operations Office declared an unreviewed safety question related to the waste surface level changes. The responsible contractor formed a project team to remediate the waste level rise and a project plan was issued (HNF-3824). During 1999, the increasing level of waste in tank 241-SY-101 was stopped through the transfer and dilution of the waste in this tank. Approximately one-half of the original waste in tank 241-SY-101 was removed, and the remainder of the waste in the tank was diluted with water. This reduced the flammable gas generation rate by a factor of 10 and decreased the specific gravity to a point where the generated gases are no longer retained and a mixer pump was no longer required to induce gas releases. The safety issue for tank 241-SY-101 was declared resolved in January 2001 and the tank was removed from the Watch List.

Hydrogen monitors were installed on all 25 tanks on the Flammable Gas Watch List; in addition, another 17 monitors were installed to gather more data on a variety of tanks and operations. These systems were designed to continuously monitor for hydrogen and trigger an alarm if the hydrogen concentration reaches a preset level. They also have the capability to obtain grab samples for additional analyses. In 2000, 14 of the systems were shut down because monitoring data showed that flammable gas releases in these tanks were much too small to be of concern.

The Tri-Party Agreement milestone for resolution of the flammable gas safety issue is scheduled for completion by September 2001.

High-Heat Tank. This safety issue was resolved in December 1999, based on the transfer of the majority of the waste in tank 241-C-106 into tank 241-AY-102. This safety issue concerned the generation of heat from a large inventory of radionuclides in tank 241-C-106, a single-shell tank in the 200-East Area that required water additions and forced ventilation for evaporative cooling. The retrieval and transfer of 712,000 liters (188,000 gallons) of waste was completed in 1999. In December 1999, DOE approved the closure of the high-heat safety issue for tank 241-C-106, and removed it from the High-Heat Watch List.

Organic Tanks. This safety issue involves the potential for uncontrolled exothermic reactions of organic complexants and organic solvents present in some of the tanks. DOE identified 20 single-shell tanks for the Organic Watch List between 1991 and 1994. In 1998, DOE closed the organic complexant safety issue and removed 18 tanks containing organic complexant from the Watch List. In August 2000, DOE declared the organic solvent safety issue resolved and removed the remaining two organic tanks from the Watch List.

Criticality. DOE closed the safety issue on the potential for criticality in the high-level waste tanks in 1999. Additional analyses, stronger tank criticality prevention controls, and improved administrative procedures and training (WHC-SD-WM-SARR-003) provided the technical basis to resolve the safety issue and satisfy the related Tri-Party Agreement milestone. No tanks were ever put on the Watch List for criticality concerns.

2.3.7.4 Vadose Zone Characterization Near Single-Shell Underground Waste Storage Tanks

Baseline vadose zone characterization was completed in 1999. Baseline data were reported in tank summary data reports for all 133 single-shell tanks with capacities of 2 million liters (530,000 gallons) or greater (100-series tanks), and in tank farm reports for each of the 12 single-shell tank farms. Since the original baseline data were acquired, additional data have been collected, new analysis techniques have been developed, and additional insights into the nature and distribution of contamination in the vadose zone have been gained. An addendum to each tank farm report was prepared during 2000 to provide additional data and revise previous visualizations (three-dimensional drawings) of the subsurface contaminant distribution. A brief discussion of specific fiscal year 2000 activities and a general summary of the results of the fiscal year 1995 to fiscal year 2000 baseline characterization is included in Section 7.2. Complete results of the Tank Farms Vadose Zone Characterization Program are posted on the Internet at http://www.doegjpo.com/programs/hanf/HTFVZ.html.

The characterization serves as a baseline against which future measurements can be compared to identify and track gamma-emitting radionuclides in the vadose zone. Thus, a comprehensive routine monitoring program for selected boreholes around single-shell tanks is being developed. The baseline characterization effort will also be extended to existing boreholes in the vicinity of former liquid waste disposal sites across the Hanford Site.

2.3.7.5 Waste Immobilization

Approximately 204 million liters (54 million gallons) of radioactive and hazardous waste, accumulated from more than 40 years of plutonium production operations, are stored in 149 underground single-shell tanks and 28 underground double-shell tanks. The River Protection Program is currently upgrading facilities to deliver waste to the planned Waste Treatment Plant. During the past year, ~300 meters (~1,000 feet) of safer, regulatory compliant, waste transfer piping was installed. The 241-AY pump pit also was upgraded to achieve regulatory compliance by repairing the concrete structure, installing leak detectors, and sealing the inside walls. Also, a more reliable computer-based master pump shutdown system was designed to halt pumping in the event of a leak.

In support of waste feed delivery to the Waste Treatment Plant, two full-scale working mixer pump prototypes were successfully tested in tank 241-AZ-101, with waste that will eventually be removed and treated. The mixer pump demonstration provided information on the safety of pump operation, quantity of sludge mobilized, power consumption, and settling rates of the mobilized sludge. These new mixer pumps will be installed in numerous other tanks, to prepare the millions of gallons of waste for treatment.

During December 2000, the Office of River Protection awarded a contract to Bechtel-Washington, to design and build the Waste Treatment Facility. The facility will be built on 26 hectares (65 acres) located in the central plateau of Hanford's 200-East Area. Three major facilities to be constructed will include a pretreatment facility, a high-level waste vitrification facility, and a low-level waste vitrification facility, as well as, supporting facilities. At this time, the 26-hectare (65-acre) site has been cleared, with road and utility construction progressing. Electrical substation construction was started, with the placement of two transformers near the facility site.

2.3.8 Solid Waste Management

Solid waste may be from work on the Hanford Site or from sources offsite that are authorized by DOE to ship waste to the site. Treatment, storage, and disposal of solid waste takes place at a number of locations on the Hanford Site. Information about specific locations is contained in the following sections.

2.3.8.1 Central Waste Complex

D. G. Saueressig

Waste is received at the Central Waste Complex in the 200-West Area (see Figure 1.3) from sources at the Hanford Site and any offsite sources that are authorized by DOE to ship waste to the Hanford Site for treatment, storage, and disposal. Ongoing cleanup, research and development activities on the Hanford Site, as well as remediation activities, generate most of the waste received at the Central Waste Complex. Offsite waste has been primarily from other DOE sites and U.S. Department of Defense facilities. The characteristics of the waste received vary greatly, including low-level, transuranic, or mixed waste, and radioactively contaminated polychlorinated biphenyls.

The Central Waste Complex can store as much as 22,710 m^3 (29,705 yd^3) of low-level mixed waste and transuranic waste. This capacity is adequate to store the projected volumes of low-level, transuranic, mixed waste, and radioactively contaminated polychlorinated biphenyls to be generated, assuming on-schedule treatment of the stored waste. Treatment will reduce the amount of waste in storage and make room for newly generated mixed waste. The dangerous waste designation of each container of waste is established at the point of origin based on process knowledge or sample analysis.

2.3.8.2 Waste Receiving and Processing Facility

H. C. Boynton

The Waste Receiving and Processing Facility began operations in 1997 and analyzes, characterizes, and prepares drums and boxes of waste for disposal. The 4,800-m^2 (52,000-ft^2) facility is located near the Central Waste Complex in the 200-West Area (see Figure 1.3). The facility is designed to process ~6,800 drums and 70 boxes of waste annually for 30 years.

Waste destined for the Waste Receiving and Processing Facility includes Hanford's legacy waste as well as newly generated waste from current site cleanup activities. The waste consists primarily of contaminated clothing, gloves, facemasks, and small tools. Processed waste that qualifies as low-level waste and meets disposal requirements is direct-buried onsite. Low-level waste not meeting direct burial requirements is processed in the facility for onsite burial or prepared for future treatment at other onsite or offsite treatment, storage, and disposal facilities. Waste designated at the facility to be transuranic is certified and packaged for shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, for permanent disposal. Other materials requiring further processing to meet disposal criteria are retained, pending treatment.

2.3.8.3 Radioactive Mixed Waste Disposal Facility

D. E. Nester

The Radioactive Mixed Waste Disposal Facility is located in the 218-W-5 low-level waste burial ground in the 200-West Area and is designated as trenches 31 and 34 (see Figure 1.3). Trench 34 began to be used for disposal during September 1999. Prior to this, trenches 31 and 34 were used for storage. Trench 31 will continue to be used for storage, when

needed, to accommodate large items awaiting disposal into trench 34. Currently, there are ~900 m^3 (1,177 yd^3) of waste contained in about 670 waste packages disposed in Trench 34. No waste is currently stored in Trench 31. The trenches are rectangular landfills, with approximate base dimensions of 76 by 30 meters (250 by 100 feet). The bottoms of the excavations slope slightly, giving a variable depth of 9 to 12 meters (30 to 40 feet). These trenches comply with RCRA requirements because they have double liners and systems to collect and remove leachate. The bottom and sides of the facilities are covered with a layer of soil (1 meter [3 feet]) to protect the liner system during fill operations. There is a recessed section at the end of each excavation that houses a sump for leachate collection. Access to the bottom of each trench is provided by ramps along the perimeter walls.

2.3.8.4 T Plant Complex

B. M. Barnes

The T Plant complex in the 200-West Area (see Figure 1.3) provides waste treatment and storage and decontamination services for the Hanford Site. The T Plant complex currently operates under interim status. Waste handling activities at the T Plant complex in 2000 included the following:

- perform content verification of waste being shipped to solid waste facilities for storage or disposal
- re-package and/or sample waste to meet solid waste acceptance criteria or to determine acceptability of waste for treatment
- treat dangerous and mixed waste to meet RCRA requirements for land disposal
- decontaminate equipment to allow for reuse or disposal as waste
- store 27 metric tons (30 tons) of spent reactor fuel (from Shippingport, Pennsylvania) in a water basin.

2.3.8.5 Radioactive Mixed Waste Treatment and Disposal

D. E. Nester

During 2000, 1,285 m^3 (1,681 yd^3) of DOE mixed waste were treated and/or direct disposed. The waste materials were obtained from a number of projects including the following:

- 1,179 m^3 (1,542 yd^3), or about 1,000 packages of various sizes, of mixed waste debris previously stored at the Central Waste Complex were shipped to the Allied Technology Group Mixed Waste Treatment Facility located in Richland, Washington. Allied Technology Group used their RCRA permitted treatment process of macroencapsulation to make the debris compliant with EPA Land Disposal Restriction requirements. The treated waste was then returned to Hanford for final disposal at the Radioactive Mixed Waste Disposal Facility.
- 78 m^3 (102 yd^3), or 375 drums, of mixed waste consisting of inorganic solids from the Effluent Treatment Facility were removed from storage at the Central Waste Complex. The waste was shipped to the Radioactive Mixed Waste Disposal Facility and prepared for disposal. The drums were visually inspected and void-filled as necessary to meet disposal requirements. The drums were then placed into the Radioactive Mixed Waste Disposal Facility for final disposal.
- 28 m^3 (37 yd^3), or one large package, of mixed waste debris was cleaned from the Canyon Deck area of Hanford's T Plant facility. The mixed waste debris was macroencapsulated at T Plant to meet EPA Land Disposal Restriction requirements. The treated waste was then shipped to the Radioactive Mixed Waste Disposal facility for final disposal.

2.3.8.6 Radioactive Mixed Waste Treatment Contracts

D. E. Nester

In November 1995, DOE awarded a contract to Allied Technology Group, Richland, Washington, for thermal treatment of Hanford's mixed waste in accordance with RCRA and the *Toxic Substances Control Act*. During December 2000, Allied Technology Group initiated treatment of Hanford's thermally treatable waste with the use of their newly obtained GASVIT® treatment technology. The treated waste was returned to Hanford for burial at the Radioactive Mixed Waste Disposal Facility. Allied Technology Group is expected to increase their thermal treatment capacity during 2001 until they reach their RCRA/*Toxic Substance Control Act* permitted levels.

During 1997, a competitive procurement was conducted for the processing of mixed waste requiring non-thermal treatment in accordance with RCRA. The contract was also awarded to Allied Technology Group. During 2000, Allied Technology Group processed 1,179 m^3 (1,542 yd^3) of Hanford's mixed waste debris via this contract. The treated waste was returned to Hanford for disposal at the Radioactive Mixed Waste Disposal Facility.

2.3.8.7 Reactor Compartments

S. G. Arnold

Eight disposal packages containing defueled United States Navy reactor compartments were received and placed in Trench 94 in the 200-East Area during 2000. All eight reactor compartments were from submarines. This brings the total number of reactor compartments received to 94. All reactor compartments shipped to the Hanford Site for disposal have originated from decommissioned nuclear-powered submarines or cruisers.

2.3.9 Liquid Effluent Treatment

Hazardous and untreated radioactive liquid waste is no longer discharged directly to the environment at the Hanford Site. Liquid effluents are managed in treatment, storage, and disposal facilities to comply with RCRA and state regulations.

2.3.9.1 242-A Evaporator

S. S. Lowe

Storage space is limited in the double-shell tanks to support remediation of tank waste and cleanup of the Hanford Site. The 242-A evaporator in the 200-East Area concentrates dilute liquid tank waste by evaporation (see Figure 1.3). The volume of tank waste is reduced to eliminate the need to construct additional double-shell tanks. The concentrated tank waste is returned to the double-shell tanks for storage. One campaign was conducted at the 242-A evaporator in 2000. The run treated 5.07 million liters (1.34 million gallons) of tank waste and produced 3.09 million liters (815,000 gallons) of process condensate. One 242-A evaporator campaign is planned for 2001, and two campaigns are planned in 2002.

Effluent treatment and disposal capabilities are available to support the continued operation of the 242-A evaporator. The Effluent Treatment Facility near the 200-East Area was constructed to treat the process condensate from the 242-A evaporator and other radioactive liquid waste. The process condensate is sent to the Liquid Effluent Retention Facility for interim storage while awaiting treatment in the Effluent Treatment Facility. Cooling water and nonradioactive steam condensate from the 242-A evaporator are discharged to the 200 Areas Treated Effluent Disposal Facility.

2.3.9.2 Liquid Effluent Retention Facility

S. S. Lowe

The Liquid Effluent Retention Facility in the 200-East Area (see Figure 1.3) consists of three RCRA-compliant surface impoundments to temporarily store process condensate from the 242-A evaporator and other aqueous waste. The Liquid Effluent Retention Facility provides equalization of the flow and pH of the feed to the Effluent Treatment Facility. Each basin has a maximum capacity of 29.5 million liters (7.8 million gallons). Generally, spare capacity is maintained in the event a leak should develop in an operational basin. Each basin is 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 chain barrier should the primary and secondary liners fail. Each basin has a mechanically tensioned floating membrane cover constructed of very low-density polyethylene to keep out unwanted material and to minimize evaporation of the basin contents. The facility began operation in April 1994 and receives liquid waste from both RCRA- and CERCLA-regulated cleanup activities. Approximately 42.3 million liters (11.2 million gallons) of aqueous waste were stored in the basins at the end of 2000.

2.3.9.3 200 Areas Effluent Treatment Facility

S. S. Lowe

Liquid effluents are treated in the Effluent Treatment Facility (200-East Area, see Figure 1.3) to remove toxic metals, radionuclides, and ammonia, and destroy organic compounds. The treated effluent is stored in verification tanks, sampled and analyzed, and discharged to the State-Approved Land Disposal Site (also know as the 616-A crib). The treatment process constitutes best available technology and includes pH adjustment, filtration, ultraviolet light/peroxide destruction of organic compounds, reverse osmosis to remove dissolved solids, and ion exchange to remove the last traces of contaminants. The facility began operation in December 1995. Treatment capacity of the facility is 570 liters per minute (150 gallons per minute). Approximately 88.6 million liters (23.4 million gallons) of aqueous waste were treated in 2000.

The treated effluent is sampled to verify that the 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 (see Figure 1.3) and consists of an underground drain field. Tritium in the liquid effluent cannot be removed practically, and the location of the disposal site maximizes the time for migration of contaminated groundwater to reach the Columbia River and, thus, allow time for radioactive decay. The disposal site is permitted under the WAC 173-216 State Waste Discharge Permit Program. The discharge permit requires monitoring of the groundwater and the treated effluent to ensure that levels for certain constituents are not exceeded. Permit limits were not exceeded in 2000. The discharge permit for the Effluent Treatment Facility was renewed in 2000.

Secondary waste from treating aqueous waste is concentrated, dried, and packaged in 208-liter (55-gallon) drums. The solid secondary waste from treating RCRA-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 the mixed waste disposal unit in the 200-West Area. The solid secondary waste from treating CERCLA-regulated aqueous waste is disposed of in the Environmental Restoration Disposal Facility near the 200-West Area (see Figure 1.3).

2.3.9.4 200 Areas Treated Effluent Disposal Facility

S. S. Lowe

The 200 Areas Treated Effluent Disposal Facility is a collection and disposal system for non-RCRA permitted waste streams. The individual waste streams must be treated or otherwise comply with "best available technology/all known available and reasonable treatment." Implementation of regulatory "best available technology/all known available and reasonable treatment" is the responsibility of the generating facilities. The major components of the 200 Areas Treated Effluent Disposal Facility include ~18 kilometers (~11 miles) of buried pipeline connecting three pumping stations, one disposal sample station (6653 Building) and two 2-hectare (5-acre) disposal ponds located east of the 200-East Area. The facility began operation in April 1995 and has a capacity of 12,900 liters per minute (3,400 gallons per minute). There are currently 15 waste streams being sent to the 200 Areas Treated Effluent Disposal Facility (see Figure 1.3). Approximately 502 million liters (133 million gallons) of effluent were discharged altogether in 2000.

The discharge from the 200 Areas Treated Effluent Disposal Facility must comply with limits in the WAC 173-216 State Waste Discharge Permit. The discharge permit requires monitoring of the effluent and the groundwater to ensure that concentrations for certain constituents are not exceeded. End-of-pipe sampling and continuous on-line monitoring (for flow, pH, and conductivity) of the combined waste stream is performed at the 6653 Building. The individual generating facilities also are required to perform on-line monitoring and sampling; the requirements depend on the individual waste streams. There were two non-compliances with the discharge permit in 2000 and both were corrected (see Section 2.2.8.1). One was for not achieving the specified practical quantification level when analyzing for a particular contaminant. The other was for use of a non-accredited laboratory for tritium analysis. The discharge permit for the 200 Areas Treated Effluent Disposal Facility was renewed in 2000.

2.3.9.5 Miscellaneous Streams

D. M. Korematsu-Olund

In February 1995, Washington State Department of Ecology approved a *Plan and Schedule for Disposition and Regulatory Compliance for Miscellaneous Streams* (DOE/RL-93-94). This plan and schedule required that all miscellaneous streams be permitted under WAC 173-216. Categorical permits were used to permit miscellaneous streams with similar characteristics. Categorical 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 streams condensate. Permit # ST-4509 was issued in May 1998
- industrial stormwater discharge. Permit # ST-4510 was issued in April 1999.

The permitting process was completed in 1999 with the issuance of the last Categorical Permit ST-4510. All compliance milestones identified in the plan and schedule (DOE/RL-93-94) have been fulfilled, and the annual submittal of the Hanford Site Miscellaneous Streams Inventory report is no longer required.

In January 2000, DOE issued the *Pollution Prevention and Best Management Practices Plan for State Waste Discharge Permits ST 4508, ST 4509, and ST 4510* (DOE/RL-97-67). This plan summarized the compliance requirements stated in all the categorical permits and set conditions for the individual streams. The pollution prevention and best management practices plan details implementation of remediation activities to prevent further contamination of groundwater.

In compliance with WAC 173-218, which requires registration of Class V underground injection control wells, a significant and ongoing effort to verify location and status of all Class V underground injection control wells on the Hanford Site was begun in February 2000. A large number of underground injection control wells were determined to be inactive and were removed from the list of active wells. The information gathered will be compiled and submitted to the Washington State Department of Ecology in 2001, as required.

2.3.10 Revegetation and Mitigation Planning

A. L. Johnson and M. R. Sackschewsky

Valuable wetland habitat was created near the Columbia River in the process of excavating fill material from Borrow Pit 24 to use as backfill at waste sites in the nearby 100-B/C Area. Restoration of the pit was initiated during the final phase of material excavations by creating channels and islands and exposing the water table. This process combined a restoration project with a construction project to create a valuable wildlife habitat at little to no additional cost to the project. Wetland species including cattails and willows have begun to inhabit the area.

Some of the native sagebrush plants in Horn Rapids Park that were burned during the June 2000 wildfire were replaced. Approximately 8,100 sagebrush plants were planted by volunteers from the local community along transects within the park and adjacent to the Yakima River. The planted sagebrush will help replace habitat and provide a seed source to the area.

The final phase of revegetation on the 100-B/C liquid effluent disposal sites 116-C-5, 116-B-1, and 116-B-11 was completed. The 5.27-hectare (13-acre) area was planted with 2,600 sagebrush plants following the hydroseeding of native grasses and forbs in December 1999. The planted sites will be monitored for 5 years to ensure the planting effort is successful.

In concert with the U.S. Fish and Wildlife Service, ~80,000 bareroot and potted sagebrush plants were planted on about 80 hectares (200 acres) at 9 locations on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit during December 2000. This effort was the last phase of sagebrush planting as mitigation for the disturbance of sagebrush habitat resulting from the development of the site and infrastructure for the planned waste vitrification facility.

2.3.11 Environmental Restoration Project

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DOE selected a contractor in 1994 to oversee environmental restoration projects at the Hanford Site. The Environmental Restoration Project includes characterization and remediation of contaminated soil and groundwater, sitewide vadose zone/groundwater project integration, decontamination and decommissioning of facilities, surveillance and maintenance of inactive waste sites, and the transition of facilities into the surveillance and maintenance program.

2.3.11.1 Environmental Restoration Disposal Facility

The Environmental Restoration Disposal Facility is located near the 200-West Area (see Figure 1.3). The facility began operations in July of

1996 and is designed to serve as the central disposal site for contaminated waste removed during cleanup operations conducted under CERCLA on the Hanford Site. In order to provide a protective barrier, the facility was constructed with a RCRA subtitle C compliant double liner and leachate collection system. In 2000, waste was first placed into the new cells that were constructed in 1999. Later in 2000, an interim cover was placed over portions of cells 1 and 2 that had been filled to their final configuration. Cleanup materials disposed in the facility include soil, rubble, or other solid waste materials contaminated with hazardous, low-level radioactive or mixed (combined hazardous, chemical, and radioactive) waste. As of early 2001, the facility had received 2.4 million metric tons (2.65 million tons) of contaminated soil and other waste.

2.3.11.2 Waste Site Remediation

Full-scale remediation of waste sites began in the 100 Areas in 1996. Remediation and backfill activities continued through 2000 at several liquid waste disposal sites in the 100-B/C, 100-D/DR, and 100-HR remediation areas located in the 100-B/C, 100-D, and 100-H Areas, respectively. In July 2000, work began in the 100-FR and 100-NR remediation areas located in the 100-F and 100-N Areas, respectively. Figure 1.1 shows the former reactor areas along the Columbia River.

In the 100-B/C Area, 12 waste sites were backfilled in 2000. Through December 2000, 621,100 metric tons (685,000 tons) of contaminated soil were removed and shipped to the Environmental Restoration Disposal Facility.

In the 100-D/DR Area, 67,000 metric tons (74,000 tons) of soil were removed from 10 waste sites. Twelve waste sites were backfilled. Through December 2000, 641,000 metric tons (709,000 tons) of contaminated soil were removed and shipped to the Environmental Restoration Disposal Facility.

In the 100-HR Area, 190,600 metric tons (211,000 tons) of soil were removed from the nine waste sites. Through December 2000, 412,000 metric tons (455,000 tons) of contaminated soil were removed and shipped to the Environmental Restoration Disposal Facility.

In the 100-FR Area, 148,300 metric tons (164,000 tons) of soil were removed from four waste sites. The startup of the remedial actions at 100-FR completed Tri-Party Agreement Milestone M-16-13A.

In the 100-NR Area, an Interim Remedial Action Record of Decision and Closure Plan was issued under the Tri-Party Agreement for cleanup of six treatment, storage, and disposal units within the 100-NR-1 Operable Unit on January 19, 2000. The Record of Decision integrated CERCLA and RCRA objectives and specified a cleanup remedy of remove/treat/dispose for the treatment, storage, and disposal units. Remedial design for the treatment, storage, and disposal units was completed in mid-2000. In July 2000, remediation began at the 116-N-3 treatment, storage, and disposal unit as required by the Hanford Sitewide RCRA Permit. Through 2000, ~25,000 metric tons (28,000 tons) of soil were removed from 116-N-3 as well as from two other treatment, storage, and disposal units, 120-N-1, 120-N-2, and associated waste site, 100-N-58. Remediation of the 116-N-3 treatment, storage, and disposal units is scheduled to continue through 2001 with completion planned for 2002.

An interim record of decision was issued for the 100 Areas Burial Grounds on September 16, 2000. It specified a cleanup remedy to remove/treat/dispose of contaminated soil, structures, and debris at the 100 Areas Burial Ground sites. This was the last interim record of decision required for the 100 Area waste sites.

Remediation work at the 300-FF-1 Operable Unit began in the 300 Area in 1997 (see Figure 1.1). Historically, both chemical and radiological materials were disposed of at the 300-FF-1

waste sites. In 2000, remediation operations excavated nearly 94,700 metric tons (104,600 tons) of contaminated soils and debris that were shipped to the Environmental Restoration Disposal Facility. Over 408,700 metric tons (531,200 tons) have been removed through 2000. Remediation of the 316-2 North Process Pond, and 300 Area Landfills 1A (300-49) and 1B (300-50) was completed in 2000.

A record of decision (EPA 1999) was issued for the 100 Areas remaining sites in 1999. The record of decision includes ~200 waste sites that were not previously addressed in the 1995 100 Areas record of decision, or the 1997 amendment to the 100 Areas record of decision (100 Areas solid waste burial sites and waste sites at 100-N Area were not included). It specified a remove/treat/dispose remedy, for contaminated soil, structures, and debris at 46 of the remaining sites. The cleanup remedy is the method applied to 100 Areas record of decision sites and is consistent with other cleanup actions that are currently being conducted within the 100 Areas. The remainder of the sites is classified as candidate sites for confirmatory sampling to determine if there is residual contamination above cleanup levels. Contaminated sites will move directly into remove/treat/dispose and others will be closed out based on the confirmatory sampling efforts. In 1999, DOE began design of remedial actions for the remaining sites. These actions were completed in early 2000.

2.3.11.3 Facility Decommissioning Project

Decontamination and decommissioning activities continued in 2000 in the 100-DR, 100-H, and 100-F Areas. During the year, all planned demolition (including valve pit, exhaust plenum, and all below-grade tunnels) was completed at the 105-DR and 105-F reactors, excluding the 105-F Reactor Fuel Storage Basin. Ancillary facilities that supported the 105-DR and 105-F reactors (except for 117-DR) were removed and disposed. A subcontract was awarded for the 105-DR and 105-F safe storage enclosure pourback work. Pourbacks are the process of enclosing openings in the safe storage enclosure wall with structural concrete to prevent inadvertent pest or weather intrusion. The subcontractor has completed nearly all of the required pourbacks. These activities support the interim safe storage of the reactor buildings.

A baseline change proposal was approved to accelerate the 105-F Reactor Fuel Storage Basin demolition, initiated in late September. Demolition work at the 105-DR reactor has been completed, and work to clean out and demolish the 105-F Fuel Storage Basin has been initiated. Removal and characterization of the upper 5.2 meters (17 feet) was completed and, with regulatory approval, will be reused as backfill. A Brokk™ excavator was procured to assist with the contaminated debris removal. DOE/RL has issued a letter of direction articulating responsibilities for the disposition of any spent nuclear fuel found in the fuel storage basin, and engineering documentation required to proceed with the work is nearly completed.

Project closeout reports for the demolition of the 119-DR Exhaust Air Filter Sampling Building, 116-D and 115-DR exhaust stacks, and the 108-F Biology Laboratory were completed. Submittal of these reports constitutes formal completion of the demolition projects for these ancillary facilities.

Decontamination and decommissioning activities also began at the 105-D and 105-H reactor buildings. These activities included biological cleanup, legacy waste removal, asbestos abatement, liquid pipe checks, and other pre-demolition activities.

2.3.11.4 233-S Plutonium Concentration Facility Decontamination Project

Decontamination and decommissioning work Area adjacent to the Reduction-Oxidation Plant.

This work is being performed under a non-time-critical removal action under CERCLA. The 233-S facility and associated process equipment were used to concentrate plutonium produced at the Reduction-Oxidation Plant from 1955 to 1967. Loadout hood dismantlement and removal, ventilation system exhaust ducting removal, gross decontamination of the process hood, and viewing room equipment removal were completed in 2000. The facility poses special challenges to workers, engineering methods, safety documentation, and work methods because of the estimated large quantities of fissile material and high levels of contamination.

2.3.11.5 Surveillance/ Maintenance and Transition Project

This project performs surveillance and maintenance of inactive facilities and waste sites until final disposition can commence. The project also provides for the transfer, or transition, of facilities and waste sites into the Environmental Restoration Program after deactivation has been completed. Facilities transferred in 1998 and 1999 include Plutonium-Uranium Extraction Plant, B Plant, and 224-B Building facilities. Also, the project performs surveillance and maintenance of the Reduction-Oxidation Plant, U Plant, 224-U Building, N Reactor, B Reactor, C Reactor, and the 105-KE and 105-KW reactors (excluding the fuel storage basins). The project maintains 14 interim status RCRA treatment, storage, and disposal units awaiting closure. Also, the project maintains three major air emission stacks and two minor emission stacks as defined by 40 CFR 61.

Outdoor tasks within the project include the Radiation Area Remedial Action Program, which is responsible for the surveillance, maintenance, and decontamination or stabilization of 955 inactive waste sites that include former cribs, ponds, ditches, trenches, unplanned release sites, and burial grounds. These sites are maintained by performing periodic surveillances, radiation surveys, and 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 in these sites from spreading in the environment.

This project also analyzed the final status/ condition of the canyon facilities (i.e., large concrete structures formerly used in Hanford Site production missions) that the project currently oversees and those that are coming to the project through facility transition activities. The U Plant canyon disposition initiative is evaluating the potential use of the canyon facilities as waste disposal units, or disposal in place with a cap, compared to standard decontamination and decommissioning of the facilities. A CERCLA feasibility study is being prepared for the U Plant facility that will result in a Record of Decision in 2002.

2.3.12 Groundwater/Vadose Zone Integration Project

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The Groundwater/Vadose Zone Integration Project brings together all activities that affect Hanford's subsurface, and ultimately, the Columbia River. Many of these activities are part of multiple cleanup projects that report to different managers and contractors. See Section 7.0 for information on monitoring and characterization activities.

A focus of the Groundwater/Vadose Zone Integration Project involves preparation of a cumulative

impact assessment of Hanford Site radioactive and hazardous contaminants that have, or may, affect the many uses and users of the Columbia River. The project continues to work on the design of a system assessment capability to meet the needs identified in the Columbia River Comprehensive Impact Assessment Part II report (DOE/RL-96-16). To be successful, the project must:

- adopt a sitewide approach to project planning, funding, and data and information management to support cleanup decisions
- ensure that management attention is maintained on the subsurface and river resources
- be recognized for technical and scientific excellence in all products
- establish and ensure effective two-way communication with diverse project participants.

2.3.12.1 Groundwater Restoration

The overall objectives of groundwater restoration are to:

- protect aquatic receptors in the river bottom substrate from contaminants in the groundwater entering Columbia River
- reduce contamination in the areas of highest concentration
- prevent further movement of contamination
- protect human health and the environment.

Summary descriptions of the groundwater restoration activities are discussed below.

Chromium. Groundwater contaminated with chromium underlies portions of the 100-D, 100-H, and 100-K Areas (the 100-HR-3 and 100-KR-4 Operable Units) and is of concern because of a potential to impact the Columbia River ecosystem. Low 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). The relevant standard for protection of freshwater aquatic life is 10 mg/L of chromium (WAC 173-201A). Chromium concentrations exceeding 600 mg/L have been measured in the pore-water sediments of the Columbia River (BHI-00778). In 1994, a groundwater extraction system was installed in the 100-D Area to test chromium removal from groundwater using ion exchange technology. Following the approval of the record of decision in 1996 (EPA 1996), full-scale pump-and-treat systems were constructed in the 100-D, 100-H, and 100-K Areas. The objective of the pump-and-treat systems is to remove chromium contamination in the groundwater and thus minimize impacts to the Columbia River.

In 2000, the total amount of groundwater treated by the 100-D and 100-H pump-and-treat systems was 305.1 million liters (80.6 million gallons), with the removal of 30 kilograms (66.2 pounds) of chromium. To date, more than 959.1 million liters (253.3 million gallons) of groundwater have been treated, with 103.1 kilograms (227.3 pounds) of chromium removed (DOE/RL 2000-14). Treated groundwater is re-injected into the aquifer upgradient from the 100-H Area extraction wells. Groundwater from both the 100-D and 100-H sites is treated in the 100-H Area using separate treatment systems.

In 2000, the 100-KR pump-and-treat system treated 286.7 million liters (75.5 million gallons) of groundwater. During the process, 33.5 kilograms (73.8 pounds) of chromium were removed. Total chromium removed since operations began is 113.9 kilograms (251 pounds) through treatment of 908 million liters (239.9 million gallons) of water. Treated groundwater is re-injected into the aquifer upgradient from the 100-KR-4 extraction wells.

To further evaluate chromium and other groundwater contamination that might enter the Columbia River between monitoring wells, 178 aquifer sample tubes were installed in 1997 along and parallel to the Columbia River shoreline. The distance between the sample tubes was ~610 meters

(2,000 feet), except in known chromium plumes, where this was reduced to ~305 meters (1,000 feet). Sample tubes are constructed of 0.6-centimeter (0.25-inch) inner-diameter polyethylene tubing with a screen at the bottom that is placed anywhere from 0.9 to 9 meters (3 to 30 feet) below ground surface. Sample tube installations begin upstream from the 100-B/C Area and continue downstream ~40 kilometers (25 miles) to near the Old Hanford Townsite. Sample tube locations are shown in Figure 7.1.8.

In the fall of 2000, samples were collected from 34 sample tube locations. These samples were analyzed for chromium, nitrate, sulfate, tritium, strontium-90, total uranium, gross beta, and carbon-14. The results are being used to characterize groundwater near the Columbia River in support of remediation operations, monitoring objectives, and other environmental programs. Sample tube data provide site-specific information on the distribution of chromium that enters the river at locations near sensitive ecological receptors (e.g., salmon spawning areas). Additional discussion of chromium in groundwater in the 100 Areas is presented in Section 7.1.6.2.

In addition to pump-and-treat remediation, a technology called in situ redox manipulation was selected to remediate a high-concentration area beginning in 2000. The in situ redox manipulation technology creates a chemically reduced zone within a portion of the contaminated aquifer. As chromium-contaminated groundwater flows through the barrier, it is converted from a dissolved toxic form to a non-toxic solid form. The technology was initially tested and successfully applied during a chromium treatability test in the 100-D Area from 1997 to 1999.

Barrier construction is still underway in 2000 and will continue into 2001. At the end of the year, it was 165 meters (543 feet) in length and 15 meters (48 feet) wide. The final barrier should be over 680 meters (744 feet) long. The barrier will intercept and neutralize chromium-contaminated groundwater moving from the aquifer to the Columbia River. The current pump-and-treat systems will also continue to operate.

Strontium-90. The 100-NR-2 (N Springs) pump-and-treat system began operating in 1995 north of the N Reactor complex and was designed to reduce the flux of strontium-90 to the Columbia River. The pump-and-treat system operates extraction wells to maintain hydraulic capture. Groundwater is pumped into a treatment system to remove the strontium-90 contamination, with treated water re-injected upgradient into the aquifer. The system was upgraded in 1996 and has continued to operate through 2000. About 106 million liters (28 million gallons) were processed in fiscal year 2000. During that period, 0.18 curies of strontium were removed from the groundwater. Over 551.9 million liters (145.5 million gallons) of groundwater have been processed since the system began operation, removing 0.91 curies of strontium.

Carbon Tetrachloride. The carbon tetrachloride plume in the 200-West Area (originating in the 200-ZP-1 Operable Unit) covers over 11 square kilometers (4.2 square miles). The 200-ZP-1 pump-and-treat system has operated since 1997. In 2000, 300.4 million liters (80.3 million gallons) of groundwater were treated, removing over 1,183 kilograms (2,608 pounds) of carbon tetrachloride. A total of ~1.25 billion liters (356 million gallons) have been processed since startup, removing 9,570 kilograms (21,098 pounds) of carbon tetrachloride.

Uranium, Technetium-99, Carbon Tetrachloride, and Nitrates. Treatment of the groundwater plume underlying the 200-UP-1 Operable Unit in the 200-West Area continued throughout 2000. The contaminant plume contains uranium, technetium-99, carbon tetrachloride, and nitrate. A pump-and-treat system has operated since 1994 to contain the high concentration area of the uranium and technetium-99 plume. During early operations, groundwater was treated using ion-exchange

resin to remove the uranium and technetium-99, and granular activated carbon to remove carbon tetrachloride. Since 1997, contaminated groundwater has been transferred by pipeline to Basin 43 at the 200 Areas Effluent Treatment Facility. Sophisticated treatment technology removes all four contaminants. Treated groundwater is then discharged north of the 200-West Area at the State-Approved Land Disposal Site.

The pump-and-treat system operated continually during the year 2000, except for a few scheduled shutdowns, including a brief period in early January because of concerns about possible computer problems. The single extraction well was used to pump 63.2 million liters (16.6 million gallons) of groundwater, which were treated to remove 5.6 grams (0.0124 pound) of technetium-99, 13.6 kilograms (29.9 pounds) of uranium, 1.66 kilograms (3.6 pounds) of carbon tetrachloride, and 2,807 kilograms (6,188 pounds) of nitrate. The pump-and-treat operation made significant progress toward reducing technetium-99 concentrations to below required cleanup concentration levels, but less progress was made with uranium (DOE/RL-99-79).

2.3.12.2 Vadose Zone Remediation

Soil vapor extraction systems designed to remove carbon tetrachloride vapor from the vadose zone beneath the 200-West Area began operating in 1992 and continued through 1999. Soil vapor extraction has been conducted in the vicinity of three historical carbon tetrachloride disposal sites: the 216-Z-1A-tile field, the 216-Z-9 trench, and the 216-Z-18 crib. Soil vapor is either pumped or flows naturally through granular activated carbon, which absorbs carbon tetrachloride. The granular activated carbon is then shipped offsite for treatment.

Soil vapor extraction systems operate at three different flow rates; 14.2-m^3 per minute (500-ft^3 per minute), 28.3-m^3 per minute (1,000-ft^3 per minute), and 42.5-m^3 per minute (1,500-ft^3 per minute). However, all three pumping systems were maintained in standby mode during 2000. Passive soil vapor extraction systems, which use atmospheric pressure fluctuations to remove carbon tetrachloride vapor from the vadose zone, were installed at wells near the 216-Z-1A-tile field and 216-Z-18 crib in 1999. These passive systems operated throughout 2000. Since operations began, soil vapor extraction has removed 76,460 kilograms (168,560 pounds) of carbon tetrachloride from the vadose zone.

2.3.12.3 Vadose Zone Characterization in the 200 Areas

Remedial investigation/feasibility study activities continued in 2000 at soil waste sites in the 200 Areas. Work was performed within the characterization and regulatory framework defined in the 200 Area Remedial Investigation/Feasibility Study Implementation Plan (DOE/RL-98-28). Work was performed at several operable units, which were at various stages of the CERCLA Remedial Investigation/Feasibility Study process. Summary descriptions of activities performed in 2000 are provided below.

200-CW-1 Gable Mountain Pond/B Pond Cooling Water Operable Unit. The 200-CW-1 Gable Mountain Pond/B Pond and Ditches Cooling Water Operable Unit consists of former ponds and ditches located within the 200-East Area and north and east of the 200-East Area. These sites received mostly cooling water from facilities such as the Plutonium-Uranium Extraction Plant and B Plant. A draft remedial investigation report was prepared for regulator review (DOE/RL-2000-35) that evaluated the results of the fieldwork (i.e., the remedial investigation) performed the previous year. The report analyzed soil contaminant data collected from 27 test pits, 2 boreholes, and 191 soil samples from four waste sites (216-A-25 pond, 216-B-2-2 ditch, 216-B-3-3 ditch, and 216-B-3 pond) as reported in BHI-01367.

200-CS-1 Chemical Sewer Operable Unit. The 200-CS-1 Operable Unit consists of waste sites that received chemical sewer wastewater from major plant facilities in both the 200-West and 200-East Areas. A remedial investigation/feasibility study work plan was approved in 2000 that defines planned remedial investigation activities at four representative waste sites (216-S-10 pond, 216-S-10 ditch, 216-B-63 trench, and 216-A-29 ditch). The work included installation of vadose zone boreholes and test pits to collect soil samples, and conduct geophysical logging (DOE/RL-99-44).

200-CW-5 U Pond/Z Ditches Cooling Water Operable Unit. The 200-CW-5 Operable Unit consists of waste sites that received cooling water, steam condensate, and chemical sewer waste from facilities in the 200-West Area, including U Plant, powerhouse and laundry facilities, 242-S evaporator, and the Plutonium Finishing Plant and associated facilities. A remedial investigation/feasibility study work plan was approved in 2000 that defines planned remedial investigation activities at one representative waste site (216-Z-11 ditch). This work plan (DOE/RL-99-66) includes installation of vadose zone boreholes to collect soil samples and conduct geophysical logging.

200-PW-2 Uranium-Rich Process Waste Operable Unit. Waste sites in this operable unit received uranium-rich condensate/process waste, primarily from waste streams generated at U Plant, Reduction-Oxidation Plant, and Plutonium-Uranium Extraction Plant, as well as B Plant and Semi-Works facilities. The draft work plan (DOE/RL-2000-60) was prepared and submitted for regulator review. The work plan proposes remedial investigation activities at four representative waste sites (216-A-19 trench, 216-B-12 crib, 216-A-10 crib, and 216-A-36B crib). The work includes installation of vadose zone boreholes to collect soil samples and conduct geophysical logging.

200-TW-1 Scavenged Waste and 200-TW-2 Tank Waste Operable Units. The 200-TW-1 Scavenged Waste Operable Unit consists of waste sites, mostly cribs and trenches, that received waste associated with uranium recovery activities at U Plant. The 200-TW-2 Tank Waste Operable Unit consists of waste sites, mostly cribs and trenches, that received waste from the decontamination process at B Plant and T Plant. The draft work plan (DOE-RL-2000-38) was prepared and submitted for regulator review. The work plan proposes remedial investigation activities at three representative waste sites (216-T-26 crib in the 200-TW-1 Operable Unit, and the 216-B-7A crib and 216-B-38 trench in the 200-TW-2 Operable Unit).

200-PW-1 Plutonium/Organic-Rich Process Waste Operable Unit. The 200-PW-1 Plutonium/Organic-Rich Process Waste Operable Unit contains waste sites that received significant quantities of both carbon tetrachloride and plutonium as well as other contaminants associated with process waste from the Plutonium Finishing Plant and Plutonium Reclamation Facility. A remedial investigation/feasibility study work plan for this operable unit was started in 2000 and scheduled for completion in 2001. Remedial investigation activities are expected to focus on two representative waste sites including the 216-Z-1A tile field and the 216-Z-9 trench.

During 2000, a proof-of-principle test was performed at the 216-Z-1A Tile Field to assess the ability of a small-diameter passive neutron probe to detect soil contaminated at or above the level designated for transuranic waste (100 nCi/g). Prior spectral gamma logging results showed that the tile field soil was contaminated with transuranic isotopes at levels above 100 nCi/g. Results for the passive neutron probe mirrored the gamma logging results, and the 100 nCi/g transuranic waste threshold was clearly discernible (BHI-01436). The passive neutron probe technique also was noted to be cost-effective.

200-BP-1 Prototype Hanford Barrier Performance Monitoring. Performance monitoring of the Prototype Hanford Barrier continued in

2000. Activities included water balance monitoring, stability surveys, and biotic surveys. Improved probes for automated monitoring of soil water content and storage were installed. An annual letter report[a] was prepared to document the monitoring results.

2.3.13 Research and Technology Development

T. M. Brouns

The Tanks Focus Area was created in 1994 by DOE's Office of Environmental Management to integrate tank waste remediation efforts across the DOE complex. In support of the Office of River Protection, the Tanks Focus Area addressed a number of high priority issues in 2000. Many of these activities contributed to improved tank farm operations, while others will support future waste retrieval, treatment, and tank closure activities at the Hanford Site.

2.3.13.1 Corrosion Control

The Tanks Focus Area assisted in developing and deploying electrochemical noise corrosion probes in Hanford waste tanks to guard against tank wall corrosion and to reduce waste volumes. In January 2000, an improved corrosion probe was installed in double-shell tank 241-AN-105 located in the AN tank farm, 200-East Area. Features of the new probe add to the functionality of the system, provide a better understanding of the relationship between corrosion and other tank operations parameters, and optimize the use of the tank riser that houses the probe. Four probes are now installed in tanks at the AN tank farm, and a central monitoring station was installed in the AN-271 instrument building in August 2000 to collect data from the probes. Data are integrated at the monitoring station for real-time comparative analyses. Replacement of current baseline chemistry monitoring techniques with corrosion monitoring equipment is being considered.

2.3.13.2 Mobile Variable Depth Fluidic Sampler Demonstration

A new mobile sampling system that uses power fluidics technology to collect and transfer Hanford tank waste samples is being designed and tested. Consistent with RCRA sampling requirements, the modified sample collection method uses an upright (as opposed to inverted) sample bottle with a septum and a needle, thereby achieving the RCRA-required zero headspace in the bottle. An initial demonstration of the fluidic sampling method in January 2000 resulted in some sand surrogates remaining in the sample reservoir. Subsequent tests on the redesign showed that surrogates containing sand completely drained from the sample holdup reservoir into the sample bottle. Conceptual design of the above-riser sample station and deployment platform was also initiated in 2000, followed by a technical review with a broad range of users directly involved in the project. The new sampling method will provide a representative, and preferably rapid, sampling and analysis system so that feeds to the cross-site waste transfer line and to both the low-level liquid waste and high-level liquid waste treatment facilities can be staged successfully with a minimum impact on tank space.

(a) Letter Report CCN 083132, *200-BP-1 Prototype Hanford Barrier Annual Monitoring Report for Fiscal Year 2000*, from M. J. Graham, Bechtel Hanford, Inc., to B. L. Foley, DOE Richland Operations Office, Richland, Washington, dated October 19, 2000.

2.3.13.3 Remote Pit Operation Enhancements at Hanford

The use of a remote system for pump pit operations would reduce worker exposure and enable more thorough removal of discarded materials. In March 2000, a kickoff meeting was held to review the functions and requirements needed for a remote pit operations system and to develop procurement specifications. The remote system needed to be protected from excessive contamination, easily dismantled, transported and stored, and at the same time function correctly during pump pit operations. It was determined that a dexterous arm on the end of a vehicle-mounted boom would likely meet the requirements for the system. Later in 2000, a contract for the manipulator arm, the critical component of the remote "Pit Viper" system, was issued.

2.3.13.4 Pipeline Unplugging Demonstrations

Pipelines for transferring tank waste is typically buried and contaminated with highly radioactive materials. Pipeline unplugging technologies must both locate the plug and perform an unplugging task without causing damage to the pipelines. Identification of viable commercial technologies to recover from potential waste transfer line plugging is critical to ensure continuous feed delivery and waste transfer operations at Hanford. Three pipelines representative of actual waste transfer line configurations were constructed in 1999 in a test bed at Florida International University to demonstrate commercial technologies for locating and unplugging pipelines. Following successful validation testing of the pipelines in 2000, four commercial vendors demonstrated their technologies to remove blockages of various sizes and compositions. Methods used included traditional "plumbing" type mechanical methods, and more innovative processes of fluidic wave action and sonic resonance vibration. Testing data will be used to help select the most efficient, cost-effective, and safest technologies for unplugging waste transfer pipes at the Hanford Site.

2.3.13.5 Double Salt Experiments

The high ionic strength of Hanford Site tank waste solutions can lead to uncertainties in equilibrium calculations for transporting dissolved saltcake. As new discoveries of double salts in Hanford tank waste is uncovered, the model database for predicting waste transfer behaviors requires updating. A series of calculations was performed on concentrated sodium nitrate to compare experimental results with predictions made by the Environmental Simulation Program for actual Hanford saltcake dissolution in an effort to improve the Environmental Simulation Program database. Approximately 180 double-salt samples were prepared in 2000 to conduct aging experiments. The data will be used to determine the effectiveness of the saltcake dissolution process with double salts and at higher operating temperatures. Data from this effort will be used to expand the Environmental Simulation Program model to include information on critical double salts found in Hanford waste.

2.4 Environmental Occurrences

G. W. Patton

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 in the Consolidated Information Center on the campus of Washington State University at Tri-Cities, Richland, Washington. The following sections summarize some of the emergency and off-normal environmental occurrences not previously discussed or that were not discussed in detail. For each occurrence, the title and report number from the Hanford Site Occurrence Notification Center is given in the heading.

2.4.1 Emergency Occurrences

As defined in DOE Order 232.1A, 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 2000.

- Highway 24 Command Wildfire on the Hanford Site (RL-PHMC-HFD-2000-0002)

The 2000 Hanford wildfire is discussed in Section 5.0. An accident investigation report was produced by DOE (Type B Accident Investigation, U.S. DOE Response to the 24 Command Wildland Fire on the Hanford Site, June 27-July 1, 2000, DOE/RL-2000-63).

2.4.2 Unusual Occurrences

An unusual occurrence is defined in the DOE Order as "a non-emergency 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 2000.

2.4.3 Off-Normal Occurrences

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 and the results of state and federal inspections are discussed in Sections 2.2.6.4 and 2.2.8.

Three environmentally related off-normal occurrences took place in 2000.

- Elevated Tritium Measured in Groundwater Monitoring Well at 618-11 Burial Ground Site (RL-PNNL-PNNLBOPER-2000-0003)

Hanford Site well 699-13-3A was sampled on January 25, 1999 and analyzed for tritium. The result (1.86 million pCi/L) was received by Pacific Northwest National Laboratory, passed through verification checks, and entered into the Hanford Environmental Information System database on May 1, 1999. Although below the DOE derived concentration guide for tritium, the result was higher than expected. The routine technical evaluation of the datum failed to identify this value as anomalous. As a result, DOE and the Hanford Environmental Restoration Contractor were not notified of the high tritium concentration in a timely manner. Because of the high tritium concentration, well 699-13-3A was re-sampled on January 27, 2000 and analyzed for tritium. The result was 8.14 million pCi/L, which exceeded the DOE derived concentration guide of 2 million pCi/L. As a result, a number of corrective actions were initiated to improve the review of groundwater data and the reporting of anomalous results.

- Water Sampling Results Exceed Bacteria Maximum Contaminant Levels (RL-PHMC-S&W-2000-0002)

The laboratory results for routine monthly samples of potable water collected February 1, 2000 in the 200-East Area indicated that the maximum contaminant level for total coliform bacteria was exceeded in one of nine samples. Repeat samples were obtained and analyzed immediately after the positive sample result was found and these samples did not indicate a bacteria problem. Additional sampling performed by the Benton-Franklin County Health Department also indicated that no *E-coli* bacteria were present. Log reviews and continued repeat sampling for chlorine residuals indicated there was adequate chlorine available in the distribution system prior to, and following the event to provide adequate disinfection.

- Non-Radioactive Miscellaneous Solid Waste was Inadvertently Shipped to Offsite Landfills (RL-BHI-GROUNDWTR-2000-0001)

On February 25, 2000, Bechtel Hanford, Inc. determined that non-radioactive miscellaneous solid waste may have been inadvertently transported off the Hanford Site and disposed in offsite landfills. This miscellaneous solid waste consisted of items such as wipes, gloves, filters, stickers, and tape that were generated during groundwater sampling, well construction, and well maintenance activities during the past several years. Some of the waste may have contacted groundwater containing low concentrations of hazardous water (e.g., carbon tetrachloride or methanol). Because of the low levels of these contaminants, it was expected that little or no contamination was present in the miscellaneous solid waste. However, consistent with management of groundwater waste, any miscellaneous solid waste that contacted the contaminated groundwater should have been managed at facility permitted to manage hazardous waste. Miscellaneous solid waste generated during groundwater sampling activities is now segregated and transported to a centralized location on the Hanford Site for appropriate disposal.

2.5 Waste Management and Chemical Inventories

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2.5.1 Waste Management

Waste produced from Hanford Site cleanup operations is classified as either radioactive, non-radioactive, mixed, or toxic. Radioactive waste is categorized as transuranic, high-level, and low-level. Mixed waste has both radioactive and hazardous non-radioactive substances. Hazardous waste contains either dangerous waste or extremely hazardous waste or both, as defined in WAC 173-303. Hanford's hazardous waste is managed in accordance with WAC 173-303.

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

Approximately 33 Hanford Site generators (WAC 173-303-040) have the capacity to produce dangerous waste during site cleanup activities. An annual report lists the dangerous waste generated, treated, stored, and disposed of onsite and offsite (DOE/RL-2001-08). Dangerous waste is treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous waste generated at the site also is shipped offsite for disposal, destruction, or recycling.

Non-dangerous waste generated at the Hanford Site historically has been buried near the 200 Areas Solid Waste Landfill. Beginning in 1999, non-dangerous waste has been disposed at the Roosevelt Regional landfill near Goldendale through a contract with Basin Disposal, Inc. Since 1996, medical waste has been shipped to Waste Management of Kennewick. Asbestos has been shipped to Basin Disposal, Inc. in Pasco and the onsite Environmental Restoration Disposal Facility. Since 1996, non-regulated drummed waste has been shipped to Waste Management of Kennewick.

Non-dangerous waste originates at a number of areas across the site. Examples include construction debris, office trash, cafeteria waste, and packaging materials. Other materials and items classified as non-dangerous 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. Demolition waste from 100 Areas decommissioning projects is buried in situ or in designated sites in the 100 Areas.

Annual reports document the quantities and types of solid waste generated onsite, received, shipped offsite, and disposed of at the Hanford Site (HNF-EP-0125-13). Solid waste program activities are regulated by the *Resource Conservation and Recovery Act* and *Toxic Substances Control Act*, discussed in Section 2.2. Solid waste quantities generated onsite, received from offsite, shipped offsite, and disposed of at the Hanford Site from 1995 through 2000 are shown in Tables 2.5.1 through 2.5.3. Table 2.5.4 provides a detailed summary of the radioactive solid waste stored or disposed of in 2000.

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

Waste Category	1995	1996	1997	1998	1999	2000
Mixed	132,000 (291,000)	199,000 (439,000)	442,000 (975,000)	509,000 (1,120,000)	421,000 (928,000)	441,000 (973,000)
Radioactive	1,890,000 (4,170,000)	3,870,000 (8,530,000)	6,590,000 (14,500,000)	1,470,000 (3,240,000)	957,000 (2,110,000)	700,000 (1,544,000)

(a) Solid waste includes containerized liquid waste.

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

Waste Category	1995	1996	1997	1998	1999	2000
Mixed	52,800 (116,000)	2,070 (4,560)	3,560 (7,850)	267 (589)	1,306 (2,880)	1,381 (3,045)
Radioactive	1,310,000 (2,890,000)	1,670,000 (3,680,000)	1,430,000 (3,150,000)	2,870,000 (6,330,000)	2,325,700 (5,128,000)	6,958,000 (15,343,000)

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

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

Waste Category	1995	1996	1997	1998	1999	2000
Containerized	224,000 (494,000)	590,000 (1,300,000)	110,000 (243,000)	65,700 (145,000)	1,732,700[b] (3,820,600)	33,200[b] (73,220)
					70,000[c] (154,000)	315,500[c] (695,700)
Bulk Solids	478,000 (1,050,000)	0	335,000 (739,000)	47,500 (105,000)	402,300[d] (887,000)	0
Bulk Liquids	130,000 (287,000)	98,800 (218,000)	5,025,000 (11,100,000)	41,800 (92,200)	0	0
Total	832,000 (1,840,000)	689,000 (1,520,000)	5,470,000 (12,100,000)	155,000 (342,000)	2,205,000 (4,862,000)	348,700 (768,883)

(a) Does not include *Toxic Substances Control Act* waste.
(b) Hazardous waste only.
(c) Mixed waste (radioactive and hazardous).
(d) Includes 399,875 kg (882,000 lb) of material associated with the extraction of carbon tetrachloride from soil.

Table 2.5.4. Radioactive Solid Waste Stored or Disposed of on the Hanford Site, 2000

Constituent[a]	Quantity, Ci		
	Low Level	Low-Level Mixed Waste	Transuranic
Tritium	3,690	38.7	[b]
Carbon-14	0.444	[b]	[b]
Manganese-54	2.78	[b]	42.6
Iron-55	40.7	47,700	[b]
Cobalt-60	24,400	[b]	38.3
Nickel-63	283	111,000	[b]
Strontium-90	229	28.6	26,500
Yttrium-90	229	28.6	26,500
Technetium-99	0.0842	0.0289	1.64
Iodine-129	0.0000015	0.0000496	[b]
Cesium-137	544	22.4	31,900
Barium-137m	514	21.2	30,200
Uranium-233	0.0433	0.000175	[b]
Uranium-234	0.194	0.00197	[b]
Uranium-235	0.01	0.000116	0.000325
Uranium-236	0.00262	0.000195	[b]
Uranium-238	0.58	0.00214	0.0187
Plutonium-238	0.371	0.0941	129
Plutonium-239	1.2	0.105	208
Plutonium-240	0.444	0.0517	93
Plutonium-241	22.2	0.692	5,090
Plutonium-242	0.000181	0.0000000133	0.0698
Americium-241	0.808	0.136	567
Curium-244	[b]	[b]	131
Total	29,959	158,841	121,401

(a) See Appendix A, Table A.5 for radionuclide half-lives.
(b) Value was not reported or was insignificant relative to other waste types.

The quantities of liquid waste generated in 2000 and stored in underground storage tanks are included in the annual dangerous waste report (DOE/RL-2001-08). Table 2.5.5 is a summary of the liquid waste generated from 1995 through 2000, which are stored in underground storage tanks.

2.5.2 Chemical Inventories

Types, quantities, and locations of hazardous chemicals are tracked through prime contractor-specific chemical management system requirements (see Section 2.2.3), which include compliance activities associated with the Emergency Planning and Community Right-To-Know Act (see Section 2.2.5). The *2000 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2001-0010) was issued in February 2001 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 2000.

Table 2.5.5. Quantities of Liquid Waste[a] Generated and Stored within the Tank Farm System on the Hanford Site in Calendar Year 2000 and in each of the Previous 5 Calendar Years, L (gal)

Type of Waste	1995[a]	1996[b]	1997[b,c]	1998[b,c]	1999[b,c]	2000[b]
Volume of waste added to double-shell tanks	18,200,000 (4,808,000)	2,420,000 (639,000)	796,000 (210,000)	1,715,000 (453,000)	5,420,000 (1,432,000)	8,920,000 (2,357,000)
Total volume in double-shell tanks (year end)		72,256,000 (19,090,000)	69,245,000 (18,295,000)	70,969,000 (18,750,000)	73,290,000 (19,363,000)	79,630,000 (21,038,000)
Volume evaporated at 242-AW		4,341,000 (1,147,000)	3,800,000 (1,004,000)	0	3,097,000 (818,000)	2,580,000 (682,000)
Volume pumped from single-shell tanks[d]		630,000 (166,000)	244,000 (64,000)	859,000 (227,000)	2,930,000 (774,100)	2,250,000 (595,000)

(a) Quantity of liquid waste is defined as liquid waste sent to double-shell underground storage tanks during these years. This does not include containerized waste (e.g., barreled) included in the solid waste category.
(b) Quantity of liquid waste is defined as shown by different categories on left-hand side of table during these years. This does not include containerized waste (e.g., barreled) included in the solid waste category.
(c) Quantity of liquid waste shown is corrected figure for these years.
(d) Volume does not include dilution or flush water.

Table 2.5.6. Average Balance of Ten Hazardous Chemicals Stored in Greatest Quantity on the Hanford Site, 2000

Hazardous Chemical	Average Quantity, kg (lb)
Mineral oil	1,700,000 (3,800,000)
Sodium	1,000,000 (2,300,000)
Diesel fuel (Grades 1 and 2)	440,000 (970,000)
Crystalline silica (quartz, cristobalite, tridymite)	300,000 (650,000)
Bentonite	270,000 (600,000)
Ethylene glycol	250,000 (540,000)
Nitrogen	130,000 (290,000)
Argon	69,000 (150,000)
Sulfuric acid	66,000 (150,000)
Propane	40,000 (94,000)

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WAC 173-303-610. "Closure and Postclosure." Washington Administrative Code, Olympia, Washington.

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3.0 Facility-Related Monitoring

The following sections provide 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) collecting samples for analyses, 2) measuring liquid and airborne effluents to characterize and quantify contaminants released to the environment, 3) providing source terms for assessing potential impact 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 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.

Additional program sampling and effluent information is contained in *Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2000* (PNNL-13487, APP. 2) and in *Environmental Releases for Calendar Year 2000* (HNF-EP-0527-10).

3.1 Facility Effluent Monitoring

L. P. Diediker and D. J. Rokkan

Liquid effluents and airborne emissions that may contain radioactive or hazardous constituents are continually monitored on 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 and/or the entire site. The evaluations are also useful in assessing the effectiveness of effluent treatment and control systems and pollution-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).

Measuring devices quantify most facility effluent flows, but some flows are calculated using process information. For most radioactive air emission units, effluent sampling methods include continuous sampling or periodic confirmatory measurements. For most liquid effluent streams, proportional sampling or grab sampling is used. 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. Non-radioactive constituents are either monitored or sampled, as applicable.

Small quantities of tritium, cobalt-60, strontium-90, antimony-125, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, and americium-241 were released to the environment at state and federally permitted release points. Most of the radionuclides in effluents at the site are nearing levels indistinguishable from the low concentrations of radionuclides in the environment that occur naturally or originated from atmospheric nuclear-weapons testing. The site mission of environmental cleanup is largely responsible for the downward trend in radioactive emissions, which results in smaller radiation doses to the maximally exposed member of the public. Figures 3.1.1 and 3.1.2 show the quantity of several long-lived radionuclides released from the site over recent years. The concentrations of radioactive and non-radioactive constituents released in effluent in 2000 were less than the applicable standards.

Effluent release data are documented in several reports besides 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-2001-32), in compliance with the Code of Federal Regulations (40 CFR 61), "National Emission Standards for Hazardous Air Pollutants," Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities," and Washington Administrative Code (WAC) 246-247, "Radiation Protection—Air Emissions." Data quantifying the radioactive liquid and airborne effluents are reported to DOE annually in an environmental releases report (HNF-EP-0527-10). 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. Non-radioactive air emissions are reported annually to the Washington State Department of Ecology.

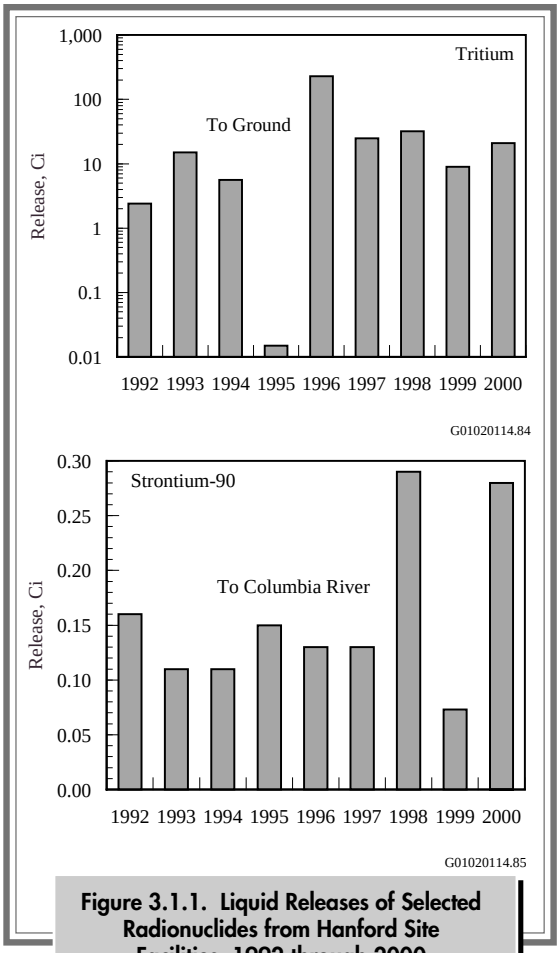

Figure 3.1.1. Liquid Releases of Selected Radionuclides from Hanford Site Facilities, 1992 through 2000

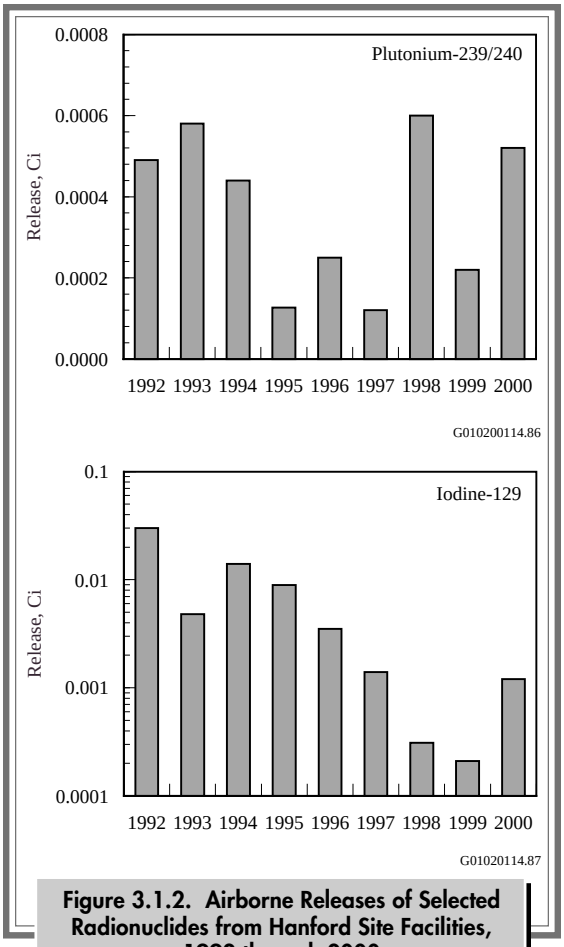

Figure 3.1.2. Airborne Releases of Selected Radionuclides from Hanford Site Facilities, 1992 through 2000

3.1.1 Radioactive Airborne Emissions

Radioactive airborne emissions from site activities contain particulate and volatile forms of radionuclides. Emissions having the potential to exceed 1% of the 10-mrem/yr standard (40 CFR 61, Subpart H) for offsite doses are monitored continuously.

The continuous monitoring of radioactive emissions involves analyzing samples collected at points of discharge to the environment, usually from a stack or a vent. Samples are analyzed for gross alpha and beta levels, as well as selected radionuclides. The selection of the specific radionuclides sampled, analyzed, and reported is based on 1) an evaluation of maximum potential of 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 emission 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 originated from the normal evaporation at two water-filled storage basins (100-K East and 100-K West Fuel Storage Basins, which contain irradiated nuclear fuel), the newly constructed Cold Vacuum Drying Facility, and from a low-level laboratory. In 2000, there were five points of radioactive emissions in the 100 Areas.
- In the 200 Areas, the primary sources of radionuclide emissions were the Plutonium Finishing Plant, T Plant, 222-S Laboratory, underground tanks for storage of high-level radioactive waste, waste evaporators, and the inactive Plutonium-Uranium Extraction Plant. In 2000, there were 50 points of radioactive emissions in the 200 Areas.
- The 300 Area primarily has laboratories and research facilities. Primary sources of airborne radionuclide emissions were the 324 Waste Technology Engineering Laboratory, 325 Applied Chemistry Laboratory, 327 Post-Irradiation Laboratory, and 340 Vault and Tanks. In 2000, there were 22 discharge points of radioactive emissions in the 300 Area.
- The 400 Area has the Fast Flux Test Facility (which did not operate in 2000), 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. In 2000, there were five points of radioactive emissions in the 400 Area.
- The 600 Area has the Waste Sampling and Characterization Facility (between the 200-West and 200-East Areas), at which low-level radiological and chemical analyses of various types of samples (e.g., particulate air filters, liquids, soil, and vegetation) are performed. This facility had two points of radioactive emissions in 2000.

A summary of the Hanford Site radioactive airborne emissions in 2000 is provided in Table 3.1.1.

3.1.2 Non-Radioactive Airborne Emissions

Non-radioactive air pollutants released 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 was released 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 tracked only when activities at these facilities are capable of generating them. In 2000, the 200 Areas tank farms produced reportable ammonia emissions, summarized in Table 3.1.2.

Onsite diesel-powered steam generating plants emitted 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. These releases to the atmosphere, listed in Table 3.1.2, do not exceed any of the ambient air quality standards. Emissions are calculated from the quantities of fossil fuel consumed, using EPA-approved formula (AP-42).

Should activities lead to chemical emissions in excess of quantities reportable under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), the release totals are reported immediately to EPA. If the emissions remain stable at predicted levels, they may be reported annually with EPA's permission. Table 3.1.2 summarizes the emissions of non-radioactive constituents in 2000. (Note: the 100, 400, and 600 Areas have no sources of non-radioactive emissions that are a regulatory concern.)

Table 3.1.1. Radionuclides Discharged to the Atmosphere at the Hanford Site, 2000

		Release, Ci[a]				
Radionuclide	**Half-Life**	**100 Areas**	**200-East Area**	**200-West Area**	**300 Area**	**400 Area**
Tritium (as HT)[b]	12.3 yr	NM[a]	NM	NM	4.3E+01	NM
Tritium (as HTO)[b]	12.3 yr	NM	NM	NM	7.9E+01	8.8E-01
Cobalt-60	5.3 yr	3.4E-08	ND[a]	ND	ND	NM
Strontium-90	29.1 yr	4.1E-05	9.1E-05[c]	1.9E-04[c]	1.0E-05[c]	NM
Technetium-99	2.13×10^5 yr	NM	NM	NM	1.7E-08	NM
Antimony-125	2.77 yr	ND	1.8E-06	ND	ND	NM
Iodine-129	1.6×10^7 yr	NM	1.2E-03	NM	NM	NM
Cesium-137	30 yr	1.1E-04	6.7E-05	2.1E-09	1.6E-06	3.5E-06[d]
Plutonium-238	87.7 yr	8.4E-07	9.8E-08	1.1E-05	7.6E-09	NM
Plutonium-239/240	2.4×10^4 yr	5.4E-06	2.5E-06[e]	5.1E-04[e]	8.2E-07[e]	NM[f]
Plutonium-241	14.4 yr	6.8E-05	6.1E-06	3.1E-04	NM	NM
Americium-241	432 yr	2.6E-06	4.8E-06	8.7E-05	3.4E-08	NM
Americium-243	7,380 yr	NM	NM	NM	ND	NM

(a) 1 Ci = 3.7E+10 becquerel; ND = not detected (i.e., either the radionuclide was not detected in any sample during the year or the average of all the measurements for that given radionuclide or type of radioactivity made during the year was below background levels); NM = not measured.
(b) HT = Elemental tritium; HTO = tritiated water vapor.
(c) This value includes gross beta release data. Gross beta and unspecified beta results were assumed to be strontium-90 in dose calculations.
(d) This value includes gross beta release data. Gross beta results were assumed to be cesium-137 in dose calculations.
(e) This value includes gross alpha release data. Gross alpha and unspecified alpha results were assumed to be plutonium-239/240 for dose calculations.
(f) Analyses were conducted for gross beta activity, but none was detected. If detected, it would have been assumed to be plutonium-239/240 for dose calculations.

3.1.3 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 levels, as well as selected radionuclides.

In 2000, only facilities in the 200 Areas discharged radioactive liquid effluents to the ground that went to a single location, the 616-A crib, also known as the State-Approved Land Disposal Site. A summary of radioactive liquid effluents 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, the sources of which include secondary cooling water used at the 100-K Basins and the shoreline seepage of groundwater that has passed near the retired 1301-N and 1325-N cribs in the 100-N Area. These measurements are used to determine potential radiation doses to the public (see Section 6.0).

Table 3.1.2. Non-Radioactive Constituents Discharged to the Atmosphere at the Hanford Site, 2000[a,b]

Constituent	Release, kg (lb) 200 Areas		300 Area	
Particulate matter	900	(1,984)	677	(1,477)
Nitrogen oxides	24,000	(52,920)	3,500	(7,717)
Sulfur oxides	3,400	(7,497)	29	(64)
Carbon monoxide	18,000	(39,690)	12,000	(26,460)
Lead	0.53	(1.2)	0.0	(0.0)
Volatile organic compounds[c]	5,700	(12,569)	800	(1,764)
Ammonia[d]	12,000	(26,460)	NE[e]	
Other toxic air pollutants[f]	2,500	(5,512)	NE	

(a) The estimate of volatile organic compounds does not include emissions from certain laboratory operations.
(b) None of these releases exceed any of the ambient air quality standards.
(c) Produced from burning fossil fuel for steam and electrical generators, calculated estimates from the 200-East and 200-West Area tank farms, and operation of the 242-A evaporator and the 200 Areas Effluent Treatment Facility.
(d) Ammonia releases are calculated estimates from the 200-East and 200-West Area tank farms and operation of the 242-A evaporator and the 200 Areas Effluent Treatment Facility.
(e) NE = No emissions.
(f) Releases are a composite of calculated estimates of toxic air pollutants, excluding ammonia, from the 200-East and 200-West Area tank farms, and operation of the 242-A evaporator and the 200 Areas Effluent Treatment Facility.

Table 3.1.3. Radionuclides in Liquid Effluents from the 200 Areas Discharged to the State-Approved Land Disposal Site, 2000

Radionuclide	Half-Life	Release, Ci
Tritium	12.3 yr	21

Table 3.1.4. Radionuclides in Liquid Effluents from the 100 Areas Discharged to the Columbia River, 2000

Radionuclide	Half-Life	Release, Ci
Tritium	12.3 yr	0.15
Strontium-90	29.1 yr	0.28
Plutonium-238	87.7 yr	0.0000092
Plutonium-239/240	2.4×10^4 yr	0.000039
Americium-241	432 yr	0.0000079

3.1.4 Non-Radioactive Hazardous Materials in Liquid Effluents

Non-radioactive hazardous materials in liquid effluent are monitored in the 100, 200, 300, and 400 Areas. These effluents are discharged to the State-Approved Land Disposal Site and to the Columbia River. Effluents entering the 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 (40 CFR 122 and WAC 173-216). Should chemicals in liquid effluents exceed quantities reportable under CERCLA, 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 2000 is given in Section 2.2.8.

Liquid waste containing both radioactive and hazardous constituents are stored at the 200 Areas in underground waste storage tanks or monitored interim storage facilities.

3.1.5 CERCLA and Washington Administrative Code Releases to the Environment

Releases that are reportable to the state and/or EPA include spills or discharges of hazardous substances or dangerous waste to the environment, other than releases permitted under state or federal law. Accidents and equipment failures cause the majority of these releases. Releases of hazardous substances that are continuous and stable in quantity and rate but that exceed specified limits must be reported as required by Section 103(f)(2) of CERCLA.

Spills or non-permitted 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 surface water (e.g., Columbia River), or into the air that may threaten human health or the environment, regardless of the quantity of dangerous waste or hazardous substance.

With both CERCLA and Washington Administrative Code reporting requirements in view, one release in 2000 was reported in accordance with WAC 173-303-145. Table 3.1.5 contains a synopsis of this release.

Table 3.1.5. Reportable Releases to the Environment at the Hanford Site, 2000

Material	Quantity	Location
Airborne radionuclides	3.6E-05 Ci of plutonium-239/240, potential	During a routine functional test of the 291-Z-1 stack constant air monitor at the Plutonium Finishing Plant in the 200-West Area, a plant worker accidentally dropped a wrench onto the constant air monitor causing it to annunciate. The record sample filter was analyzed, but the results were determined to be only a potential release, since the higher activity on the filter that triggered the alarm likely originated from radioactive material that had gradually deposited within the sampling line leading to the filter during the normal course of operations, spanning years.

3.2 Near-Facility Environmental Monitoring

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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 Finishing Plant, Canister Storage Building, and the K Basins; inactive nuclear facilities such as N Reactor and the Plutonium-Uranium Extraction Plant; and active and inactive waste storage or disposal facilities such as burial grounds, cribs, ditches, ponds, waste tank farms, and trenches.

Much of the monitoring program consists of collecting and analyzing environmental samples and conducting radiological surveys in areas near facilities. The program also is designed to evaluate and report analytical data, determine the effectiveness of facility effluent monitoring and controls, measure the adequacy of containment at waste disposal units, and detect and monitor unusual conditions. The program implements applicable portions of DOE Orders 435.1, 5400.1, 5400.5, and 5484.1; 10 CFR 835 and 40 CFR 61; and WAC 246-247.

Near Hanford Site facilities, several types of environmental media are sampled, and various radiological and non-radiological measurements are taken to monitor the effectiveness of effluent treatment and control practices, diffuse source emissions, and contamination control in waste management and restoration activities. These sample types and measurements include air, spring water, surface contamination, soil and vegetation, external radiation measurements, and investigative sampling. 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.

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

Sampling and analysis information and analytical results for 2000 are summarized in the following sections. Additional data may be found in *Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2000* (PNNL-13487, APP. 2). Near-facility monitoring in 2000 is summarized in Table 3.2.1, which shows the type, quantity, and general location of samples collected.

3.2.1 Air Monitoring

A special section addressing near-facility air monitoring results related to the June 2000 wildfire is provided in Section 5.0.

In 2000, routine monitoring for radioactivity in air near Hanford Site facilities used a network of continuously operating samplers at 85 locations (Table 3.2.2) (sampling locations illustrated in PNNL-13487, APP. 2). Air samplers were located primarily at or within ~500 meters (1,500 feet) of sites and/or facilities having the potential for, or

Table 3.2.1. Near-Facility Routine Environmental Monitoring Samples and Locations, 2000

Sample Type	Number of Sample Locations	Operational Area								
		100-B/C	100-D/DR	100-K	100-F	100-H	100-N	ERDF[a]	200/600	300/400
Air	85	0	11	8	6	6	4	3	41[b]	6
Water	14	0	0	0	0	0	14	0	0	0
Soil	91	0	2	0	2	2	9	1	57	18
Vegetation	75	0	0	0	0	0	8	0	52	15
External radiation	148	5	5	15[c]	5	3	14	3	77[d]	21

(a) Environmental Restoration Disposal Facility in the 200-West Area.
(b) Includes one station at the Wye Barricade, 19 in the 200-East Area, and 21 in the 200-West Area.
(c) Includes 4 locations at the Cold Vacuum Drying Facility.
(d) Includes 66 locations in the 200 Areas, 10 at the Tank Waste Remediation System located east of the 200-East Area, and one at the 212-R facility in the 200-West Area.

history of, environmental releases and are predominantly located in the prevailing downwind direction. To avoid duplication of sampling, air data for the 300 and 400 Areas, some onsite remediation projects, and some offsite distant locations were obtained from Pacific Northwest National Laboratory.

Samples were collected according to a schedule established before the 2000 monitoring year. Airborne particles were sampled at each sampling location 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, short-lived 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 specific radionuclide analyses, the amount of radioactive material collected on a single filter during a 2-week period was too small to be measured accurately. To increase the accuracy of the analysis, the samples were combined into either quarterly or semiannual samples for each location.

Figure 3.2.1 shows the average concentrations of selected radionuclides in the 100 and 200/600 Areas compared to DOE derived concentration guides and air concentrations measured in distant communities. The DOE derived concentration guides (DOE Order 5400.5) are reference values that are used as indexes of performance. The data indicate a large degree of variability. Air samples collected from areas located at or directly adjacent to Hanford Site facilities had higher concentrations than did those samples collected farther away. In general, analytical results for most radionuclides were at or near Hanford Site background levels, which is much less than DOE derived concentration guides but greater than those measured off the site. In all areas, the data also show that concentrations of certain radionuclides were higher within different operational areas. Table 3.2.3 shows the annual average and maximum concentrations of radionuclides in near-facility air samples during 2000.

The 2000 analytical results for the remedial action projects at 100-D, 100-F, and 100-H Areas generally indicated that for most radionuclides, concentrations were greater than levels measured off the site. At the 100-D site, ambient air monitoring locations included eight samplers. Remedial action activities for fiscal year 2000 were completed

Table 3.2.2. Near-Facility Air Sampling Locations and Analyses, 2000

Site	Number of Samplers	EDP Code[a]	Analyses	
			Biweekly	Composite
100-D remedial action project	8	N467, N468, N469, N470, N512, N513, N514, N515	Gross alpha, gross beta	GEA,[b] Sr-90, Pu-iso,[c] U-iso[d]
105-D interim safe storage project	1	N523	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-DR interim safe storage project	2	N492, N493	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-F interim safe storage project	2	N494, N495	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-H interim safe storage project	2	N524, N525	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
100-H remedial action project	4	N507, N508, N509, N510	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
100-F remedial action project	4	N519, N520, N521, N522	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
100-K spent nuclear fuels	8	N401, N402, N403, N404, N476, N477, N478, N479	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso, Pu-241, Am-241
100-N surveillance, maintenance and transition/ remedial action	4	N102, N103, N105, N106	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
200-East Area	17	N019, N158, N498, N499, N957, N967, N968, N969, N970, N972, N973, N976, N977, N978, N984, N985, N999	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
Canister Storage Building, 200-East Area	2	N480, N481	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso, Pu-241, Am-241
200-West Area	21	N155, N161, N165, N168, N200, N304, N433, N441, N442, N449, N456, N457, N956, N963, N964, N965, N966, N974, N975, N987, N994	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
300-FF-1 remedial action project (300 Area)	6	N130, N485, N486, N487, N488, N489	Gross alpha, gross beta	GEA, U-iso
600 Area (Wye Barricade)	1	N981	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
Environmental Restoration Disposal Facility	3	N482, N483/N517, N484/N518	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso

(a) EDP Code = Sampler location code. See PNNL-13487, APP. 2.
(b) GEA = Gamma energy analysis.
(c) Isotopic plutonium-238 and -239/240.
(d) Isotopic uranium-234, -235, and -238.

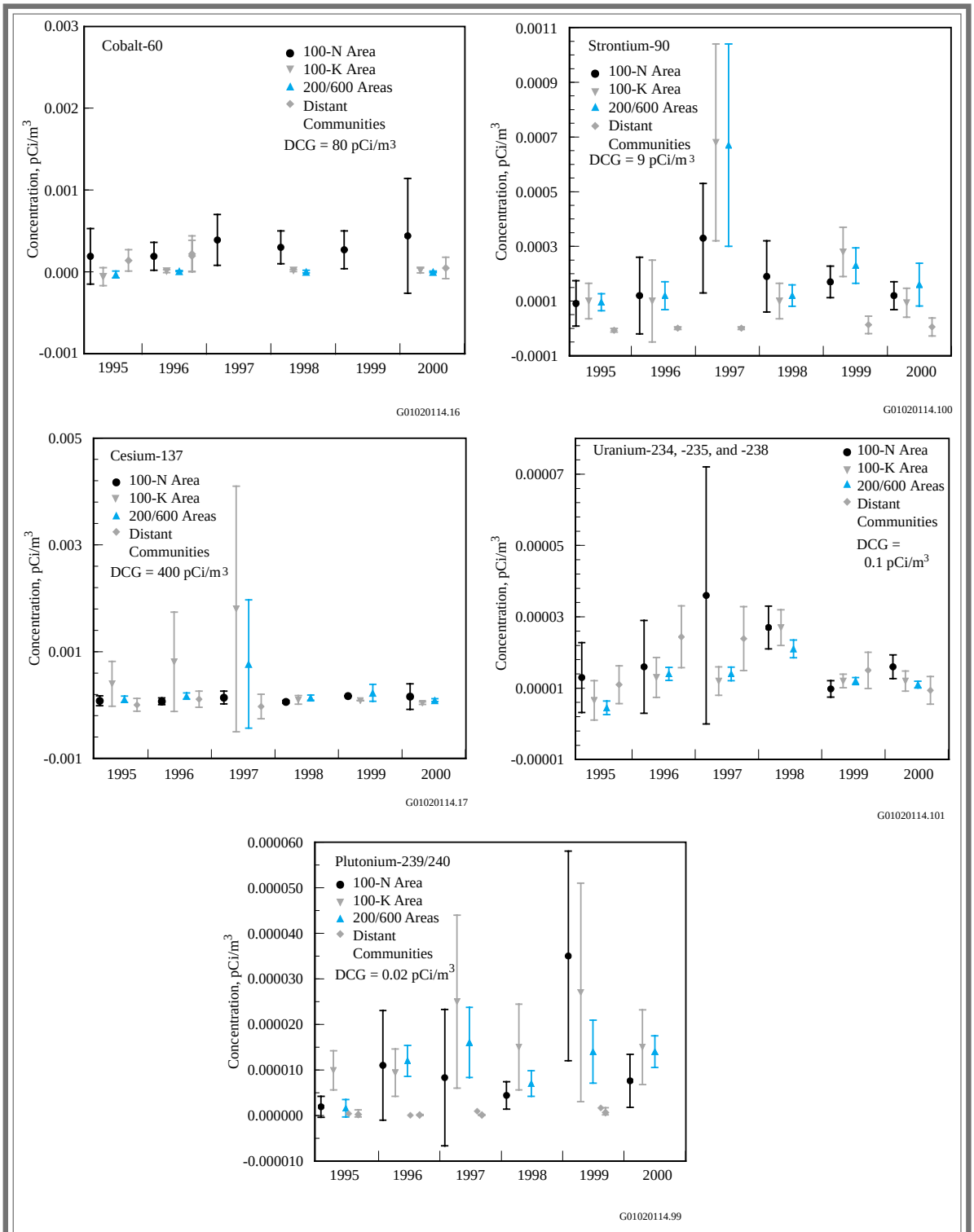


Figure 3.2.1. Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Air Samples Compared to Those in Distant Communities, 1995 through 2000. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol. Cobalt-60 was not detected in the 100-K or 200/600 Areas in 1999. DCG = Derived concentration guide (DOE Order 5400.5).

Table 3.2.3. Annual Average and Maximum Concentrations (aCi/m^3) of Radionuclides in Near-Facility Air Samples, 2000

Cobalt-60

Site	Average[a]	Maximum[b]	EDP Code[c]
100-D RA[d]	7.0 ± 35	170 ± 360	N468
100-H RA	3.8 ± 29	59 ± 83	N510
100-F RA	6.5 ± 30	63 ± 110	N520
105-DR/F/D/H ISS[e]	-74 ± 323	1,000 ± 1,700	N525
100-K	18 ± 30	110 ± 110	N479
100-N	442 ± 704	2,900 ± 350	N105
200-East	4.2 ± 13	71 ± 110	N967
200-West	-2.2 ± 12	120 ± 90	N433
300-FF-1[f]	26 ± 75	380 ± 1,200	N489
ERDF[g]	-22 ± 29	29 ± 93	N484
Distant community[h]	48 ± 128	411 ± 950	
DCG[i]		80,000,000	

Strontium-90

Site	Average[a]	Maximum[b]	EDP Code[c]
100-D RA[d]	121 ± 60	340 ± 310	N512
100-H RA	90 ± 50	160 ± 88	N507
100-F RA	105 ± 96	340 ± 140	N519
105-DR/F/D/H ISS[e]	761 ± 907	8,400 ± 4,600	N523
100-K	94 ± 53	270 ± 95	N477
100-N	120 ± 51	240 ± 84	N102
200-East	221 ± 165	3,200 ± 640	N984
200-West	114 ± 26	330 ± 130	N975
ERDF[g]	111 ± 76	210 ± 86	N483
Distant community[h]	5.5 ± 33	63 ± 63	
DCG[i]		9,000,000	

Cesium-137

Site	Average[a]	Maximum[b]	EDP Code[c]
100-D RA[d]	29 ± 45	120 ± 170	N467
100-H RA	22 ± 23	69 ± 83	N507
100-F RA	67 ± 42	190 ± 140	N519
105-DR/F/D/H ISS[e]	296 ± 470	4,400 ± 3,600	N523
100-K	37 ± 25	160 ± 100	N403
100-N	161 ± 239	990 ± 260	N105
200-East	68 ± 28	470 ± 180	N985
200-West	113 ± 45	890 ± 250	N155
300-FF-1[f]	0.8 ± 56	91 ± 210	N485
ERDF[g]	41 ± 48	96 ± 69	N482
Distant community[h]	-43 ± 186	371 ± 440	
DCG[i]		400,000,000	

Uranium-234

Site	Average[a]	Maximum[b]	EDP Code[c]
100-D RA[d]	55 ± 40	260 ± 86	N468
100-H RA	9.5 ± 2.6	16 ± 7.7	N509
100-F RA	16 ± 7.3	38 ± 14	N519
105-DR/F/D/H ISS[e]	34 ± 8.2	82 ± 37	N493
100-K	18 ± 5.3	47 ± 13	N477
100-N	20 ± 5.2	33 ± 11	N106
200-East	16 ± 1.9	29 ± 12	N977
200-West	16 ± 1.8	38 ± 12	N974
300-FF-1[f]	48 ± 16	86 ± 63	N489
ERDF[g]	17 ± 6.8	32 ± 11	N484
Distant community[h]	15 ± 6.2	28 ± 19	
DCG[i]		90,000	

Uranium-235

Site	Average[a]	Maximum[b]	EDP Code[c]
100-D RA[d]	31 ± 31	230 ± 83	N468
100-H RA	4.1 ± 1.9	9.2 ± 6.1	N508
100-F RA	7.3 ± 4.8	22 ± 11	N519
105-DR/F/D/H ISS[e]	21 ± 9.4	88 ± 180	N523
100-K	7.4 ± 4.3	32 ± 9.9	N477
100-N	13 ± 6.1	27 ± 10	N103
200-East	4.8 ± 1.0	13 ± 6.2	N968
200-West	4.6 ± 1.3	24 ± 9.1	N974
300-FF-1[f]	14 ± 6.2	35 ± 63	N489
ERDF[g]	7.3 ± 6.7	22 ± 8.8	N484
Distant community[h]	0.5 ± 1.9	7.0 ± 9.3	
DCG[i]		100,000	

Uranium-238

Site	Average[a]	Maximum[b]	EDP Code[c]
100-D RA[d]	36 ± 24	160 ± 62	N468
100-H RA	9.2 ± 2.1	14 ± 7.1	N509
100-F RA	11 ± 4.6	19 ± 9.3	N521
105-DR/F/D/H ISS[e]	37 ± 17	160 ± 190	N523
100-K	12 ± 3.9	36 ± 11	N477
100-N	15 ± 5.3	30 ± 11	N103
200-East	13 ± 1.6	23 ± 11	N999
200-West	13 ± 1.8	31 ± 10	N974
300-FF-1[f]	47 ± 20	130 ± 84	N489
ERDF[g]	12 ± 3.3	19 ± 9.1	N517
Distant community[h]	13 ± 6.3	28 ± 10	
DCG[i]		100,000	

Table 3.2.3. (contd)

Plutonium-238

Site	Average[a]	Maximum[b]	EDP Code[c]
100-D RA[d]	-4.9 ± 16	59 ± 59	N470
100-H RA	3.5 ± 3.9	11 ± 14	N507
100-F RA	9.3 ± 8.7	31 ± 16	N520
105-DR/F/D/H ISS[e]	25 ± 41	390 ± 860	N523
100-K	5.3 ± 5.5	33 ± 26	N479
100-N	-5.0 ± 12	13 ± 13	N105
200-East	2.9 ± 3.3	33 ± 36	N481
200-West	1.5 ± 1.7	15 ± 20	N964
ERDF[g]	-1.0 ± 5.5	7.6 ± 11	N483
Distant community[h]	-0.4 ± 0.3	0.3 ± 1.8	
DCG[i]		30,000	

Plutonium-239/240

Site	Average[a]	Maximum[b]	EDP Code[c]
100-D RA[d]	12 ± 4.5	28 ± 10	N469
100-H RA	6.0 ± 2.2	9.5 ± 5.7	N510
100-F RA	8.0 ± 11	44 ± 17	N520
105-DR/F/D/H ISS[e]	40 ± 44	420 ± 320	N523
100-K	15 ± 8.2	58 ± 23	N401
100-N	7.6 ± 5.8	26 ± 19	N105
200-East	12 ± 5.8	88 ± 22	N499
200-West	16 ± 4.1	70 ± 19	N956
ERDF[g]	14 ± 18	58 ± 17	N483
Distant community[h]	-0.1 ± 0.5	0.6 ± 1.6	
DCG[i]		20,000	

Plutonium-241

Site	Average[a]	Maximum[b]	EDP Code[c]
100-K	214 ± 215	1,300 ± 390	N401
200-East	-270 ± 883	530 ± 160	N481
Distant community[h]		Not reported	
DCG[i]		1,000,000	

Americium-241

Site	Average[a]	Maximum[b]	EDP Code[c]
100-K	14 ± 6.5	36 ± 17	N476
200-East	16 ± 17	33 ± 17	N481
Distant community[h]		Not reported	
DCG[i]		20,000	

(a) ±2 standard error of the mean.
(b) ± total analytical uncertainty.
(c) See PNNL-13487, APP. 2.
(d) RA = Remedial Action project.
(e) ISS = Interim Safe Storage project.
(f) 300 Area.
(g) ERDF = Environmental Restoration Disposal Facility.
(h) See Section 4.1.
(i) DOE Derived Concentration Guide.

at the 100-D site, and air monitoring ended in September. At the 100-F site, ambient air monitoring began in March at four locations and continued throughout the rest of the year. At the 100-H Area, ambient air monitoring locations included four project-specific samplers, one upwind and three downwind. Strontium-90 and uranium-234 and -238 were consistently detected at the 100-H monitoring locations. Plutonium-239/240 was occasionally detected.

In 2000, two samplers operated at each of the 105-DR and 105-F interim safe storage projects. The quarterly analytical results from these air samples were generally similar to the results seen over the past 2 years (sampling began in November 1998). Third quarter uranium results were slightly higher than previous levels but returned to typical levels during the fourth quarter.

Air monitoring at the 105-H and 105-D interim safe storage projects began in November 2000 and, at the projects' request, the air samplers (two at 105-H; one at 105-D) were operated only while actual decontamination and decommissioning work was being done (i.e., one work shift on weekdays). This led to sample volumes that were significantly lower for these three samplers than for all other near-facility air samplers. The overall effect of reduced sample volume was radionuclide concentrations that appeared to be higher than those measured at the other site samplers. Air sample concentrations are mathematically calculated by dividing the concentration (picocuries) measured in the laboratory by the sample volume (cubic meters of air that passed through the filter). Environmental air sample concentrations are typically very low (at or near background levels) and when divided by a small sample volume, the resulting concentration will appear to be higher than the calculated concentration obtained from an air sample with a higher (normal) sample volume. Given the small number of samples and the abnormal monitoring regime, it is difficult to derive definitive conclusions about these air sampling results.

The airborne contaminant levels in the 100-K Area were similar to those measured over the previous 5 years. Facility emissions in the 100-K Area decreased substantially in 1996 and subsequent radionuclide concentrations in the ambient air samples have been near detection limits. The radionuclides uranium-234 and -238 were detected consistently. Occasionally the radionuclides strontium-90, uranium-235, plutonium-239/240, and americium-241 were detected also.

Analytical results for ambient air samples from the 100-N Area in 2000 were similar to those measured in the previous 5 years. The radionuclides strontium-90, uranium-234, -235, -238, and plutonium-239/240 were detected consistently.

Radionuclide levels measured in 2000 in the 200-East Area were generally similar to those measured in the previous 5 years. The radionuclides strontium-90 and uranium-234 and -238 were detected consistently. Occasionally the radionuclides cesium-137, uranium-235, and plutonium-239/240 were detected. Strontium-90 and plutonium-239/240 concentrations were slightly higher than the 1999 levels.

Radionuclide levels measured in the 200-West Area were also similar to results for previous years. The radionuclides strontium-90, uranium-234 and -238, and plutonium-239/240 were detected consistently. Cesium-137 and uranium-235 were occasionally detected.

Ambient air monitoring at the 300-FF-1 operable unit remedial action project in the 300 Area included eight samplers: one near-facility monitoring upwind sampler, located at the nearby 300 Area Treated Effluent Disposal Facility; two Pacific Northwest National Laboratory upwind samplers in the 300 Area (stations #14 "300 Trench" and #15 "300 NE;" see Section 4.1); and five downwind, project-specific air samplers. Remedial action activities for fiscal year 2000 were completed at this site and air monitoring was discontinued in September. Analytical results indicated that radionuclide concentrations in air samples collected at this site were much less than DOE derived concentration guides and were slightly lower than those measured since 1997 when the project began. Uranium-234, -235, and -238 were the only radionuclides that were detected consistently.

The air sampling network at the Environmental Restoration Disposal Facility (200-West Area) is made up of six samplers: two existing Hanford Site samplers for upwind monitoring (one near-facility sampler, "N-963;" one Pacific Northwest National Laboratory sampler, station #13 "200 W SE" [see Section 4.1]) and three air samplers at the facility that provided downwind coverage. Disposal activities expanded during 2000, and two of the existing facility air samplers (N-483 and N-484) were retired

and replaced with two new stations (N-517 and N-518, respectively) to provide technically appropriate sampling locations. The 2000 analytical results indicated that the strontium-90 and uranium-234, -235, and -238 levels were slightly lower than 1999 levels. Consistently detectable radionuclides were strontium-90, uranium-234, -235, and -238, and plutonium-239/240.

The remedial action, interim safe storage, and surveillance and maintenance/transition projects discussed above are described in more detail in Section 2.3.11. A complete listing of the 2000 near-facility ambient air monitoring results can be found in PNNL-13487, APP. 2. Results for selected Pacific Northwest National Laboratory air samples are also reported in PNNL-13487, APP. 2, as well as in Section 4.1.

3.2.2 Spring Water Monitoring

In the past, radioactive effluent streams were sent to the 1301-N and 1325-N Liquid Waste Disposal Facilities in the 100-N Area. This waste migrated with the groundwater and contributed to the release of radionuclides to the Columbia River. Radionuclides from these facilities enter the Columbia River along the riverbank region sometimes called N Springs. Groundwater springs and/or shoreline seepage wells at the N Springs are sampled annually to verify that the reported radionuclide releases to the Columbia River are conservative (i.e., not underreported). The amount of radionuclides entering the Columbia River at these springs (i.e., release) is calculated based on analyses of monthly samples collected from monitoring well 199-N-46 located near the shoreline. Analytical results and discussion of these releases may be found in Section 3.1 and in HNF-EP-0527-10.

In October 2000, samples were collected from all 13 100-N Area shoreline wells. The samples were collected using a bailer carefully lowered into the water column of each well to avoid sediment suspension, and a 4-liter (1-gallon) sample was obtained. Analyses of these samples detected tritium, strontium-90, and gamma-emitting radionuclides.

In 2000, the levels of strontium-90 detected in samples from riverbank springs were highest in N Springs wells Y303 and Y304, which are nearest well 199-N-46. None of the concentrations exceeded the DOE derived concentration guide value of 1,000 pCi/L. The highest tritium level was measured ~60 meters (200 feet) upstream of well 199-N-46 at well Y301. Tritium concentrations at all sampling locations were well below the 2 million pCi/L derived concentration guide. Nearly all gamma-emitting radionuclide concentrations were below analytical detection limits in 2000. Tritium and strontium-90 data from 2000 riverbank springs sampling are summarized in Table 3.2.4.

3.2.3 Radiological Surveys of Surface Contamination

Radiological surveys are used to monitor and detect contamination on the Hanford Site. The main types of contaminated areas are underground radioactive materials areas, contamination areas, soil contamination areas, and high contamination areas.

Underground radioactive materials areas are 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.

Table 3.2.4. Radionuclide Concentrations (pCi/L) in 100-N Area Riverbank Springs, 2000

Radionuclide	Facility Effluent Monitoring Well 199-N-46 (average)[a]	Shoreline Springs Maximum[b]	Shoreline Springs Average[a]	DCG[c]
Tritium	7,000 ± 3,100	1,300 ± 330	390 ± 190	2,000,000
Strontium-90	13,000 ± 3,900	180 ± 27	44 ± 35	1,000

(a) ±2 standard error of the mean.
(b) ± total analytical uncertainty.
(c) DCG = DOE derived concentration guide (DOE Order 5400.5).

Contamination/soil contamination areas may or may not be associated with an underground structure containing radioactive material. A breach in the barrier of a contaminated underground area may result in the growth of contaminated vegetation. Insects or animals may burrow into the soil and bring contamination to the surface. Vent pipes or risers from an underground structure may be a source of speck contamination (particles with a diameter less than 0.6 centimeter [0.25 inch]). Areas of contamination not related to subsurface structures can include sites contaminated with fallout from effluent stacks and sites that are the result of unplanned releases (e.g., contaminated tumbleweeds, animal feces). All contaminated areas may be susceptible to contamination migration and are surveyed at least annually to document the current radiological status (locations of contaminated areas are illustrated in PNNL-13487, APP. 2).

In 2000, the Hanford Site had ~3,628 hectares (8,965 acres) of posted outdoor contamination areas (all types) and 664 hectares (1,641 acres) of posted underground radioactive materials areas not including active facilities. It was estimated that the external dose rate at 80% of the outdoor contaminated areas was less than 1 mrem/h, though direct dose rate readings from isolated radioactive specks could have been higher. Table 3.2.5 lists the contaminated areas and underground radioactive materials areas. Vehicles equipped with radiation detection devices and a global positioning system were again used in 2000 to measure more accurately the extent of the contamination. Area measurements are entered into the Hanford Geographical Information System, a computer database maintained by Bechtel Hanford, Inc.

The number and size of contaminated areas vary from year to year because of efforts to cleanup, stabilize, and remediate areas of known contamination. New areas of contamination also are being identified, though no areas of significance were added in 2000. Table 3.2.6 indicates the changes resulting from stabilization activities during 2000. Approximately 2.9 hectares (7.2 acres) were reclassified from contamination/soil contamination areas to underground radioactive materials areas. In addition, 5.9 hectares (14.6 acres) were posted as contamination areas. Newly identified areas are generally the result of either contaminant migration or an increased effort to investigate outdoor areas for radiological contamination.

3.2.4 Soil and Vegetation Monitoring

Soil and vegetation samples were collected on or adjacent to waste disposal units and from locations downwind and near or within the boundaries of operating facilities and remedial action activity sites. Samples were collected to evaluate long-term

Table 3.2.5. Outdoor Contamination Status, 2000

Area	Contamination Areas,[a] ha (acres)		Underground Radioactive Materials Areas,[b] ha (acres)	
100-B/C	8	(20)	39	(96)
100-D/DR	0	(0)	39	(96)
100-F	0	(0)	34	(84)
100-H	0	(0)	14	(35)
100-K	6	(15)	65	(161)
100-N	29	(72)	12	(30)
200-East[c]	67	(165)	141	(348)
200-West[c]	30	(74)	224	(554)
300	11	(27)	41	(101)
400	0	(0)	0	(0)
600[d]	3,477	(8,592)	55	(136)
Totals	3,628	(8,965)	664	(1,641)

(a) Includes areas posted as contamination/soil contamination or as radiologically controlled and areas that had both underground radioactive material and surface contamination/soil contamination.
(b) Includes areas with only underground contamination. Does not include areas that had surface contamination/soil contamination as well as underground radioactive material.
(c) Includes tank farms.
(d) Includes BC controlled area and waste disposal facilities outside the 200-East Area boundary that received waste from 200-East Area facilities (e.g., 216-A-25, 216-B-3) and waste disposal facilities outside the 200-West Area boundary that received waste from 200-West Area facilities (e.g., 216-S-19, 216-U-11). The first cell of the Environmental Restoration Disposal Facility was added during 1997.

Table 3.2.6. Zone Status Change of Posted Contamination Areas, 2000[a]

Areas	Zone Changes[b]	Area, ha (acres)	
100	CA to URM	0	(0)
200-East	CA to URM	0.8	(2.0)
200-East	None to CA	2.9	(7.2)
200-West	CA to URM	2.1	(5.2)
200-West	None to CA	3.0	(7.4)
300	CA to URM	0	(0)
400	CA to URM	0	(0)
600	CA to URM	0	(0)

(a) Changes from stabilization activities, newly discovered sites, or resurveyed using a global positioning system.
(b) CA = Contamination/soil contamination area.
URM = Underground radioactive materials area.

trends in environmental accumulation of radioactivity and to detect potential migration and deposition of facility effluents. Special samples also were collected where potential physical or biological pathway problems were identified. Contaminant movement 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 animal activities at the waste site. The sampling methods and locations used are discussed in detail in WMTS-OEM-001. Radiological analyses of soil and vegetation samples included strontium-90, isotopic uranium, isotopic plutonium, and gamma-emitting radionuclides.

The number and location of soil and vegetation samples collected in 2000 are shown in Table 3.2.1. A comprehensive presentation of the analytical data results can be found in PNNL-13487, APP. 2. Only those radionuclide concentrations above analytical detection limits are discussed in this section.

Each soil sample represents a composite of five plugs of soil 2.5 centimeters (1 inch) deep and 10 centimeters (4 inches) in diameter collected from each site. Each vegetation sample consists of new-growth leaf cuttings taken from the available species of interest at a sample location. Often, the vegetation sample consisted of a composite of several like members of the sampling site plant community to avoid decimation of any individual plant through overharvesting.

Early in the summer of each year, soil and vegetation samples are collected on the

Hanford Site and submitted for radioanalyses. The analyses include those for radionuclides expected to be found in the areas sampled (i.e., gamma-emitting radionuclides, strontium isotopes, uranium isotopes, and/or plutonium isotopes). The results are then compared to levels found at various offsite sample locations in Yakima, Benton, and Franklin Counties (PNL-10574; PNNL-11795). Comparison of the levels can be used to determine the difference between contributions from site operations and remedial action sites and contributions from natural causes and worldwide fallout.

Soil sampling results also are compared to the "accessible soil" concentrations (WHC-SD-EN-TI-070) developed specifically for use at the Hanford Site (see PNNL-13487, APP. 2 for complete listing). These radioactive limits were established to ensure that effective dose equivalents to the public do not exceed the established limits for any reasonable scenario, such as direct exposure, inadvertent ingestion, inhalation, and ingestion of food crops, including animal products. The accessible soil concentration values are based on a radiation dose estimate scenario where an individual would have to spend 100 hours per year in direct contact with the contaminated soil. The conservatism inherent in pathway modeling ensures that the required degrees of protection are in place (WHC-SD-EN-TI-070). These concentrations apply specifically to the Hanford Site with respect to onsite disposal operations, stabilization, cleanup, and decontamination and decommissioning operations.

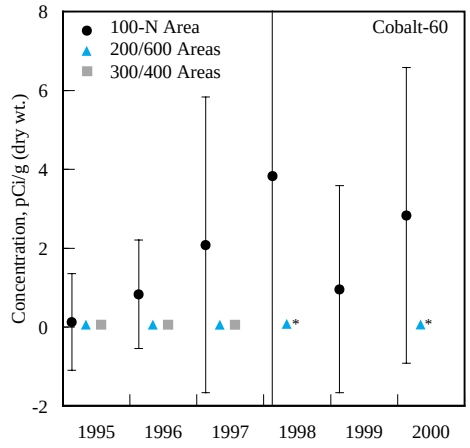
In general, radionuclide concentrations in soil and vegetation samples collected from, or adjacent to, waste disposal facilities were higher than the concentrations in samples collected farther away and were significantly higher than concentrations measured offsite. The data also show, as expected, that 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.

3.2.4.1 Radiological Results for Soil Samples

Of the radionuclide analyses performed, cobalt-60, strontium-90, cesium-137, plutonium-239/240, and uranium were detected consistently. The concentrations of these radionuclides in soil samples were elevated near and within facility boundaries when compared to historical concentrations measured off the site. Figure 3.2.2 shows average soil values for 2000 and the preceding 5 years. The levels show a large degree of variability.

Generally, the surface soil samples collected near the 1301-N Liquid Waste Disposal Facility exhibited higher radionuclide concentrations than those collected at the other soil sampling locations in the 100-N Area. Average radionuclide concentrations detected in the surface soil samples near the facility from 1995 through 2000 are presented in Table 3.2.7. Results were at or near historical levels measured on the Hanford Site, and the concentrations for most radionuclides were somewhat lower than the 1999 levels.

Average radionuclide concentrations detected in all of the surface soil samples collected in the 100-N Area from 1995 through 2000 are presented in Table 3.2.8. The average values for 100-N Area soil were down in 2000 for strontium-90, while the averages for cobalt-60, cesium-137, and plutonium-239/240 isotopes were slightly elevated over the 1999 sample results. The 2000 maximum, average, offsite average concentrations, and accessible soil concentrations are compared in Table 3.2.9. The maximum cobalt-60 concentration in soil of 11.0 pCi/g shown in Table 3.2.9 exceeds the accessible soil concentration of 7.1 pCi/g. Given the remoteness of this sample location, and the restrictions to access to the area by Hanford Security and the 100-N Operations, this is a highly unlikely situation, and considered not to be a problem.



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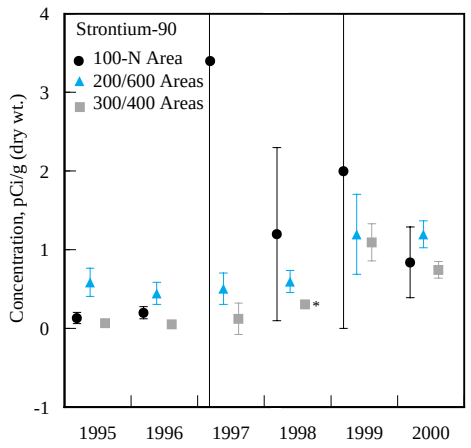

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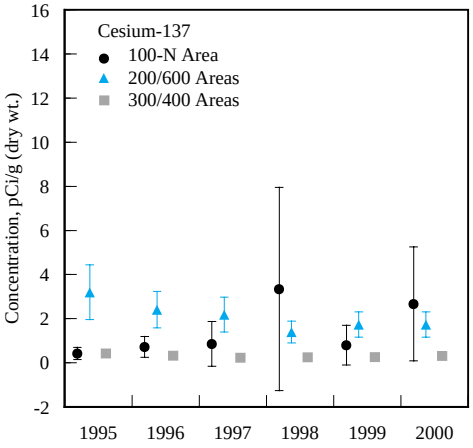

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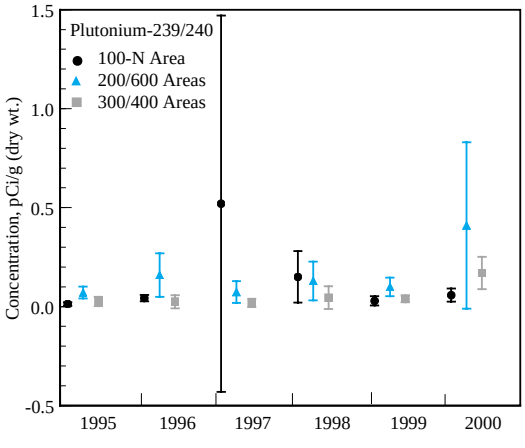

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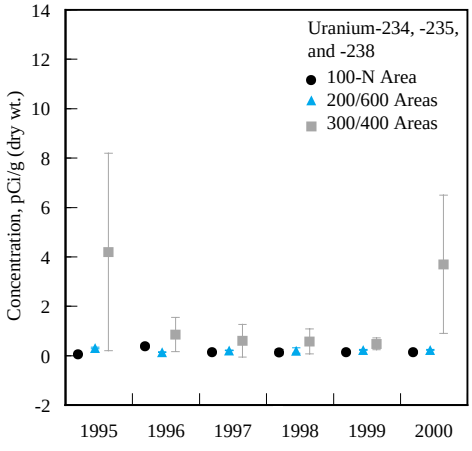

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Figure 3.2.2. Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Soil Samples, 1995 through 2000. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol. Cobalt-60 was not detected in the 200/600 Areas in 1999 or in the 300/400 Areas in 1999 and 2000.

Table 3.2.7. Average Radionuclide Concentrations (pCi/g dry wt.)[a] Detected in Surface Soil Samples near the 1301-N Liquid Waste Disposal Facility, 1995 through 2000

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
1995	2.1 ± 2.2	0.15 ± 0.17	0.77 ± 0.53	0.078 ± 0.015	0.003 ± 0.001	0.081 ± 0.012	0.010 ± 0.013
1996	2.5 ± 1.5	0.23 ± 0.11	0.98 ± 0.57	0.568 ± 0.142	0.025 ± 0.023	0.563 ± 0.222	0.048 ± 0.026
1997	4.3 ± 5.2	5.8 ± 10.8	1.5 ± 1.5	0.22 ± 0.07	0.020 ± 0.004	0.218 ± 0.057	0.98 ± 1.79
1998	8.5 ± 14.4	1.6 ± 1.2	5.2 ± 7.4	0.223 ± 0.112	0.039 ± 0.007	0.160 ± 0.041	0.19 ± 0.19
1999	2.6 ± 3.5	2.9 ± 3.4	1.3 ± 1.3	0.210 ± 0.061	0.014 ± 0.004	0.190 ± 0.053	0.03 ± 0.04
2000	1.6 ± 1.3	0.8 ± 0.5	2.7 ± 3.2	0.20 ± 0.04	0.010 ± 0.004	0.22 ± 0.05	0.07 ± 0.04

(a) ±2 standard error of the mean.

Table 3.2.8. Average Radionuclide Concentrations (pCi/g dry wt.)[a] Detected in 100-N Area Surface Soil Samples, 1995 through 2000

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
1995	0.94 ± 0.98	0.13 ± 0.07	0.51 ± 0.24	0.091 ± 0.012	0.004 ± 0.001	0.097 ± 0.014	0.014 ± 0.009
1996	1.5 ± 1.1	0.20 ± 0.08	0.077 ± 0.042	0.567 ± 0.082	0.038 ± 0.021	0.566 ± 0.125	0.043 ± 0.016
1997	2.5 ± 3.0	3.9 ± 7.2	0.89 ± 0.90	0.21 ± 0.04	0.020 ± 0.002	0.207 ± 0.036	0.91 ± 1.79
1998	4.9 ± 8.4	1.2 ± 1.2	3.1 ± 4.4	0.214 ± 0.063	0.033 ± 0.008	0.166 ± 0.026	0.15 ± 0.14
1999	1.6 ± 2.1	2.0 ± 2.0	0.84 ± 0.80	0.220 ± 0.037	0.016 ± 0.004	0.200 ± 0.033	0.029 ± 0.023
2000	3.1 ± 3.0	0.84 ± 0.45	2.5 ± 2.3	0.220 ± 0.087	0.018 ± 0.007	0.220 ± 0.032	0.058 ± 0.033

(a) ±2 standard error of the mean.

Table 3.2.9. Concentrations of Selected Radionuclides (pCi/g dry wt.) in 100-N Area Soil, 2000

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[a]	11.0 ± 0.9	1.5 ± 0.3	7.6 ± 1.1	0.26 ± 0.06	0.024 ± 0.015	0.26 ± 0.07	0.12 ± 0.04
Average[b]	3.1 ± 3.0	0.84 ± 0.45	2.5 ± 2.3	0.220 ± 0.087	0.018 ± 0.007	0.220 ± 0.032	0.058 ± 0.033
Offsite average[b,c]	NR[d]	0.062 ± 0.052	0.30 ± 0.30	0.24 ± 0.09	0.11 ± 0.04	0.25 ± 0.10	0.011 ± 0.001
Accessible soil concentration (WHC-SD-EN-TI-070)[e]	7.1	2,800	30	630	170	370	190

(a) ± total analytical uncertainty.
(b) ±2 standard error of the mean.
(c) PNL-10574 and PNNL-11795.
(d) NR = Not reported.
(e) Hanford soils that are not behind security fences.

Offsite averages for isotopic uranium, strontium-90, and cesium-137 are from PNNL-11795 and offsite values for plutonium-239/240 are contained in PNL-10574. Complete listings of radionuclide concentrations and sample location maps are provided in PNNL-13487, APP. 2.

Soil samples from 57 of 111 sampling locations in the 200/600 Areas were collected in 2000. A follow-up sampling location (D146) was again included this year from the southern end of the Environmental Restoration Disposal Facility (200-West Area) and is now sampled on an annual basis. The 2000 maximum, average, offsite average, and accessible soil concentrations are compared in Table 3.2.10. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-13487, APP. 2.

Analytical results from soil samples taken from the 200/600 Areas showed generally level trends for the average values for all of the radionuclides measured in 2000, with the exception of plutonium-239/240, which was slightly higher than the value reported in 1999.

Soil samples from 18 sampling locations in the 300/400 Areas were collected in 2000: 17 from the 300 Area and 1 from the 400 Area. The 2000 maximum, average, offsite average concentrations, and accessible soil concentrations are compared in Table 3.2.11. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-13487, APP. 2. For the samples collected in 2000, average values were higher for the uranium isotopes and plutonium-239/240 than in 1999. However, uranium concentrations were expected to be higher in the 300 Area samples than at other site locations because uranium was used during past fuel fabrication operations in the 300 Area.

In 2000, two soil samples each were collected at the remedial action locations in the 100-D, 100-F, and 100-H Areas, and three samples were collected from the 100-N Area. A single sample was collected from the Environmental Restoration Disposal Facility (200-West Area) to determine the effectiveness of contamination controls. The samples collected from these locations provide baseline samples to be compared with future samples. Table 3.2.12 provides a summary of the analytical data for selected radionuclides. All of the 2000 data are provided in PNNL-13487, APP. 2.

Table 3.2.10. Concentrations of Selected Radionuclides (pCi/g dry wt.) in 200/600 Areas Soil, 2000

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[a]	0.006[b]	3.3 ± 0.7	9.0 ± 1.2	1.0 ± 0.2	0.086 ± 0.033	1.0 ± 0.2	8.5 ± 1.6
Average[c]	--	1.1 ± 0.2	1.4 ± 0.5	0.23 ± 0.03	0.027 ± 0.004	0.23 ± 0.03	0.41 ± 0.42
Offsite average[c,d]	NR[e]	0.062 ± 0.052	0.30 ± 0.30	0.24 ± 0.09	0.11 ± 0.04	0.25 ± 0.10	0.011 ± 0.001
Accessible soil concentration limits (WHC-SD-EN-TI-070)[f]	7.1	2,800	30	630	170	370	190

(a) ± total analytical uncertainty.
(b) Single value above detection limit.
(c) ±2 standard error of the mean.
(d) PNL-10574 and PNNL-11795.
(e) NR = Not reported.
(f) Hanford soils that are not behind security fences.

Table 3.2.11. Concentrations of Selected Radionuclides (pCi/g dry wt.) in 300/400 Areas Soil, 2000

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[a]	ND[b]	1.0 ± 0.3	0.41 ± 0.07	43.0 ± 8.2	2.4 ± 0.5	44.0 ± 8.4	0.33 ± 0.08
Average[c]	ND	0.59 ± 0.18	0.14 ± 0.06	5.4 ± 5.6	0.37 ± 0.36	5.4 ± 5.7	0.17 ± 0.08
Offsite average[c,d]	NR[e]	0.062 ± 0.052	0.30 ± 0.30	0.24 ± 0.09	0.11 ± 0.04	0.25 ± 0.10	0.011 ± 0.001
Accessible soil concentration limits (WHC-SD-EN-TI-070)[f]	7.1	2,800	30	630	170	370	190

(a) ± total analytical uncertainty.
(b) ND = Not detected.
(c) ±2 standard error of the mean.
(d) PNL-10574 and PNNL-11795.
(e) NR = Not reported.
(f) Hanford soils that are not behind security fences.

Table 3.2.12. Radionuclide Concentrations (pCi/g dry wt. ± total analytical uncertainty) in Environmental Restoration Contractor Projects' Soil Samples, 2000

Site	Sample Location[a]	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
ERDF[b]	D146	ND[c]	0.36 ± 0.23	ND	0.15 ± 0.05	0.016 ± 0.012	0.13 ± 0.04	0.064 ± 0.026
100-D	D147	0.011 ± 0.006	0.48 ± 0.22	0.2 ± 0.03	0.20 ± 0.06	0.032 ± 0.019	0.20 ± 0.06	ND
100-D	D148	0.03 ± 0.01	0.66 ± 0.026	0.43 ± 0.06	0.16 ± 0.05	0.023 ± 0.017	0.15 ± 0.05	0.051 ± 0.023
100-H	D151	ND	0.30 ± 0.21	0.74 ± 0.1	0.20 ± 0.06	0.033 ± 0.019	0.13 ± 0.04	0.041 ± 0.02
100-H	D152	0.015 ± 0.008	0.81 ± 0.28	0.23 ± 0.04	0.14 ± 0.05	0.021 ± 0.025	0.17 ± 0.05	ND
100-F	D154	ND	0.55 ± 0.3	0.06 ± 0.02	0.18 ± 0.07	0.018 ± 0.014	0.17 ± 0.06	ND
100-F	D155	0.018 ± 0.007	0.43 ± 0.24	0.37 ± 0.05	0.18 ± 0.07	0.001 ± 0.001	0.16 ± 0.06	0.028 ± 0.018
100-N	D156	0.047 ± 0.009	0.59 ± 0.21	0.07 ± 0.02	0.21 ± 0.08	0.03 ± 0.029	0.16 ± 0.07	ND
100-N	D157	0.096 ± 0.013	0.72 ± 0.25	0.13 ± 0.03	0.20 ± 0.05	0.021 ± 0.013	0.19 ± 0.05	ND
100-N	D158	0.036 ± 0.009	0.50 ± 0.21	0.05 ± 0.01	0.35 ± 0.08	0.02 ± 0.013	0.28 ± 0.07	ND
Offsite Average[d,e]		NR[f]	0.06 ± 0.052	0.3 ± 0.3	0.24 ± 0.09	0.11 ± 0.04	0.25 ± 0.1	0.011 ± 0.001
Accessible Soil Concentration[g]		7.1	2,800	30	630	170	370	190

(a) Sampling location code. See PNNL-13487, APP. 2.
(b) ERDF = Environmental Restoration Disposal Facility.
(c) ND = Not detected.
(d) ±2 standard error of the mean.
(e) PNL-10574 and PNNL-11795.
(f) NR = Not reported.
(g) Hanford soils that are not behind security fences.

3.2.4.2 Radiological Results for Vegetation Samples

Of the radionuclide analyses performed, cobalt-60, strontium-90, cesium-137, plutonium-239/240, and uranium were consistently detected. Concentrations of these radionuclides in vegetation were elevated near and within facility boundaries compared to the concentrations measured off the site. Figure 3.2.3 shows average vegetation values for 2000 and the preceding 5 years. The results show a high degree of variability.

Average radionuclide concentrations detected in the vegetation samples near the retired 1301-N Liquid Waste Disposal Facility from 1995 through 2000 are presented in Table 3.2.13. In 2000, these samples had non-detectable concentrations of cobalt-60 and plutonium-239/240 and significantly lower concentrations of strontium-90 and cesium-137 (see PNNL-13487, APP. 2) when compared to 1999 levels. This same trend occurred at 1301-N in 1996 with elevated concentrations being reported for cobalt-60, strontium-90, and cesium-137. This was followed in 1997 by a significant reduction in the concentrations of these same radionuclides (see Table 3.2.13). The elevated values were due to vegetation collected from sample location Y705 in 1996 and 1999. However, vegetation samples from this site were not available in 1997 and 2000 due to either construction activities or limited access.

Average radionuclide concentrations detected in all of the vegetation samples collected in the 100-N Area from 1995 through 2000 are presented in Table 3.2.14. These concentrations were also significantly lower than concentrations measured in 1999.

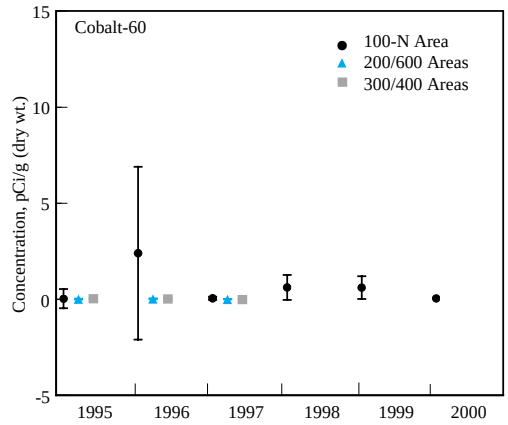
Vegetation samples collected along the 100-N Area shoreline (N Springs) contain radionuclides that were not completely retained in the soil columns beneath the retired 1301-N and 1325-N Liquid Waste Disposal Facilities. Values for all of the radionuclides analyzed were about the same in 2000, with the exception of strontium-90. The data presented in Table 3.2.15 show the average radionuclide concentrations detected in the vegetation samples collected along N Springs in 2000 were higher than 1999 results, but only plutonium-239/240 was above detection limits.

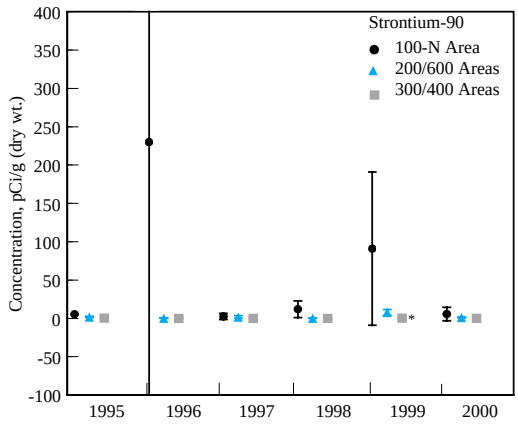
The 2000 analytical results for vegetation samples collected at the 100-N Area are compared to offsite averages in Table 3.2.16. A complete list of radionuclide concentrations and sampling location maps are provided in PNNL-13487, APP. 2. In 2000, analytical results from vegetation samples collected from the 100-N Area were generally less than those observed in 1999. The radionuclide levels measured in 100-N Area vegetation were greater than those measured off the Hanford Site.

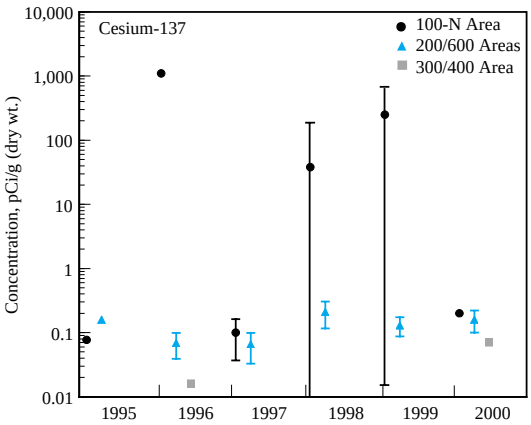
In 2000, 47 vegetation samples were collected from the 200/600 Areas. The 2000 maximum, average, and offsite average are compared in Table 3.2.17. A complete list of radionuclide concentrations and sampling location maps is provided in PNNL-13487, APP. 2. Analytical results from vegetation samples taken in 2000 from the 200/600 Areas were comparable to those observed in previous years. Radionuclide levels for strontium-90, cesium-137, and plutonium-239/240 were greater than those measured off the Hanford Site. The levels of cesium-137 and strontium-90 at the 200/600 Areas was higher than found in the 100 and 300/400 Areas.

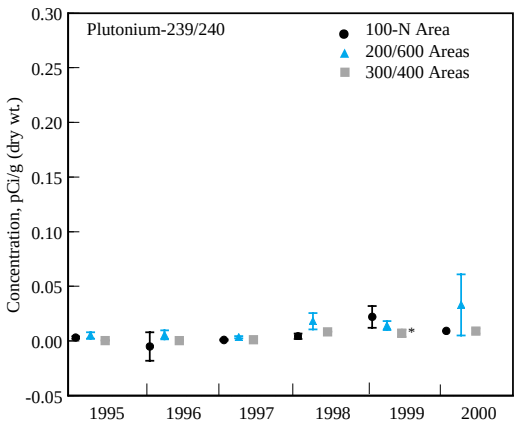
This was the ninth year of sampling at locations established to more directly monitor facilities and active/inactive waste sites in the 300 and 400 Areas. The 2000 maximum, average, offsite average, and accessible soil limits for 300/400 Areas samples are listed in Table 3.2.18. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-13487, APP. 2.

The levels of most radionuclides measured in the 300 Area were greater than those measured off the Hanford Site, and uranium levels were higher than levels measured in the 100 and 200 Areas. The









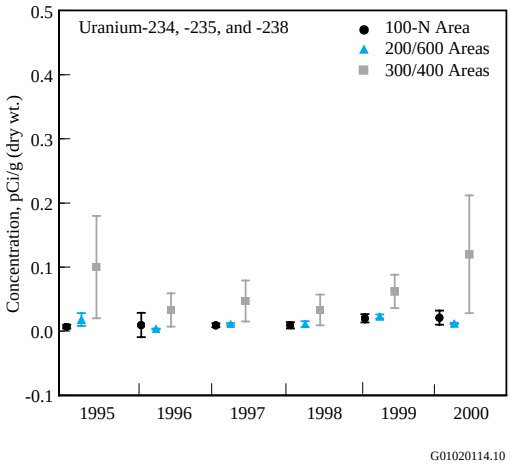


Figure 3.2.3. Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Vegetation Samples, 1995 through 2000. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol. The 1997 cesium-137 data point for the 300/400 Areas is less than zero and cannot be plotted on a log scale. Cobalt-60 was not detected in the 200/600 or 300/400 Areas since 1997. Cesium-137 was not detected in the 300/400 Areas in 1995 and 1997 through 1999.

Table 3.2.13. Average Radionuclide Concentrations (pCi/g dry wt.)[a] Detected in Vegetation Samples Collected near the 1301-N Liquid Waste Disposal Facility, 1995 through 2000

Year	^{60}Co	^{90}Sr	^{137}Cs	$^{239/240}$Pu
1995	0.054 ± 0.10	0.064 ± 0.019	0.12 ± 0.14	0.008 ± 0.003
1996	6.1 ± 11.9	575 ± 1,150	2,750 ± 5,500	-0.013 ± 0.38[b]
1997	0.42[c]	0.49[c]	0.14 ± 0.06	ND[d]
1998	0.54 ± 0.93	13.6 ± 26.4	50.1 ± 99.8	0.0071[c]
1999	0.99 ± 0.97	205 ± 201	505 ± 410	0.009 ± 0.010
2000	ND	0.06 ± 0.06	0.2[c]	ND

(a) ±2 standard error of the mean.
(b) Negative value indicates results at or below background levels of radioactivity.
(c) Single value above detection limit.
(d) ND = Not detected.

Table 3.2.14. Average Radionuclide Concentrations (pCi/g dry wt.)[a] Detected in 100-N Area Vegetation Samples, 1995 through 2000

Year	^{60}Co	^{90}Sr	^{137}Cs	$^{239/240}$Pu
1995	0.03 ± 0.05	5.4 ± 4.8	0.081 ± 0.044	0.0033 ± 0.0016
1996	2.4 ± 4.5	230 ± 430	1,100 ± 2,000	-0.0051 ± 0.013[b]
1997	0.42 ± 0.05	3.6 ± 5.3	0.16 ± 0.008	ND[c]
1998	0.62 ± 0.73	11.7 ± 11.1	37.6 ± 74.9	0.0042 ± 0.0029
1999	0.61 ± 0.59	91 ± 100	250 ± 250	0.022 ± 0.010
2000	0.05[d]	5.7 ± 8.7	0.2[d]	0.009[d]

(a) ±2 standard error of the mean.
(b) Negative value indicates results at or below background levels of radioactivity.
(c) ND = Not detected.
(d) Single value above detection limit.

higher uranium levels were expected because uranium was released during past fuel fabrication operations in the 300 Area. In the 400 Area, the levels recorded for most radionuclides were higher than those measured off the site in previous years.

3.2.5 External Radiation

In 2000, there were 148 locations collecting external radiation information. At 78 locations, the dosimeter results showed a decrease in external radiation from 1999 levels. At one location (312-R), there was a 3% increase in radiation detected. At 66 locations in the 200/600 Areas, there was no change in the external radiation detected.

External radiation fields were monitored near facilities and waste handling, storage, and disposal sites to measure and assess the impact of operations. Thermoluminescent dosimeters are used at numerous fixed locations to gather dose rate information over longer periods of time. Thermoluminescent

Table 3.2.15. Average Radionuclide Concentrations (pCi/g dry wt.)[a] Detected in N Springs Vegetation Samples, 1995 through 2000

Year	^{60}Co	^{90}Sr	^{137}Cs	$^{239/240}$Pu
1995	0.014 ± 0.045	13.4 ± 10.2	0.094 ± 0.059	0.0028 ± 0.0008
1996	0.01 ± 0.01	2.4 ± 4.2	0.038 ± 0.010	-0.0015 ± 0.002[b]
1997	ND[c]	6.2 ± 9.9	0.18 ± 0.17	ND
1998	0.068[d]	21.0 ± 19.0	ND	0.0028[d]
1999	ND	0.98 ± 0.80	0.28 ± 0.49	ND
2000	ND	9.4 ± 15.6	ND	0.009[d]

(a) ±2 standard error of the mean.
(b) Negative value indicates results at or below background levels of radioactivity.
(c) ND = Not detected.
(d) Single value above detection limit.

Table 3.2.16. Concentrations of Selected Radionuclides (pCi/g dry wt.) in 100-N Area Vegetation Samples, 2000

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[a]	0.048 ± 0.032[b]	25.0 ± 3.8	0.2 ± 0.12[b]	0.12 ± 0.09	0.016 ± 0.012	0.073 ± 0.066	0.009 ± 0.008[b]
Average[c]		5.7 ± 8.7		0.033 ± 0.027	0.016 ± 0.00	0.024 ± 0.018	
Offsite average[c,d]	NR[e]	0.025 ± 0.012	0.0072 ± 0.0083	0.014 ± 0.006	ND[f]	0.013 ± 0.004	0.00018 ± 0.00013

(a) ± total analytical uncertainty.
(b) Single value above detection limit.
(c) ±2 standard error of the mean.
(d) PNL-10574 and PNNL-11795.
(e) NR = Not reported.
(f) ND = Not detected.

Table 3.2.17. Concentrations of Selected Radionuclides (pCi/g dry wt.) in 200/600 Areas Vegetation Samples, 2000

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[a]	ND[b]	11.0 ± 1.6	0.52 ± 0.10	0.05 ± 0.02	0.015 ± 0.010	0.06 ± 0.03	0.22 ± 0.05
Average[c]	ND	1.3 ± 0.08	0.16 ± 0.06	0.02 ± 0.03	0.009 ± 0.001	0.014 ± 0.002	0.033 ± 0.028
Offsite averages[c,d]	NR[e]	0.025 ± 0.012	0.0072 ± 0.0083	0.014 ± 0.006	ND	0.013 ± 0.004	0.00018 ± 0.00013

(a) ± total analytical uncertainty.
(b) ND = Not detected.
(c) ±2 standard error of the mean.
(d) PNL-10574 and PNNL-11795.
(e) NR = Not reported.

Table 3.2.18. Concentrations of Selected Radionuclides (pCi/g dry wt.) in 300/400 Areas Vegetation Samples, 2000

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Maximum[a]	ND[b]	0.24 ± 0.12	0.07[c]	1.4 ± 0.3	0.075 ± 0.023	1.4 ± 0.3	0.013 ± 0.007
Average[d]	ND	0.21 ± 0.03		0.018 ± 0.019	0.018 ± 0.01	0.017 ± 0.019	0.0091 ± 0.0029
Offsite averages[d,e]	NR[f]	0.025 ± 0.012	0.0072 ± 0.0083	0.014 ± 0.006	ND	0.013 ± 0.004	0.00018 ± 0.00013

(a) ± total analytical uncertainty.
(b) ND = Not detected.
(c) Single value above detection limit.
(d) ±2 standard error of the mean.
(e) PNL-10574 and PNNL-11795.
(f) NR = Not reported.

dosimeter results can be used individually or averaged to determine dose rates in a given area for a particular sampling period. A summary of the 1999 and 2000 thermoluminescent dosimeter results can be found in Table 3.2.19. Individual thermoluminescent dosimeter results and locations are provided in PNNL-13487, APP. 2. Specific information regarding external radiation sampling methods and locations can be found in WMTS-OEM-001. Dose rate information for the Hanford perimeter locations can be found in Section 4.6.

Environmental thermoluminescent dosimeters measure dose rates from all types of external radiation sources. These sources include cosmic radiation, naturally occurring radioactivity in air and soil, and fallout from nuclear weapons testing, as well as any contribution from Hanford Site

Table 3.2.19. Thermoluminescent Dosimeter Results (mrem/yr) for Waste Handling Facilities, 1999 and 2000, based on 24 hours/day

Area	No. of Locations, 2000	1999 Maximum	1999 Mean	2000 Maximum	2000 Mean	% Change[a]
100-B/C	5	100	90	87	84	-7
100-D,DR	5	97	91	89	84	-8
100-F	5	NA[b]	NA	88	85	NA
100-H	3	99	95	90	88	-7
100-K	11	320	130	390	120	-8
100-N	14	6,500	1,400	4,700	1,100	-21
200/600	66	290	110	300	106	-4
212-R	1	1,980	1,940	2,500	2,000	3
300 TEDF[c]	6	90	87	85	83	-5
300	8	220	110	180	100	-9
400	7	93	85	81	80	-6
CVSF[d]	4	120	85	81	75	-12
ERDF[e]	3	94	91	93	89	-2
TWRS[f]	10	90	88	84	83	-6

(a) Numbers indicate a decrease (-) or increase from the 1999 mean.
(b) NA = Not applicable: comparisons cannot be made because monitoring locations were new in 2000.
(c) TEDF = 300 Area Treated Effluent Disposal Facility.
(d) CVDF = Cold Vacuum Drying Facility.
(e) ERDF = Environmental Restoration Disposal Facility.
(f) TWRS = Tank Waste Remediation System Phase I demonstration project.

activities. These outside radiation sources cause an estimated 20% deviation in thermoluminescent dosimeter results. The results are reported in units of millirems per year.

Near-facility monitoring uses the Harshaw thermoluminescent dosimeter system, which includes the Harshaw 8807 dosimeter and the Harshaw 8800 reader. The packaging, which uses an O-ring seal, protects the dosimeter from light, heat, moisture, and dirt. The thermoluminescent dosimeters were placed 1 meter (3.3 feet) above the ground near facilities, active and inactive surface-water disposal sites, and remedial action projects. The dosimeters were exchanged and analyzed each calendar quarter. The Radiological Calibrations Facility in the 318 Building (300 Area) calibrates the response of the chips; results are reported in terms of external dose.

To evaluate environmental restoration activities at the former 116-B-11 and 116-C-1 Liquid Waste Disposal Facilities (located in the 100-B/C Area), four thermoluminescent dosimeter monitoring sites were established during the fourth quarter of 1997. An additional dosimeter location, collocated with a Washington State Department of Health dosimeter, was established during the fourth quarter of 1999. Dose rates measured at these locations in 2000 were 7% lower compared to the data from 1999. The 2000 average dose rate was 84 mrem/yr, comparable to the Hanford perimeter 5-year average of 92 mrem/yr (PNNL-13230).

This was the fifth year that thermoluminescent dosimeters were placed in the 100-D/DR Area to evaluate cleanup activities at the former 116-D-7 and 116-DR-9 Liquid Waste Disposal Facilities. Dose rates measured at these locations were 8% lower than the results of 1999, with an average dose of 84 mrem/yr, comparable to the Hanford perimeter 5-year average of 92 mrem/yr.

To evaluate environmental restoration activities in the 100-F Area, five new thermoluminescent dosimeter monitoring sites were established for the last three quarters of 2000. Because only three quarters of data were collected at these sites, the thermoluminescent dosimeter results were extrapolated to one year, resulting in an average of 85 mrem/yr, comparable to the Hanford perimeter 5-year average of 92 mrem/yr.

To evaluate environmental restoration activities in the 100-H Area, three thermoluminescent dosimeter monitoring sites were established in 1999. Dose rates in this area decreased 79% in 2000, with an average of 88 mrem/yr, which is comparable to the Hanford perimeter 5-year average of 92 mrem/yr.

The cleanup activities at the K Basins and adjacent retired reactor buildings in the 100-K Area continue to be monitored. Dose rates in this area in 2000 decreased 8% relative to 1999 values, with an average of 120 mrem/yr, because of the removal of radioactive waste stored in proximity to the three thermoluminescent dosimeter locations.

Four thermoluminescent dosimeter monitoring sites were established around the Cold Vacuum Drying Facility in 1999 to perform preoperational monitoring. Dose rates around this facility decreased 12% in 2000, with an average of 75 mrem/yr, which is comparable to the Hanford perimeter 5-year average of 92 mrem/yr.

The 2000 results for the 100-N Area indicate that direct radiation levels are highest near facilities that contained or received liquid effluent from N Reactor. These facilities primarily include the retired 1301-N and 1325-N Liquid Waste Disposal Facilities. The results for these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations, but were 41% lower than dose levels measured at these locations in 1999. This reduction was directly attributable to the removal of source material at the 1325-N facility by the Environmental Restoration Contractor. Overall, the average dose rate measured in the 100-N Area in 2000 was ~13% lower than

that measured in 1998. Annual average thermoluminescent dosimeter results for the entire 100-N Area from 1987 through 2000 are presented in Figure 3.2.4.

Dose rates were measured at the N Springs shoreline to determine potential external radiation doses to the public as well as to onsite workers. Because of the "skyshine" effect (i.e., radiation reflected by the atmosphere back to the earth's surface) from the retired 1301-N facility, annual dose rates at the N Springs shoreline were greater than 100 mrem/yr, which is the DOE annual external dose limit to members of the public. However, neither a member of the public nor a Hanford worker would conceivably spend an entire year at the N Springs; therefore, the values shown in Figure 3.2.5 are for comparison only.

The highest dose rates in the 200 Areas were measured near waste handling facilities. The location within the 200 Areas exhibiting the highest dose rate was at tank farm A in the 200-East Area. The average annual dose rate measured in 2000 in the 200 Areas (106 mrem/yr) was slightly lower than the average 1999 measurement. The annual average thermoluminescent dosimeter results from 1987 through 2000 are presented in Figure 3.2.6.

Ten thermoluminescent dosimeter locations were established around the perimeter of the Tank Waste Remediation System Phase I demonstration project during the fourth quarter of 1997 to collect pre-operational monitoring data. Dose rates measured at these locations in 2000 were 6% lower than the average 1999 measurements, with an average of 83 mrem/yr. This is comparable to the Hanford perimeter 5-year average background level.

This is the fifth year that thermoluminescent dosimeters have been placed at the Environmental Restoration Disposal Facility to evaluate dose rates during ongoing activities. Dose rates measured in 2000 were ~2% lower than the 1999 results, with an average of 89 mrem/yr, which is comparable to the Hanford perimeter 5-year average background level.

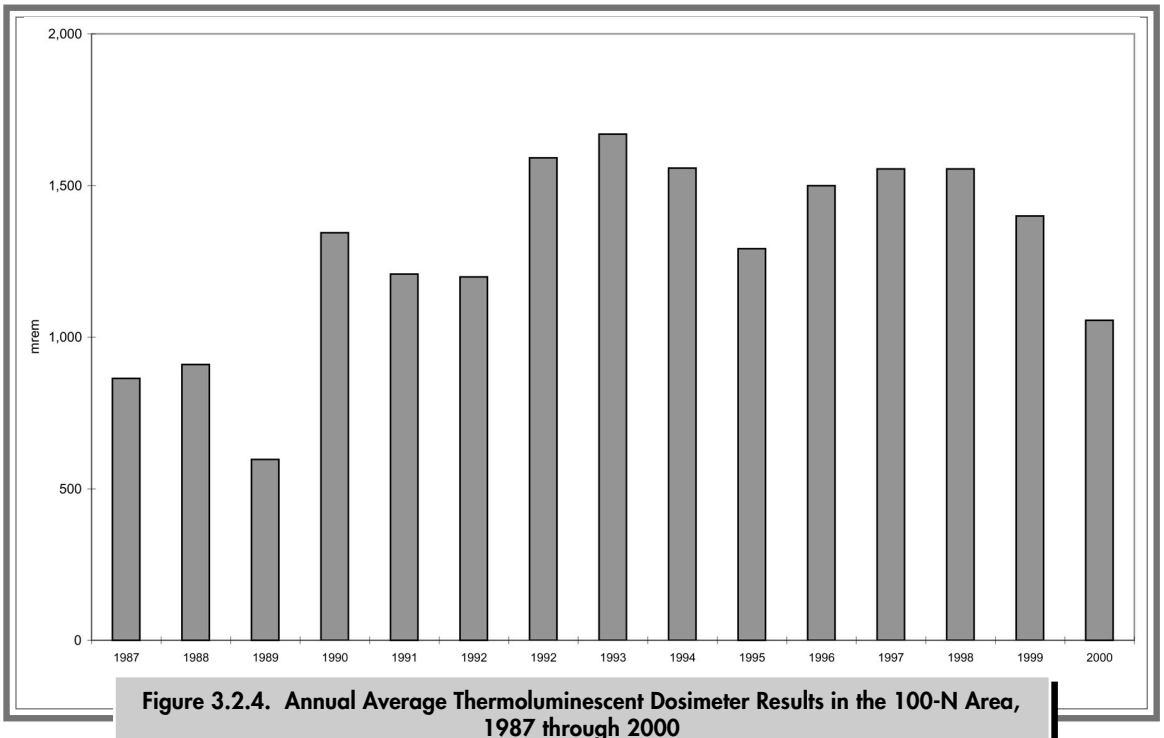


Figure 3.2.4. Annual Average Thermoluminescent Dosimeter Results in the 100-N Area, 1987 through 2000

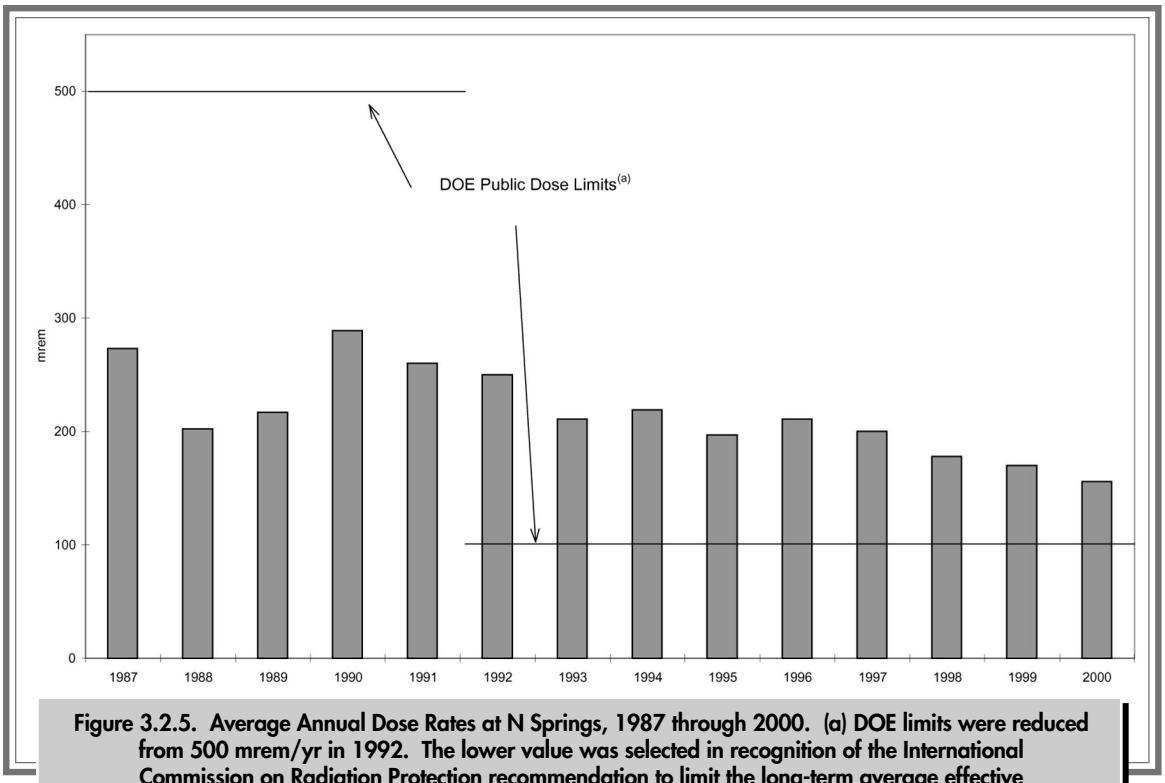


Figure 3.2.5. Average Annual Dose Rates at N Springs, 1987 through 2000. (a) DOE limits were reduced from 500 mrem/yr in 1992. The lower value was selected in recognition of the International Commission on Radiation Protection recommendation to limit the long-term average effective dose equivalence to 100 mrem (1 mSv)/yr or less (DOE Order 5400.5).

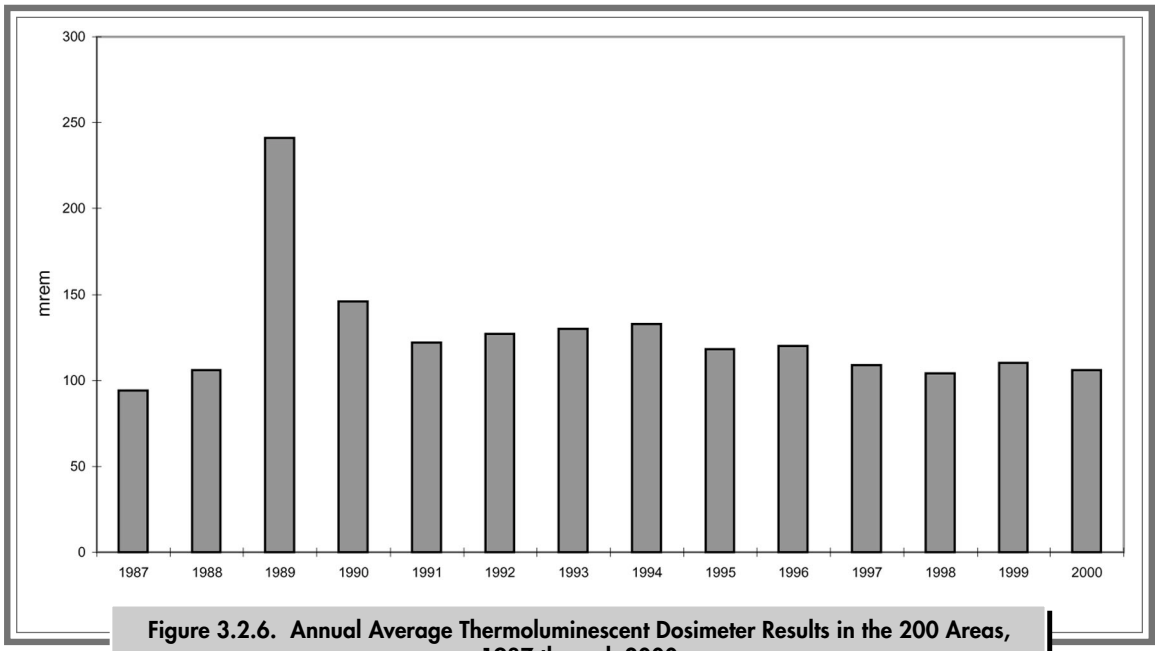


Figure 3.2.6. Annual Average Thermoluminescent Dosimeter Results in the 200 Areas, 1987 through 2000

The highest dose rates in the 300 Area in 2000 were measured near the 316-3 process trench. The average dose rate measured in the 300 Area in 2000 was 100 mrem/yr, which is 9% lower than the average dose rate measured in 1999. The average dose rate at the 300 Area Treated Effluent Disposal Facility in 2000 was 83 mrem/yr, which is a 5% decrease compared to the average dose rate of 80 mrem/yr measured in 1999. The average dose rate measured in the 400 Area in 2000 was 80 mrem/yr, which is a 6% decrease compared to the average dose of 85 mrem/yr measured in 1999. The annual average thermoluminescent dosimeter results for the 300 and 400 Areas from 1991 through 2000 are presented in Figure 3.2.7.

One new thermoluminescent dosimeter monitoring site was established in the 200 North Area, at the (contaminated) 212-R Railroad Car Disposition Area in 1999 to monitor expected high radiation levels in the immediate vicinity. The annual average dose rate at 212-R in 2000 was 2,005 mrem/yr. This value exceeds the DOE annual external dose (greater than 100 mrem/yr) limit to the members of the public. However, no member of the public, or Hanford worker, would conceivably spend an entire year at this location.

3.2.6 Investigative Sampling

Investigative sampling was conducted in the operations areas to monitor the presence or movement of radioactive and/or hazardous materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. 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

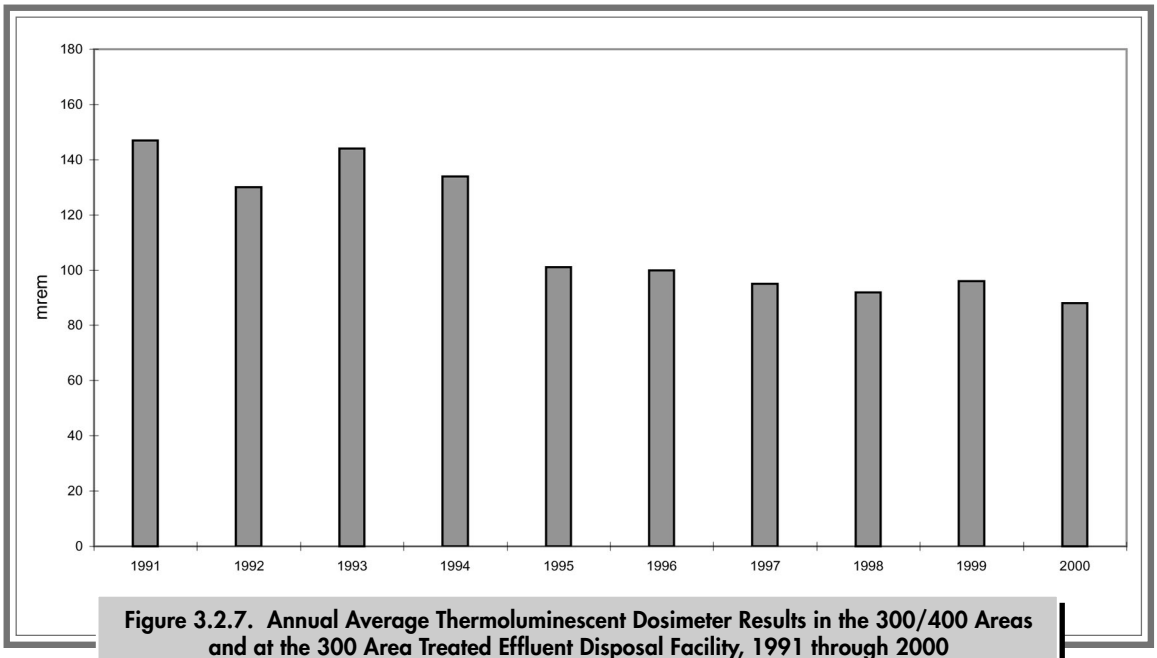


Figure 3.2.7. Annual Average Thermoluminescent Dosimeter Results in the 300/400 Areas and at the 300 Area Treated Effluent Disposal Facility, 1991 through 2000

- to conduct preoperational surveys to characterize the radiological/chemical conditions at a site before facility construction, operation, or ultimate 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.

Generally, the predominant radionuclides discovered during these efforts were cesium-137, strontium-89/90, and plutonium-239/240 in the 100 and 200 Areas and uranium-234, -235, and -238 in the 300 Area. Hazardous chemicals generally have not been identified above background levels in preoperational environmental monitoring samples.

Investigative samples collected in 2000 included mammals (mice, bats, rabbit), feces (mouse, coyote, bird), and tumbleweed fragments. Methods for collecting investigative samples are described in WMTS-OEM-001. Field monitoring was conducted to detect radioactivity in samples before they were submitted for analysis. Field monitoring results are expressed as disintegrations per minute when a Geiger-Müeller detector was used, or as millirad per hour when an ion chamber was used. To obtain the field instrument readings, measured background radioactivity was subtracted from the Geiger-Müeller readings (in counts per minute) and the results were converted to disintegrations per minute per 100 cm^2. Laboratory sample analysis results are expressed in picocuries per gram, except for extremely small samples. Small samples are expressed in picocuries per sample. Maximum concentrations, rather than averages, are presented in this section.

In 2000, nine investigative samples were analyzed for radionuclides at the 222-S Laboratory in the 200-West Area. Of the samples analyzed, all showed measurable levels of activity. Analytical results are provided in PNNL-13487, APP. 2. Another 102 contaminated investigative environmental samples were reported and disposed of without isotopic analyses (though field instrument survey readings were recorded) during cleanup operations. These results are also provided in PNNL-13487, APP. 2. Only radionuclide concentrations above analytical detection limits are provided in this section.

In 2000, there were 25 instances of radiological contamination in investigative soil samples. Of the 25, 16 were identified as speck or soil speck contamination. None of the investigative soil samples were submitted for radioisotopic analysis. Twenty-four of the 25 areas of soil contamination were cleaned up and the contaminated soil was disposed of in low-level burial grounds without analysis. At the remaining site, the contamination levels did not exceed limitations of the posting and was left in place. For all samples, external radioactivity levels ranged from 6,000 dpm/100 cm^2 to more than 1 million dpm/100 cm^2.

The number of investigative soil contamination incidents, range of radiation dose levels, and radionuclide concentrations in 2000 were generally within historical values (WHC-MR-0418). Areas of special soil sampling that were found outside radiological control areas and that had dose levels greater than radiological control limits were cleaned up or posted as surface contamination areas.

In 2000, there were 66 instances of radiological contamination in investigative vegetation samples. Of the 66, 65 were identified as tumbleweed or tumbleweed fragments and one as rabbitbrush. One tumbleweed sample was analyzed for radionuclide activities. There were six tumbleweed samples with field readings of 1 million dpm/100 cm^2 or higher. Of these, three were suspected to have originated from the 218-E-12B burial ground in the 200-East Area, two were found on the 218-A-30 crib also in the 200-East Area, and one was suspected to have originated from an inactive transfer line in the 200-West Area. Investigative vegetation samples not sent to the laboratory for analysis were disposed of in low-level burial grounds.

The number of incidents of contaminated vegetation in 1999 (84) was the highest number of annual incidents since 1994 when data collections began. These high numbers can be attributed largely to situations in which herbicide applications were not made at optimum times, and in some cases, not made at all. Tumbleweed and rabbitbrush are deep-rooted species and become radiologically contaminated by the uptake of below ground contaminants through their root systems. Herbicide application is intended to halt vegetation growth before this uptake occurs. During 2000, application techniques were improved, and administrative procedures were implemented to improve vegetation management. The somewhat reduced number of incidents in 2000 (66) appears to reflect these improvements. Nevertheless, contaminated vegetation continued to be identified by radiological surveys. However, as "old" contaminated vegetation from past years is identified and cleaned up, subsequent years will show the results of program improvements.

Investigative wildlife samples were collected directly from or near facilities to monitor and track the effectiveness of measures designed to deter animal intrusion. Samples were collected either as part of an integrated pest management program designed to limit the exposure of animals to radioactive materials, or as a result of finding radiologically contaminated wildlife-related material (e.g., feces, nests) during radiation surveys.

Radiological surveys were performed after the collection of wildlife 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, location, 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 2000, 12 wildlife and wildlife-related samples were collected, 8 of which were submitted for laboratory analysis. The number of samples submitted for analysis depended on opportunity (i.e., resulting from the pest control activities) and analytical budget, rather than prescheduled sampling at established sampling points.

The maximum radionuclide concentrations in investigative wildlife samples in 2000 were in mouse feces collected near the 241-TX-155 Diversion Box in the 200-West Area. Field readings showed 300,000 dpm/100 cm^2 beta/gamma and 2,800 dpm/100 cm^2 alpha. Contaminants included cobalt-60 (93 pCi/g), strontium-89/90 (116,000 pCi/g), cesium-137 (42,900 pCi/g), europium-154 (627 pCi/g), europium-155 (417 pCi/g), plutonium-238 (39,100 pCi/g), and plutonium-239/240 (384,000 pCi/g). The numbers of animals found to be contaminated with radioactivity, their radioactivity levels, and the range of radionuclide activities were within historical levels (WHC-MR-0418).

There were four cases of contaminated wildlife or related samples found during cleanup operations that were not submitted to a laboratory for analysis. These samples included ant mounds and mouse feces. The field instrument readings for these samples ranged from 12,000 to 129,000 dpm/100 cm^2.

Special characterization projects conducted or completed in 2000 to ascertain the radiological, and in some cases, potential hazardous chemical status of site-specific operations included the projects listed below.

- A preoperational environmental survey was completed in support of the Spent Nuclear Fuels Project Facilities. Environmental samples were collected in the proximity of the Canister Storage Building and the Interim Storage Area in the 200-East Area and near the Cold Vacuum Drying Facility in the 100-K Area. A final report (HNF-6150) was prepared and issued.

- A preoperational monitoring plan (RPP-6877) was developed to support the Waste Vitrification initiative. As a part of this plan, a survey will be conducted on the proposed location for the Remote-Handled Immobilized Low-Activity Waste Disposal Facility to be located in the 200-East Area. Efforts will include radiological and ground penetrating radar surveys, surface and subsurface soil sampling, vegetation sampling, and air and thermoluminescent dosimeter monitoring.

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4.0 Environmental Surveillance Information

R. W. Hanf and L. E. Bisping

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 4.6 describe results of the Hanford Site surface environmental surveillance and drinking water surveillance projects for 2000 and include, where applicable, information on both radiological and non-radiological constituents. The objectives, criteria, design, and description of these projects are summarized below and provided in detail in the Hanford Site environmental monitoring plan (DOE/RL-91-50). Radiological doses associated with the surveillance results are discussed in Section 6.0. The quality assurance and quality control programs developed to ensure the value of surveillance data are described in Section 9.0.

Many samples are collected and analyzed for the Hanford Site environmental surveillance project, and the resulting data are compiled in a large database. It is not practical nor desirable to list individual results in this report; therefore, only summary information is included, emphasizing those radionuclides or chemicals of Hanford Site origin that are important to the environment or human health and safety. Supplemental data for some sections can be found in Appendix B. More detailed results for specific surface environmental surveillance sampling locations are contained in *Hanford Site Environmental Surveillance Data Report for Calendar Year 2000* (PNNL-13487, APP. 1). The intent of these sections (Sections 4.1 through 4.6) is to provide current surveillance data, to compare 2000 data to past data and existing and accepted standards, and to present a general overview of Hanford Site surveillance activities.

In addition to Hanford Site environmental surveillance, environmental monitoring is conducted at or near facilities on the site. These near-facility monitoring efforts are discussed in Section 3.0.

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 potential effects of these materials on the environment and the public. Samples of air, surface water, sediment, soil and natural vegetation, agricultural products, fish, and wildlife are collected routinely or periodically. Analyses include the measurement of radionuclides at very low environmental levels and non-radiological chemicals, including metals and anions. In addition, ambient external radiation is measured.

The project focuses on routine releases from DOE facilities on the Hanford Site; however, the project also responds 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 or designated subcontractor, environmental surveillance is conducted under an independent program that reports directly to the DOE Richland Operations Office, Office of Site Services.

4.0.1.1 Surveillance Objectives

The general requirements and objectives for environmental surveillance are contained in DOE Orders 5400.1, "General Environmental Protection Program," and 5400.5, "Radiation Protection of the Public and the Environment." 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, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance," and include the following:

- determine compliance with applicable environmental quality standards, 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 include
  - conduct preoperational assessments
  - assess radiological doses to the public and environment
  - 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 stipulates 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 issues, primarily through public involvement and by providing public information
- provide environmental data and assessments to assist the DOE 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 site offices. 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 interests and concerns. 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 the impact to the environment 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 and studies conducted at the Hanford Site for more than 50 years provides valuable technical background for planning the surveillance design and managing the site.

The Hanford Site environmental surveillance project historically focused on radionuclides in various media and non-radiological water quality parameters. In recent years, surveillance for non-radiological constituents, including hazardous chemicals, has been expanded. A detailed chemical pathway and exposure analysis for the Hanford Site was completed in 1995 (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 2000 pathway analysis was based on 2000 source-term data and on the comprehensive pathway and dose assessment methods included in the Generation II (GENII) computer code (PNL-6584) used to estimate radiation doses to the public from Hanford Site operations. The Biota Dose Calculator, a spreadsheet program, was used to calculate doses to animals. 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., skin 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 off the site by 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

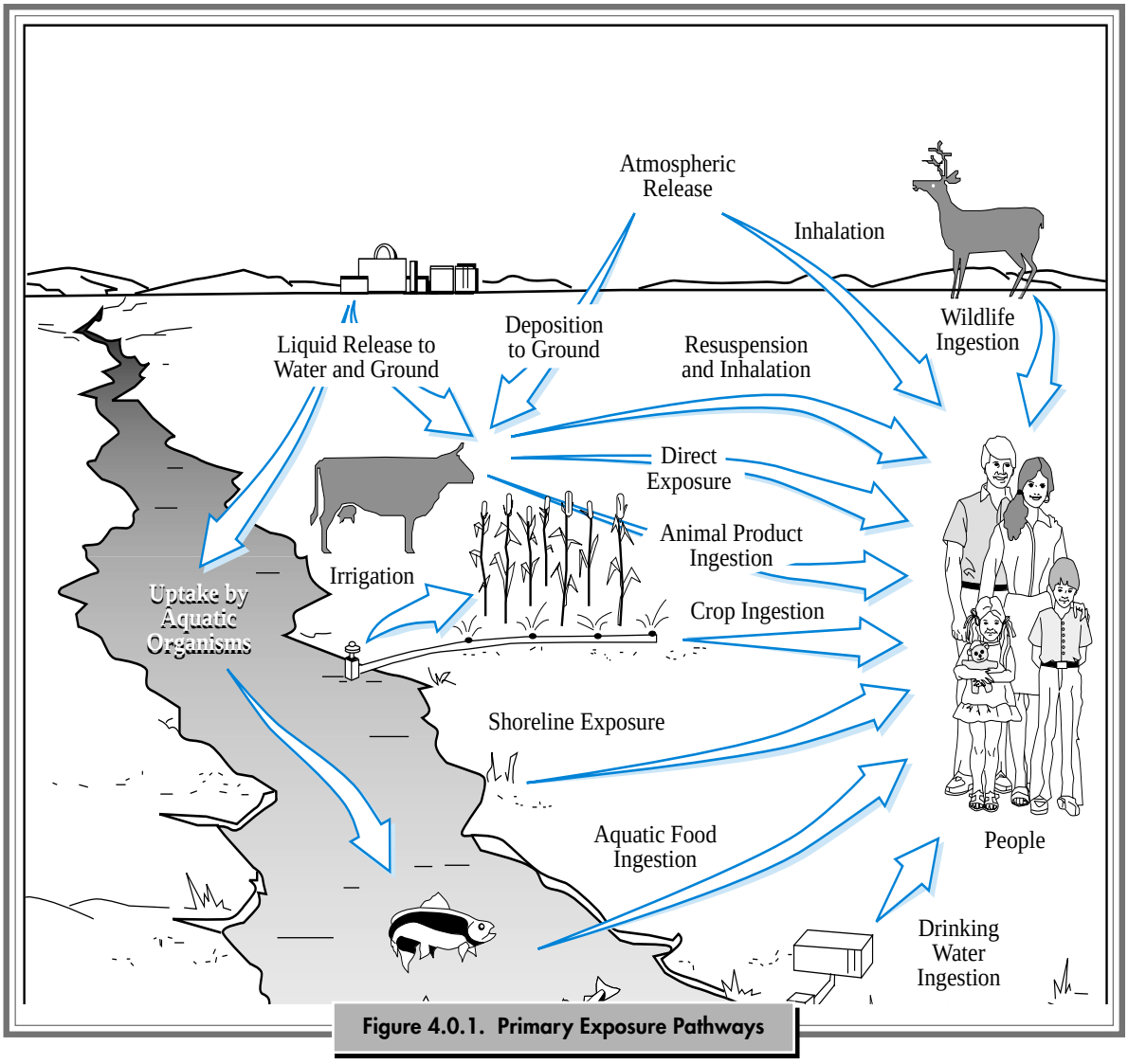


Figure 4.0.1. Primary Exposure Pathways

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 (see Figure 1.1). 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-kilometer (50-mile) 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 established to protect public health.

Table 4.0.1 summarizes the sample types and measurement locations in all three zones for 2000. A summary of the number and types of samples collected during 2000, and the number of analytical results obtained from those samples is provided in Table 4.0.2. Routine soil and vegetation samples were not collected in 2000 but are scheduled for collection in 2001. Except for special studies, soil and vegetation samples are collected every 3 to 5 years. Routine soil and vegetation were last collected in 1998 (PNNL-12088).

Background concentrations were measured at distant locations and compared with concentrations measured on the site 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 concentrations at these background locations to concentrations measured on or near the site indicated the impact, if any, of Hanford Site operations.

Table 4.0.1. Routine Environmental Surveillance Sample Types and Measurement Locations, 2000

		Sample Locations						
						Columbia River		
Type	Total Number	Onsite[a]	Site Perimeter[b]	Nearby[c]	Distant[c]	Upstream[c]	Hanford Reach[b]	Downstream[c]
Air	45	24	11	8[d]	2[e]			
Spring water	8	8					8	
Spring sediment	5						5	
Columbia River	7					2	4	1
Irrigation water	2		2					
Drinking water	4	4						
River sediment	6					1	3	2
Ponds	2	2						
Foodstuffs	8			6	2			
Wildlife	12	4	3		2	1	2	
External dose	76	29	37	8[d]	2[e]			
External shoreline radiation	14		14					
Exposure rate	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.

Table 4.0.2. Samples Collected for the Surface Environmental Surveillance Project and Analytical Results Obtained, 2000

Media	Number of Samples Collected	Number of Analytical Results Obtained
Air	1,562	4,239
Biota[a]	180	1,247
Soil[a] and sediment	73	981
Surface water	475	4,319
External radiation	293	293
Totals	2,583	11,079

(a) Some biota and soil samples were collected for special studies conducted following the wildfire in June 2000 (see Section 5.0).

To the extent possible, radiological dose assessments should be based on direct measurements of dose rates and radionuclide activities 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 sources from those associated with Hanford Site releases. Therefore, offsite doses in 2000 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 in Columbia River water 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-13109).

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 onsite and at the site perimeter. This section discusses sample collection techniques and analytes tested for at each air sampling location and summarizes the analytical results. A complete listing of all analytical results summarized in this section is reported separately (PNNL-13487, APP. 1). Detailed descriptions of all routine radiological sampling and analytical techniques are provided in the environmental monitoring plan (DOE/RL-91-50). Data from air samples collected during and after a wildfire on the Hanford Site in June 2000 are included in this sections annual data summaries. In addition, air sampling results related to the wildfire are discussed separately in Section 5.0.

4.1.1 Collection of Air Samples and Analytes Tested

Airborne radionuclide samples were collected at 45 continuously operating samplers: 24 on the Hanford Site, 11 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 8.4) that were managed and operated by local school teachers (under contract with Pacific Northwest National Laboratory) as part of an ongoing DOE-sponsored program to promote public awareness of Hanford Site environmental monitoring programs. 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 8.1). Continuous samplers located in Benton City, Kennewick, Mattawa, Othello, Pasco, and Richland provided data for the nearest population centers. Samplers in the distant communities of Toppenish and Yakima provided background data for communities essentially unaffected by Hanford Site operations.

Samples were collected according to a schedule established before the monitoring year (PNNL-13109). The air sampling locations and the analytes tested for at each location are given in Table 4.1.1. 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 72 hours. 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

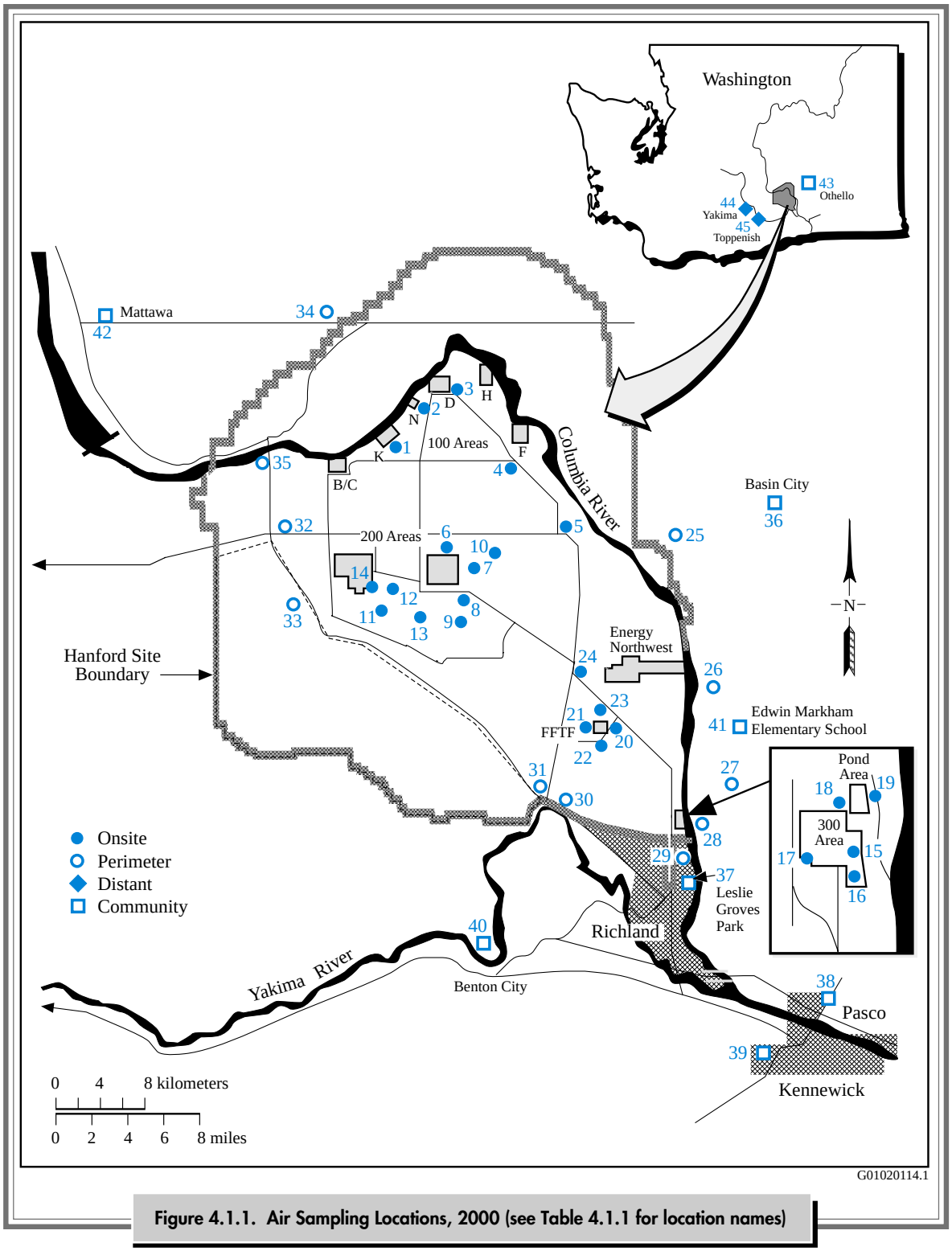


Figure 4.1.1. Air Sampling Locations, 2000 (see Table 4.1.1 for location names)

Table 4.1.1. Air Sampling Locations, Sample Composite Groups, and Analytes, 2000

Map Location[a]	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	100 F Met Tower	Alpha, Beta	Hanford Townsite	Gamma, Sr, Pu
5	Hanford Townsite	Alpha, Beta		
6	N of 200 E	Beta	N of 200 E	Gamma
7	E of 200 E	Alpha, Beta	200 E Area	Gamma, Sr, Pu, U
8	200 ESE	Alpha, Beta, ^{3}H, ^{129}I		
9	S of 200 E	Alpha, Beta		
10	B Pond	Alpha, Beta	B Pond	Gamma, Sr, Pu, U
11	Army Loop Camp	Alpha, Beta	200 W South East	Gamma, Sr, Pu, U
12	200 Tel. Exchange	Alpha, Beta, ^{3}H		
13	SW of B/C Crib	Alpha, Beta		
14	200 W SE	Alpha, Beta	200 West	Gamma, Sr, Pu, U
15	300 Water Intake	Alpha, Beta, ^{3}H	300 Area	Gamma, Sr, Pu, U
16	300 South Gate	Alpha, Beta, ^{3}H		
17	300 South West	Alpha, Beta, ^{3}H		
18	300 Trench	Alpha, Beta, ^{3}H	300 NE	Gamma, Sr, Pu, U
19	300 NE	Alpha, Beta, ^{3}H		
20	400 E	Alpha, Beta, ^{3}H	400 Area	Gamma, Sr, Pu
21	400 W	Alpha, Beta		
22	400 S	Alpha, Beta		
23	400 N	Alpha, Beta		
24	Wye Barricade	Alpha, Beta	Wye Barricade	Gamma, Sr, Pu, U
Perimeter				
25	Ringold Met Tower	Alpha, Beta, ^{3}H, ^{129}I	Ringold Met Tower	Gamma, Sr, Pu
26	W End of Fir Road	Alpha, Beta	W End of Fir Road	Gamma, Sr, Pu, U
27	Dogwood Met Tower	Alpha, Beta, ^{3}H	Dogwood Met Tower	Gamma, Sr, Pu, U
28	Byers Landing	Alpha, Beta, ^{3}H, ^{129}I	Byers Landing	Gamma, Sr, Pu, U
29	Battelle Complex	Beta	Battelle Complex	Gamma
30	Horn Rapids Substation	Alpha, Beta	Prosser Barricade	Gamma, Sr, Pu, U
31	Prosser Barricade	^{3}H		
32	Yakima Barricade	Alpha, Beta	Yakima Barricade	Gamma, Sr, Pu
33	Rattlesnake Springs	Alpha, Beta		
34	Wahluke Slope	Alpha, Beta, ^{3}H	Wahluke Slope	Gamma, Sr, Pu
35	S End Vernita Bridge	Alpha, Beta		

Table 4.1.1. (contd)

Map Location[a]	Sampling Location	Analytes[b]	Composite Group	Analytes[c]
Nearby Communities				
36	Basin City School[d]	Alpha, Beta, ^{3}H	Basin City School	Gamma, Sr, Pu, U
37	Leslie Groves-Rchlnd[d]	Alpha, Beta, ^{3}H	Leslie Groves-Rchlnd	Gamma, Sr, Pu, U
38	Pasco[d]	Beta	Tri-Cities	Gamma, Sr, Pu
39	Kennewick[d]	Alpha, Beta		
40	Benton City[d]	Beta	Benton City	Gamma
41	Edwin Markham School[d]	Alpha, Beta, ^{3}H	Edwin Markham School	Gamma, Sr, Pu, U
42	Mattawa[d]	Beta	Mattawa	Gamma
43	Othello[d]	Beta	Othello	Gamma
Distant Communities				
44	Yakima	Alpha, Beta, ^{3}H, ^{129}I	Yakima	Gamma, Sr, Pu, U
45	Toppenish[d]	Alpha, Beta, ^{3}H	Toppenish	Gamma, Sr, Pu, U

(a) See Figure 4.1.1.
(b) Alpha (gross) and beta (gross) samples are collected and analyzed every 2 weeks, ^{3}H samples are collected and analyzed every 4 weeks, and ^{129}I samples are collected every 4 weeks, combined into a quarterly composite sample and analyzed for each location.
(c) Gamma spectroscopy, strontium-90, isotopic plutonium (^{238}Pu, $^{239/240}Pu$), and isotopic uranium (^{234}U, ^{235}U, ^{238}U) analyses are performed on quarterly composite samples.
(d) A community-operated environmental surveillance station.

period was too small to be readily measured. The sensitivity and accuracy of sample results were increased by combining biweekly samples for nearby locations (or, in some cases, a single location) into quarterly composite samples. The quarterly composite samples were analyzed for specific gamma-emitting radionuclides (see Appendix F), strontium-90, and plutonium isotopes, with selected composites also analyzed for uranium isotopes.

Samples were collected for iodine-129 analysis at four 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 20 locations by continuously passing air through cartridges containing silica gel, which were exchanged every 4 weeks. The collection efficiency of the silica gel adsorbent is discussed in Patton et al. (1997). The collected water was distilled from the silica gel and analyzed for its tritium content.

The samples collected at the community-operated environmental surveillance stations 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 minimum detectable level or above the 2-sigma total propagated analytical uncertainty. A gamma-emitting radionuclide is detectable if the radionuclide library of the software determines an isotope concentration above the minimum detectable concentration of a sample. The nominal detection limit is defined as the average 2-sigma total propagated analytical uncertainty of the population of reported values.

For calendar year 2000, the average gross alpha radioactivity concentrations at the site perimeter were comparable to the levels measured at distant stations (see Table 4.1.2), indicating that the observed levels were predominantly a result of natural sources and worldwide radioactive fallout. The 2000 gross alpha average concentration values were similar to values reported for 1995 through 1999 (see Figure 4.1.2). The highest onsite gross alpha concentration was at the 100 D Area sampling location (3 on Figure 4.1.1).

Gross beta concentrations in air for 2000 (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 concentration value at the distant location; however, the difference was not statistically significant (log transformed, two-tailed t-test, 5% significance level). The 2000 average values were similar to the average values reported for 1995 through 1999 (see Table 4.1.2).

Tritium concentrations measured in 2000 (excluding 300 Area samples) were similar to values reported for 1995 through 1999 (see Table 4.1.2 and Figure 4.1.4). For 2000, ~73% of the samples analyzed for tritium had results reported above the detection limit (the method is capable of detecting concentrations of no less than 3 pCi/m^3). Sample results above the detection limit were consistently determined for the 300 Area samples. Tritium releases in the 300 Area are associated with research and development activities (see Table 3.1.1). These research and development activities are expected to continue for the next year; therefore, elevated tritium concentrations are expected for the 300 Area samples in 2001 as well. Figure 4.1.4 shows the slightly elevated 300 Area average tritium concentration with respect to other onsite average tritium concentrations, as well as perimeter and distant locations.

The annual average tritium concentration measured at the site perimeter (2.2 ± 0.7 pCi/m^3) appeared to be slightly higher than the annual average value at the distant locations (1.4 ± 0.56 pCi/m^3); however, the difference was not statistically significant (log transformed, two-tailed t-test, 5% significance level). The annual average tritium concentration measured at the site perimeter in 2000 was less than 0.002% of the 100,000-pCi/m^3 DOE derived concentration guide (DOE Order 5400.5).

For samples analyzed for strontium-90 in 2000 (Figure 4.1.5), 13 of the 92 samples were above the detection limit (see Table 4.1.2). The perimeter average is similar to the distant concentrations. The highest level (330 ± 130 aCi/m^3) was determined for the 200 West composite sample (location 14 on Figure 4.1.1), which is 0.004% of the 9 million-aCi/m^3 derived concentration guide. For comparison purposes, there are 1 million attocuries (aCi) in 1 picocurie (pCi).

Iodine-129 analyses were performed on samples collected downwind of the Plutonium-Uranium

Table 4.1.2. Airborne Radionuclide Concentrations in the Hanford Environs, 2000 Compared to Previous Years

		2000				1995-1999				
Radionuclide	Location Group[a]	No. of Samples	No. of Detections[b]	Maximum[c]	Average[d]	No. of Samples	No. of Detections[b]	Maximum[c]	Average[d]	Derived Concentration Guide[e]
				pCi/m^3	pCi/m^3			pCi/m^3	pCi/m^3	pCi/m^3
Tritium	300 Area	75	69	23 ± 2.1	3.8 ± 1.0	265	149	25 ± 3.0	2.4 ± 0.35	100,000
	Onsite	63	47	7.4 ± 1.4	2.0 ± 0.35	317	134	24 ± 20	1.4 ± 0.22	
	Perimeter	64	38	12 ± 1.5	2.2 ± 0.70	315	101	24 ± 2.3	1.3 ± 0.25	
	Nearby communities	36	27	15 ± 1.3	3.2 ± 1.2	191	64	16 ± 15	1.6 ± 0.37	
	Distant communities	25	10	6.1 ± 1.0	1.4 ± 0.56	141	30	7.9 ± 1.1	0.89 ± 0.21	
Gross beta	Onsite	617	611	0.084 ± 0.014	0.016 ± 0.00092	2,617	2,615	0.070 ± 0.0073	0.016 ± 0.00035	No standard
	Perimeter	261	261	0.070 ± 0.011	0.015 ± 0.0012	1,069	1,067	0.098 ± 0.010	0.016 ± 0.00057	
	Nearby communities	210	209	0.053 ± 0.0088	0.016 ± 0.0013	1,038	1,038	0.062 ± 0.0062	0.016 ± 0.00051	
	Distant communities	59	59	0.059 ± 0.010	0.017 ± 0.0027	294	293	0.061 ± 0.0064	0.014 ± 0.0010	
				aCi/m^3[f]	aCi/m^3[f]			aCi/m^3[f]	aCi/m^3[f]	aCi/m^3[f]
Gross alpha	Onsite	591	469	3,500 ± 1,500	750 ± 41	2,391	1,775	5,500 ± 1,300	580 ± 16	No standard
	Perimeter	261	211	2,500 ± 900	710 ± 51	952	764	2,600 ± 1,200	600 ± 23	
	Nearby communities	115	91	2,600 ± 990	870 ± 100	537	418	2,000 ± 760	580 ± 28	
	Distant communities[g]	58	43	2,500 ± 1,200	800 ± 140	294	204	2,300 ± 100	480 ± 44	
Strontium-90	Onsite	40	8	330 ± 130	27 ± 19	83	32	300 ± 96	38 ± 14	9,000,000
	Perimeter	28	2	66 ± 27	5.9 ± 10	56	14	390 ± 79	25 ± 15	
	Nearby communities	16	3	140 ± 83	29 ± 25	32	6	210 ± 190	24 ± 18	
	Distant communities	8	0	63 ± 67	5.5 ± 33	17	2	79 ± 37	10 ± 18	
Iodine-129	Onsite	4	4	26 ± 2.4	20 ± 4.0	20	20	50 ± 12	29 ± 5.0	70,000,000
	Perimeter	8	8	1.2 ± 0.14	0.60 ± 0.32	40	40	2.3 ± 0.28	0.88 ± 0.16	
	Distant communities	4	4	0.22 ± 0.015	0.091 ± 0.088	20	20	0.088 ± 0.056	0.047 ± 0.010	
Plutonium-238	Onsite	40	0	0.89 ± 2.7	-0.17 ± 0.13	83	5	2.9 ± 5.8	-0.021 ± 0.12	30,000
	Perimeter	28	0	0.94 ± 1.4	-0.19 ± 0.15	56	1	1.9 ± 1.4	-0.013 ± 0.10	
	Nearby communities	16	0	1.5 ± 1.8	-0.19 ± 0.33	32	1	0.76 ± 1.3	-0.044 ± 0.15	
	Distant communities	8	0	0.31 ± 1.8	-0.43 ± 0.30	17	0	0.17 ± 1.2	-0.17 ± 0.12	
Plutonium-239/240	Onsite	40	14	6.4 ± 3.7	0.86 ± 0.49	83	35	12 ± 2.5	1.1 ± 0.46	20,000
	Perimeter	28	3	4.3 ± 2.0	0.48 ± 0.38	56	14	4.1 ± 3.3	0.49 ± 0.19	
	Nearby communities	16	1	1.7 ± 2.3	0.44 ± 0.30	32	7	1.3 ± 1.6	0.35 ± 0.15	
	Distant communities	8	0	0.64 ± 1.6	-0.11 ± 0.51	17	3	3.2 ± 2.9	0.54 ± 0.44	

Table 4.1.2. (contd)

Radionuclide	Location Group[a]	2000 No. of Samples	2000 No. of Detections[b]	2000 Maximum[c] aCi/m³[f]	2000 Average[d] aCi/m³[f]	1995-1999 No. of Samples	1995-1999 No. of Detections[b]	1995-1999 Maximum[c] aCi/m³[f]	1995-1999 Average[d] aCi/m³[f]	Derived Concentration Guide[e] aCi/m³[f]
Uranium-234	Onsite	32	31	74 ± 18	16 ± 5.1	69	65	85 ± 21	24 ± 4.2	90,000
	Perimeter	16	16	140 ± 32	27 ± 16	32	32	66 ± 21	31 ± 5.1	
	Nearby communities	12	11	50 ± 18	20 ± 9.4	24	24	54 ± 17	28 ± 4.2	
	Distant communities	8	8	28 ± 19	15 ± 6.2	17	16	41 ± 15	20 ± 3.7	
Uranium-235	Onsite	32	3	2.6 ± 3.4	0.13 ± 0.38	69	13	3.7 ± 2.7	0.71 ± 0.26	100,000
	Perimeter	16	1	4.3 ± 4.7	0.69 ± 0.71	32	10	6.0 ± 6.0	1.6 ± 0.55	
	Nearby communities	12	0	2.2 ± 4.5	0.14 ± 0.78	24	7	6.2 ± 5.6	0.92 ± 0.63	
	Distant communities	8	0	7.0 ± 9.3	0.50 ± 1.9	17	0	6.2 ± 6.3	0.40 ± 0.79	
Uranium-238	Onsite	32	27	80 ± 20	14 ± 5.4	69	67	92 ± 27	22 ± 4.0	100,000
	Perimeter	16	15	140 ± 32	26 ± 17	32	32	59 ± 20	28 ± 4.7	
	Nearby communities	12	12	36 ± 15	18 ± 7.5	24	23	56 ± 18	25 ± 4.6	
	Distant communities	8	8	28 ± 10	13 ± 6.3	17	17	33 ± 15	19 ± 3.0	
Cobalt-60	Onsite	55	0	3,800 ± 2,500	89 ± 177	218	10	880 ± 490	62 ± 35	80,000,000
	Perimeter	40	0	520 ± 4,900	-124 ± 186	148	7	1,000 ± 530	43 ± 55	
	Nearby communities	33	0	1,800 ± 3,600	-97 ± 244	106	2	1,000 ± 960	28 ± 62	
	Distant communities	9	0	410 ± 950	48 ± 128	46	2	680 ± 440	140 ± 77	
Cesium-137	Onsite	55	0	540 ± 870	-29 ± 140	218	7	710 ± 530	18 ± 38	400,000,000
	Perimeter	40	0	1,200 ± 2,000	76 ± 140	148	2	670 ± 620	-17 ± 43	
	Nearby communities	33	0	2,100 ± 3,100	130 ± 180	106	2	860 ± 580	22 ± 48	
	Distant communities	9	0	370 ± 440	-43 ± 190	46	1	390 ± 290	18 ± 72	

(a) Location groups are identified in Table 4.1.1.
(b) Detection is defined as a value reported above the minimum detectable activity or above the 2-sigma total propagated analytical uncertainty. A detection for gamma-emitting radionuclides, cobalt-60 and cesium-137, is defined as a value above the minimum detectable activity.
(c) Maximum single sample result ± total propagated analytical uncertainty at 2-sigma. Negative concentration values are explained in Appendix A.
(d) Average of all samples ±2 times the standard error of the mean.
(e) DOE derived concentration guide (see Appendix D, Table D.5).
(f) There are 1 million attocuries (aCi) in 1 picocurie (pCi).
(g) One result from the distant communities was excluded as anomalous (5,530 ± 1,900 aCi/m³ at Yakima).

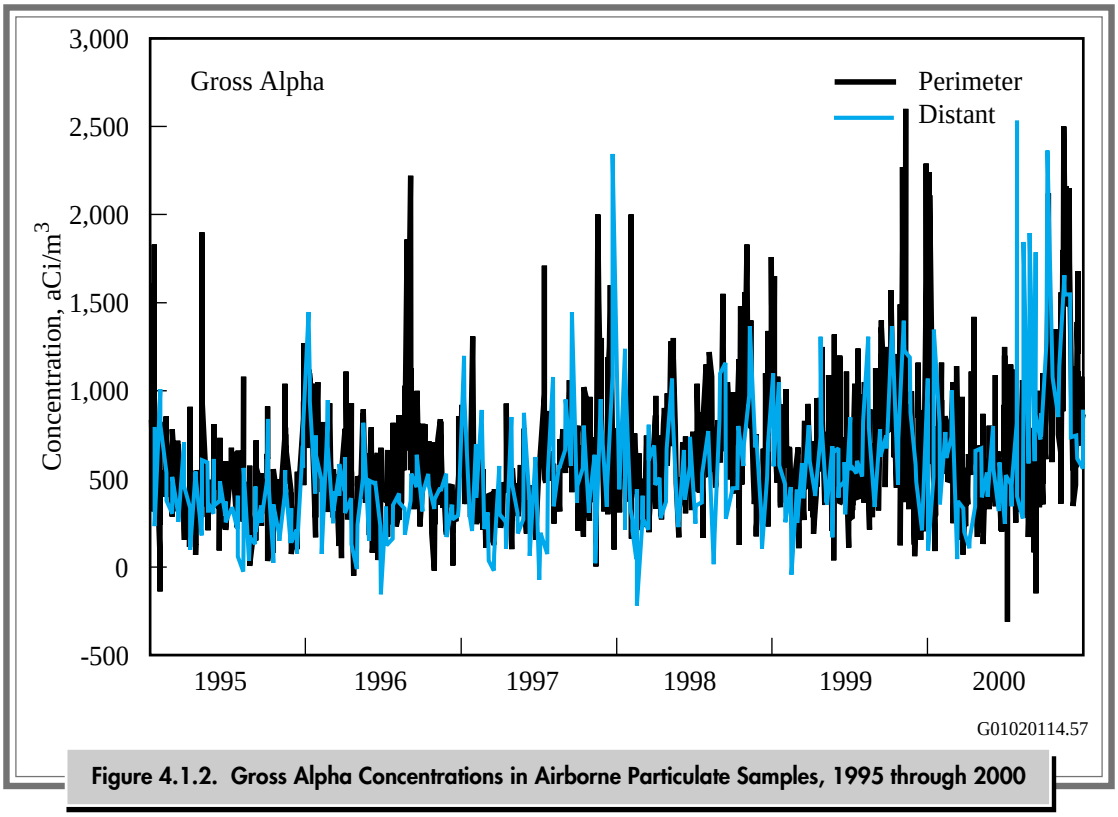


Figure 4.1.2. Gross Alpha Concentrations in Airborne Particulate Samples, 1995 through 2000

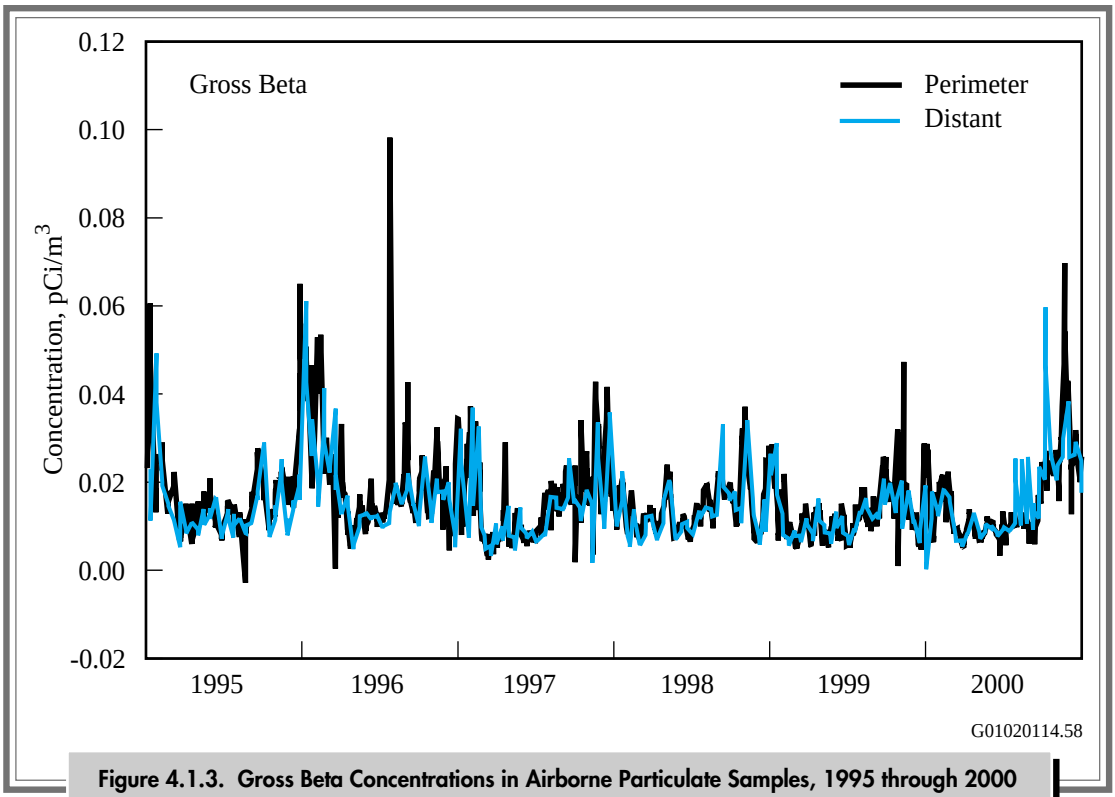


Figure 4.1.3. Gross Beta Concentrations in Airborne Particulate Samples, 1995 through 2000

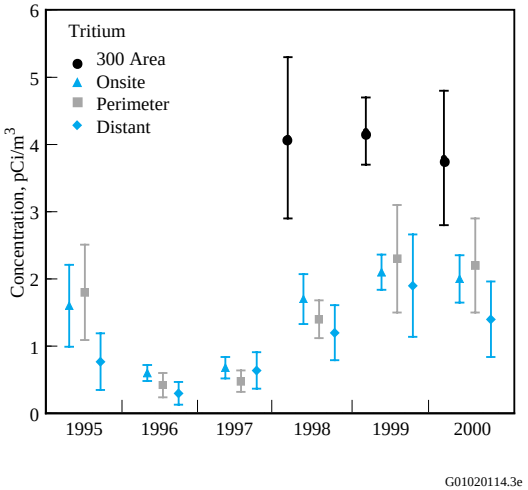


Figure 4.1.4. Annual Average Tritium Concentrations (±2 standard error of the mean) in Air, 1995 through 2000

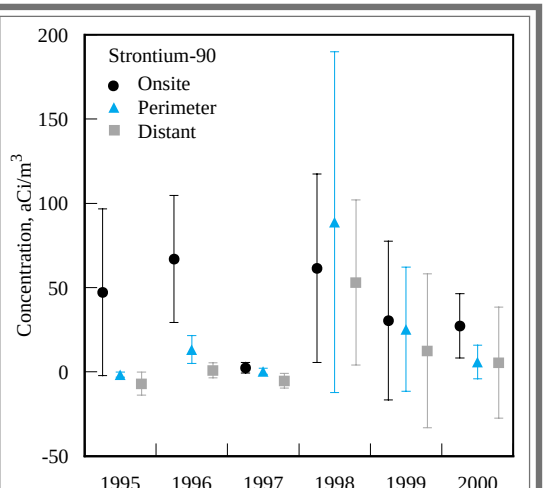


Figure 4.1.5. Annual Average Strontium-90 Concentrations (±2 standard error of the mean) in Air, 1995 through 2000 (1 pCi = 1,000,000 aCi)

Extraction Plant, at two downwind perimeter locations, and at a distant location (Yakima) in 2000 (see Figure 4.1.1). Onsite concentrations in 2000 were elevated compared to those measured at the site perimeter, and perimeter levels were higher than those measured at Yakima, the distant location (Figure 4.1.6 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 1995 through 2000 (see Figure 4.1.6). Onsite air concentrations of iodine-129 were influenced by minor emissions (0.0012 curie; 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 2000 (0.60 ± 0.32 aCi/m^3) was less than 0.000001% of the 70 million-aCi/m^3 derived concentration guide.

Plutonium-238 was not detected in any samples for 2000 (nominal detection limit of 0.87 aCi/m^3). The annual average air concentration of plutonium-238 for all samples was less than zero (i.e., not detected).

The average plutonium-239/240 concentrations detected in onsite and offsite air samples are given in Table 4.1.2 and Figure 4.1.7. The annual average air concentration of plutonium-239/240 at the site perimeter was 0.48 ± 0.38 aCi/m^3, which is less than 0.003% of the 20,000-aCi/m^3 derived concentration guide. The annual average air concentration appeared to be higher for the site perimeter locations than the distant locations; however, the difference was not statistically significant (log transformed, two-tailed t-test, 5% significance level). The maximum Hanford Site plutonium-239/240 air concentration (6.4 ± 3.7 aCi/m^3) was observed for the 200 West composite sample (location 14 on Figure 4.1.1). This represents less than 0.04% of the 20,000-aCi/m^3 derived concentration guide.

Average isotopic uranium concentrations (uranium-234, -235, and -238) in airborne particulate matter in 2000 were similar on the site, at the site perimeter, and at distant communities (see Table 4.1.2 and Figure 4.1.8). The 2000 annual average uranium-238 concentration for the site perimeter was 26 ± 17 aCi/m^3, which is 0.03% of the 100,000-aCi/m^3 derived concentration guide.

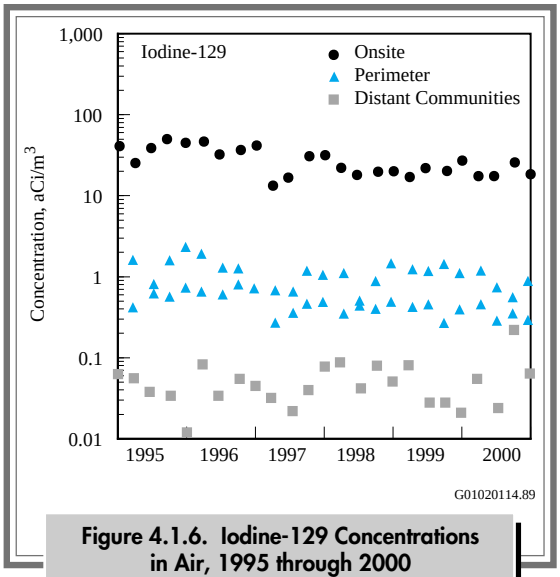


Figure 4.1.6. Iodine-129 Concentrations in Air, 1995 through 2000 (1 pCi = 1,000,000 aCi)

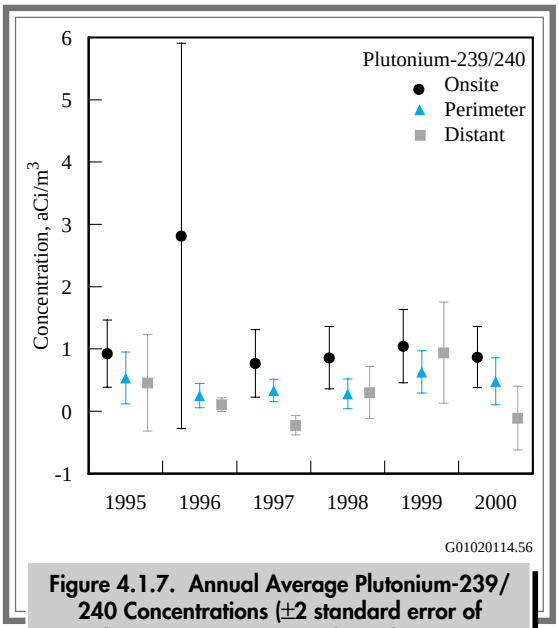


Figure 4.1.7. Annual Average Plutonium-239/240 Concentrations (±2 standard error of the mean) in Air, 1995 through 2000 (1 pCi = 1,000,000 aCi)

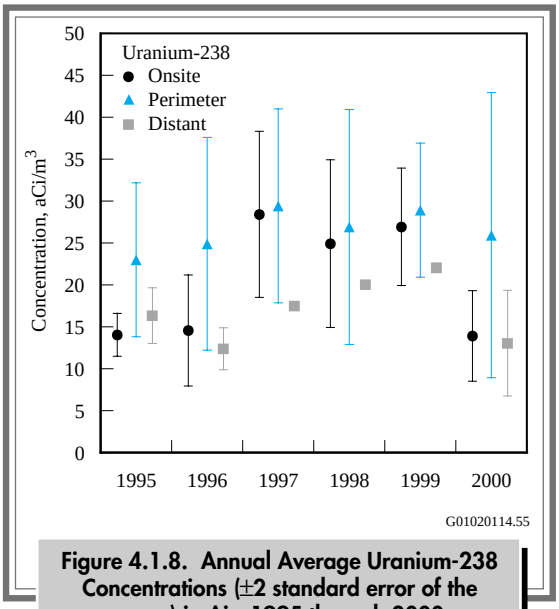


Figure 4.1.8. Annual Average Uranium-238 Concentrations (±2 standard error of the mean) in Air, 1995 through 2000 (1 pCi = 1,000,000 aCi)

Samples were analyzed quarterly 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 137 samples analyzed by gamma spectroscopy, none of the samples had concentrations above the minimum detectable level for the sample for that isotope. The cobalt-60 and cesium-137 results for 2000 samples are included in Table 4.1.2. Even the maximum estimated individual measurements for these radionuclides (3,770 ± 2,500 and 2,060 ± 3,100 aCi/m^3, respectively) were less than 0.004% of their derived concentration guides.

4.2 Surface Water and Sediment Surveillance

G. W. Patton

Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the potential impact to the public and to the aquatic environment from Hanford-originated radiological and chemical contaminants. Surface-water bodies included in routine surveillance were the Columbia River and associated riverbank springs, onsite ponds, and irrigation sources. Sediment surveillance was 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 2000. Sampling 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-13487, APP. 1.

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 also is used 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 and its tributaries drain an area of ~670,000 square kilometers (260,000 square miles) en route to the Pacific Ocean. The flow of the river is regulated by three dams in Canada and eleven dams in the United States, seven upstream and four downstream of the Hanford 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.

River flow through the Hanford Reach fluctuates significantly and is 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 (120,000 ft^3) per second (WA-94-1). In 2000, the Columbia River had normal flows; the average daily flow rate below Priest Rapids Dam was 3,400 m^3 (120,000 ft^3) per second. The peak monthly average flow rate occurred during May (4,640 m^3 [164,000 ft^3] per second) (Figure 4.2.2). The lowest monthly average flow rate occurred during October (2,190 m^3 [77,200 ft^3] per second). Daily flow rates varied from 1,210 to 6,600 m^3 (42,400 to 233,000 ft^3) per second during 2000. As a result of fluctuations in discharges, the depth of the river varies significantly over time. River stage (surface level) may change along the Hanford Reach by up to 3 meters (10 feet)

Table 4.2.1. Surface-Water Surveillance, 2000

Location	Sample Type	Frequency[a]	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland Pumphouse	Cumulative	M Comp[b] Q Comp[e]	Alpha, beta, lo ^{3}H,[c] ^{90}Sr, ^{99}Tc, U[d] ^{129}I
	Particulate (filter)	M Cont[f] Q Cont[g]	Gamma energy analysis Pu[h]
	Soluble (resin)	M Cont Q Cont	Gamma energy analysis 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 - Non-Radiological			
Vernita Bridge and Richland Pumphouse[i]	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[j] metals, anions
	Grab (transects)	A	Cyanide (CN^-), VOA[k]
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 energy analysis
Fast Flux Test Facility pond	Grab	Q	Alpha, beta, ^{3}H, gamma energy analysis
Offsite Irrigation Water			
Riverview irrigation canal	Grab	3/year	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma energy analysis
Horn Rapids	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma energy analysis
Riverbank Springs			
100-H Area	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U, gamma energy analysis, ICP metals, anions
100-F Area	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma energy analysis, ICP metals, anions, VOA
100-B Area	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, gamma energy analysis, ICP metals, anions, VOA
100-D, 100-K, and 100-N Areas	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, gamma energy analysis, ICP metals, anions, VOA (100-K Area only)
Old Hanford Townsite	Grab	A	Alpha, beta, ^{3}H, ^{129}I, ^{90}Sr, ^{99}Tc, U, gamma energy analysis, ICP metals, anions
300 Area	Grab	A	Alpha, beta, ^{3}H, ^{129}I, ^{90}Sr, gamma energy analysis, ICP metals, anions, VOA

(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, and -238.
(e) Collected weekly and composited for quarterly analysis.
(f) M Cont = River water was sampled for 2 wk by continuous flow through a filter and resin column and multiple samples were composited monthly for analysis.
(g) Q Cont = River water was sampled for 2 wk by continuous flow through a filter and resin column and multiple samples were composited quarterly for analysis.
(h) Pu = Isotopic plutonium-238 and -239/240.
(i) Numerous water quality analyses are performed by the U.S. Geological Survey in conjunction with the National Stream Quality Accounting Network (NASQAN) Program.
(j) ICP = Inductively coupled plasma analysis method.
(k) VOA = Volatile organic compounds.

Table 4.2.2. Sediment Surveillance, 2000

Location[a]	Frequency	Analyses
River		All river sediment analyses included gamma energy analysis, ^{90}Sr, U[b], Pu[c], ICP[d] metals, SEM/AVS[e]
Priest Rapids Dam: 2 locations near the dam	A[f]	
White Bluffs Slough	A	
100-F Slough	A	
Hanford Slough	A	
Richland	A	
McNary Dam: 2 locations near the dam	A	
Springs[g]		All springs sediment analyses included gamma energy analysis, ^{90}Sr, U, ICP metals
100-B Area	A	
100-K Area	A	
100-N Area	A	
100-F Area	A	
Old Hanford Townsite Springs	A	
300 Area	A	

(a) See Figure 4.2.1.
(b) U = Uranium-235 and -238 analyzed by low-energy photon analysis.
(c) Pu = Isotopic plutonium-238 and -239/240.
(d) ICP = Inductively coupled plasma analysis method.
(e) SEM/AVS = Simultaneously extracted metals and acid volatile sulfide.
(f) A = Annually.
(g) Sediment is collected when available.

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 ~300 to 1,000 meters (980 to 3,300 feet) through the Hanford Site.

Pollutants, both radiological and chemical, 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 operational discharges to the ground seep into the river (DOE/RL-92-12; PNL-5289; PNL-7500; WHC-SD-EN-TI-006). Effluents from each direct discharge point are monitored routinely and reported by the responsible operating contractor; these were summarized in Section 3.1. Direct discharges are identified and regulated for non-radiological 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 are summarized in Section 2.2.8.

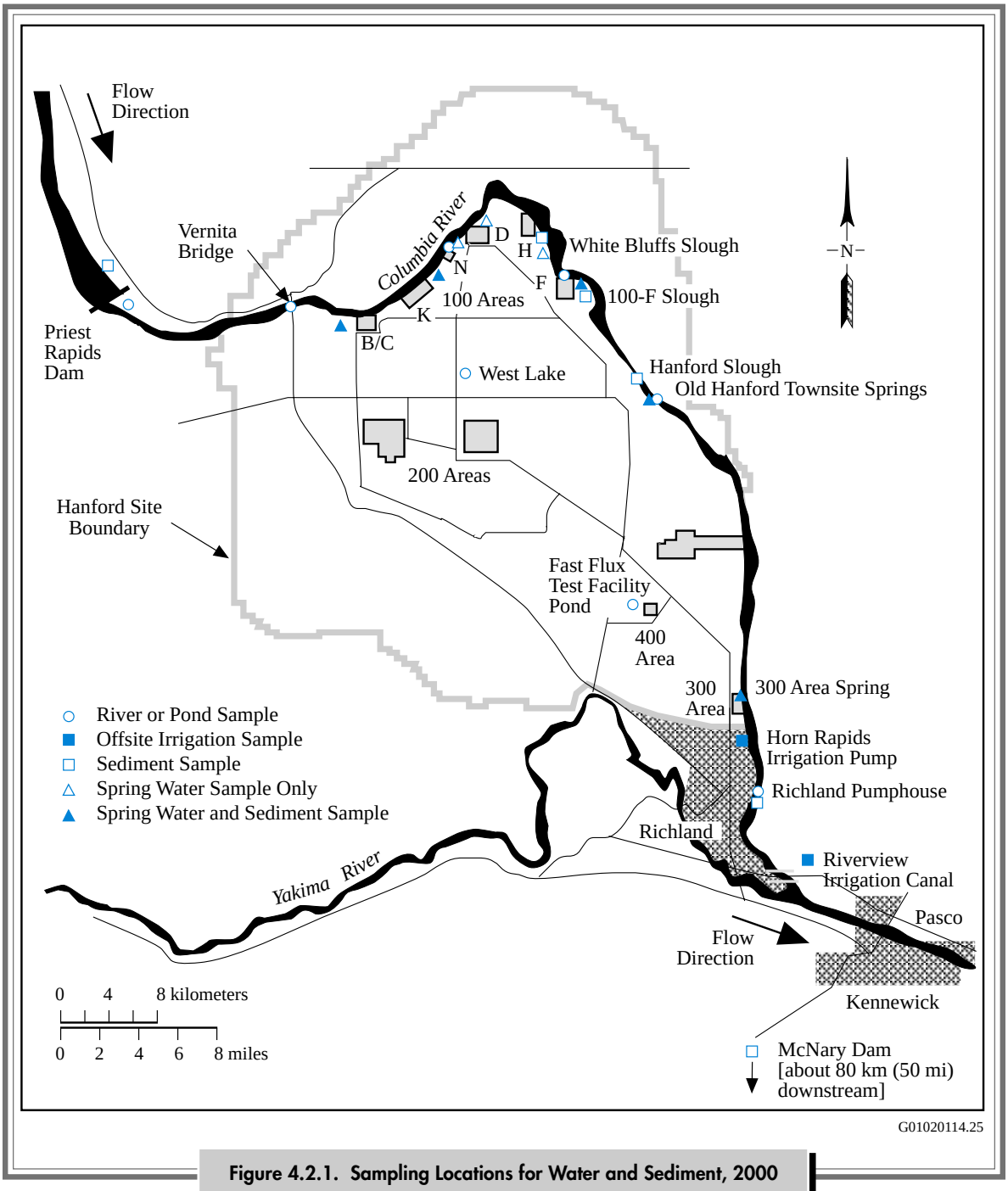


Figure 4.2.1. Sampling Locations for Water and Sediment, 2000

Washington State has classified the stretch of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, as Class A, Excellent (WAC 173-201A). Water quality criteria and water use guidelines have been established in conjunction with this designation and are provided in Appendix D (Table D.1).

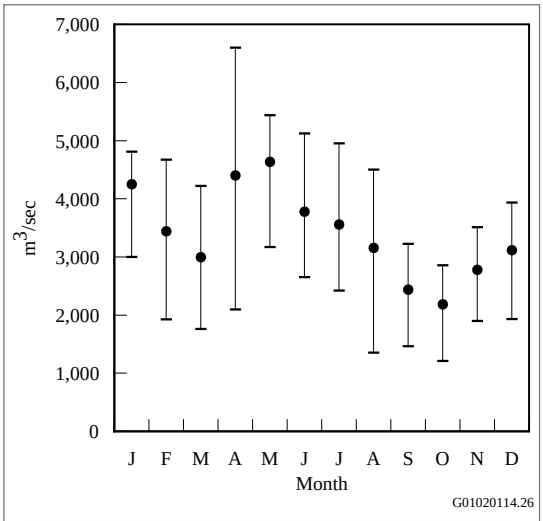


Figure 4.2.2. Mean, Maximum, and Minimum Monthly Columbia River Flow Rates, 2000

4.2.1.1 Collection of River-Water Samples and Analytes of Interest

Samples of Columbia River water were collected throughout 2000 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 and near-shore locations 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 obtained hourly and collected weekly. Weekly samples were 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.

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
- their importance in determining water quality, verifying effluent control and monitoring systems, and determining compliance with applicable standards.

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 a timely indication of change. Gamma energy analysis provides the ability to detect numerous specific radionuclides (see Appendix F). 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. Analytical detection levels for all radionuclides were less than 10% of their respective water quality criteria levels (see Appendix D, Tables D.1 and D.2).

Transect sampling (multiple samples collected along a line across the Columbia River) 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 when sampled at routine monitoring stations located downriver. Incomplete mixing results in a slightly conservative (high) bias in the data generated using the routine, single-point, sampling system at the Richland Pumphouse. In 1999, the transect sampling strategy was modified, with some of the mid-river sampling points shifted to near-shore locations in the vicinity of the transect. For example, at the 100-N Area instead of collecting ten evenly-spaced cross-river transect samples, only six cross-river samples were collected and the other four samples were obtained at near-shore locations. This sampling pattern allows the cross-river concentration profile to be determined and provides information over a larger portion of the Hanford shoreline where the highest contaminant concentrations would be expected. The Vernita Bridge and the Richland Pumphouse transects and near-shore locations were sampled quarterly during 2000. Annual transect and near-shore sampling was conducted at the 100-F Area, 100-N Area, Old Hanford Townsite, and 300 Area locations in the late summer when river flows were low.

Columbia River transect water samples collected in 2000 were analyzed for both radiological and chemical contaminants (see Table 4.2.1). Metals and anions (listed in DOE/RL-93-94) 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, except for metals analyses, which were performed on both filtered and unfiltered samples.

In addition to Columbia River monitoring conducted by Pacific Northwest National Laboratory in 2000, non-radiological water quality monitoring also was performed by the U.S. Geological Survey. U.S. Geological Survey samples were collected along Columbia River transects quarterly at the Vernita Bridge and the Richland Pumphouse (Appendix B, Table B.5). Sample analyses were performed at the U.S. Geological Survey laboratory in Denver, Colorado for numerous physical parameters and chemical constituents.

4.2.1.2 Radiological Results for 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 2000 are reported in PNNL-13487, APP. 1 and summarized in Appendix B (Tables B.1 and B.2). These tables also list the maximum and mean concentrations of selected radionuclides detected in Columbia River water in 2000 and during the previous 5 years. All radiological contaminant concentrations measured in Columbia River water in 2000 were less than DOE derived concentration guides (DOE Order 5400.5) and Washington State ambient surface-water quality criteria (WAC 173-201A and 40 CFR 141) levels (see Appendix D, Tables D.5, D.3, and D.2, respectively). Significant results are discussed and illustrated below, and comparisons to previous years are provided.

Radionuclide concentrations monitored in Columbia River water were extremely low throughout the year. The radionuclides consistently detected in river water during 2000 included tritium, strontium-90, iodine-129, uranium-234, -238, plutonium-239/240, and naturally occurring beryllium-7 and potassium-40. The concentrations of all other measured radionuclides were below detection limits in more than 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 2000 average gross alpha and gross beta concentrations were similar to those observed during recent years. Monthly measurements at the Richland Pumphouse in 2000 were not statistically higher than those measured at Priest Rapids Dam. Unless otherwise noted in this section, the statistical tests for differences are paired sample comparisons and two-tailed t-tests, 5% significance level. The average alpha and beta concentrations in Columbia River water at the Richland Pumphouse in 2000 were less than the ambient surface-water quality criteria levels of 15 and 50 pCi/L, respectively.

Figure 4.2.5 compares the annual average tritium concentrations at Priest Rapids Dam and Richland Pumphouse from 1995 through 2000. Statistical analysis indicated that monthly tritium concentrations in river water samples at the Richland Pumphouse were higher than concentrations in

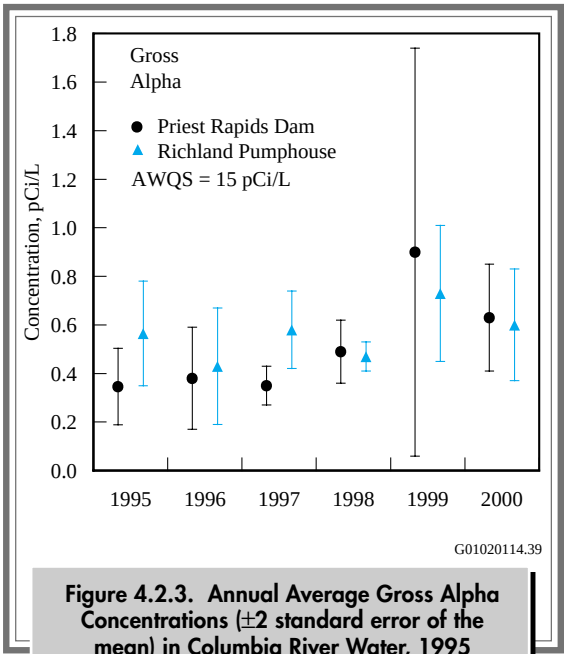


Figure 4.2.3. Annual Average Gross Alpha Concentrations (±2 standard error of the mean) in Columbia River Water, 1995 through 2000 (AWQS = ambient water quality standard)

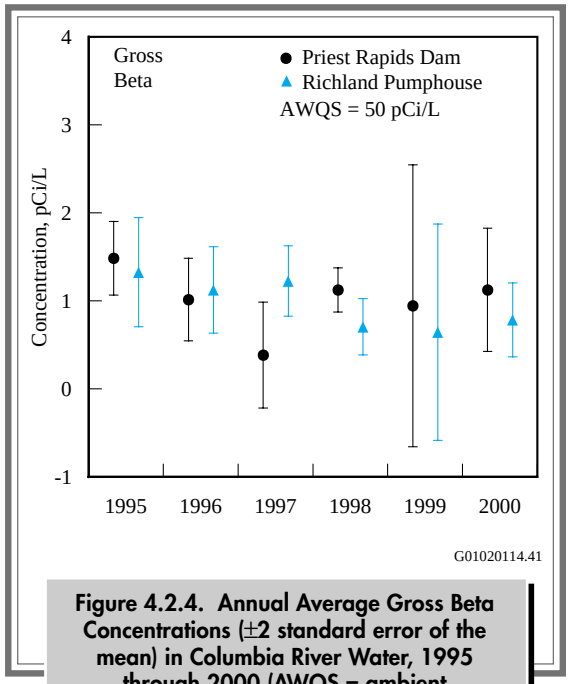


Figure 4.2.4. Annual Average Gross Beta Concentrations (±2 standard error of the mean) in Columbia River Water, 1995 through 2000 (AWQS = ambient water quality standard)

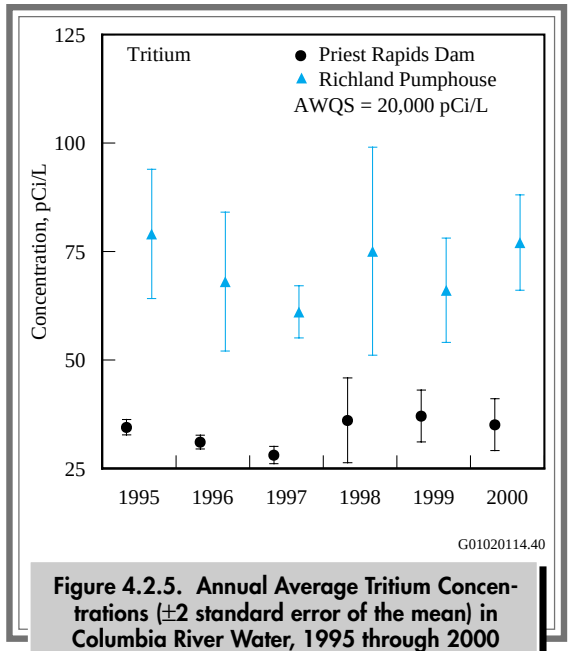


Figure 4.2.5. Annual Average Tritium Concentrations (±2 standard error of the mean) in Columbia River Water, 1995 through 2000 (AWQS = ambient water quality standard)

samples from Priest Rapids Dam. However, 2000 average tritium concentrations in Columbia River water collected at the Richland Pumphouse were only 0.4% of the ambient surface-water quality criteria level of 20,000 pCi/L. Onsite sources of tritium entering the river include groundwater seepage and direct discharge from permitted outfalls located in the 100 Areas (see Sections 3.1 and 7.1). 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 tritium concentrations across 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 cross-river transects at the pumphouse during 2000 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 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 1995 through 2000 are presented in Figure 4.2.6. Levels observed in 2000 were similar to those reported previously. Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Areas (see Section 7.1.6.1). Some of the highest strontium-90 levels that have been found in onsite groundwater 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 2000 were not statistically different.

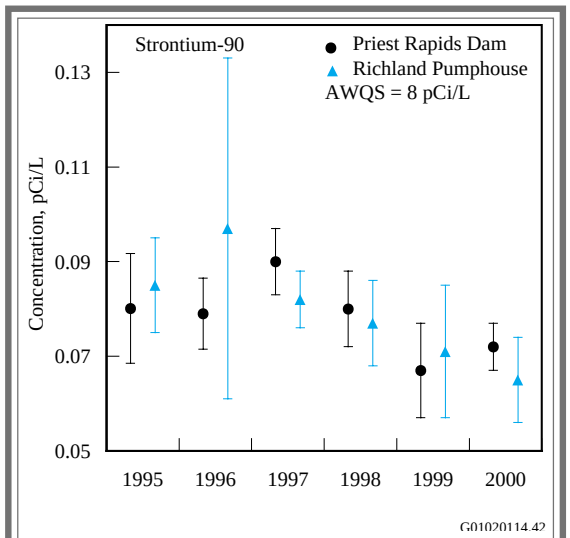


Figure 4.2.6. Annual Average Strontium-90 Concentrations (±2 standard error of the mean) in Columbia River Water, 1995 through 2000 (AWQS = ambient water quality standard)

Average strontium-90 concentrations in Columbia River water at the Richland Pumphouse were less than 0.8% of the 8-pCi/L ambient surface-water quality criteria level.

Annual average total uranium concentrations (i.e., the sum of uranium-234, -235, -238) at Priest Rapids Dam and Richland Pumphouse for 1995 through 2000 are shown in Figure 4.2.7. Total uranium concentrations observed in 2000 were similar to those observed during recent years. Monthly total uranium concentrations measured at the Richland Pumphouse in 2000 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 7.1) and has been detected at elevated levels in riverbank springs in this area (see Section 4.2.3). 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 no ambient

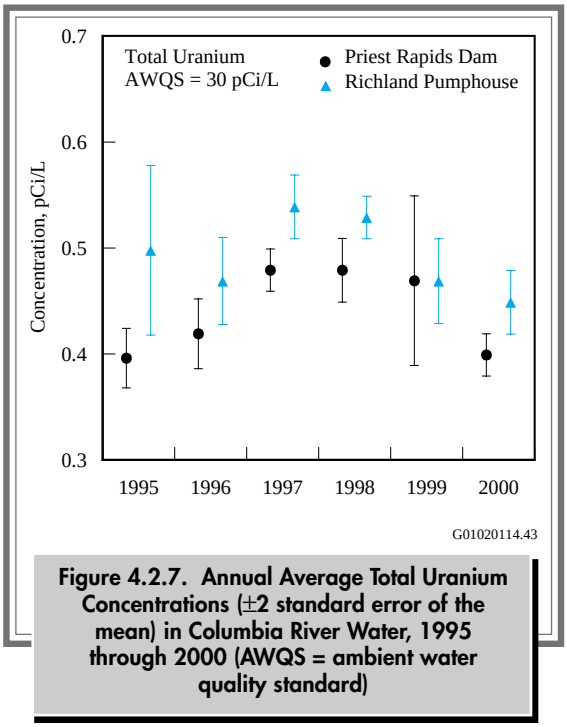


Figure 4.2.7. Annual Average Total Uranium Concentrations (±2 standard error of the mean) in Columbia River Water, 1995 through 2000 (AWQS = ambient water quality standard)

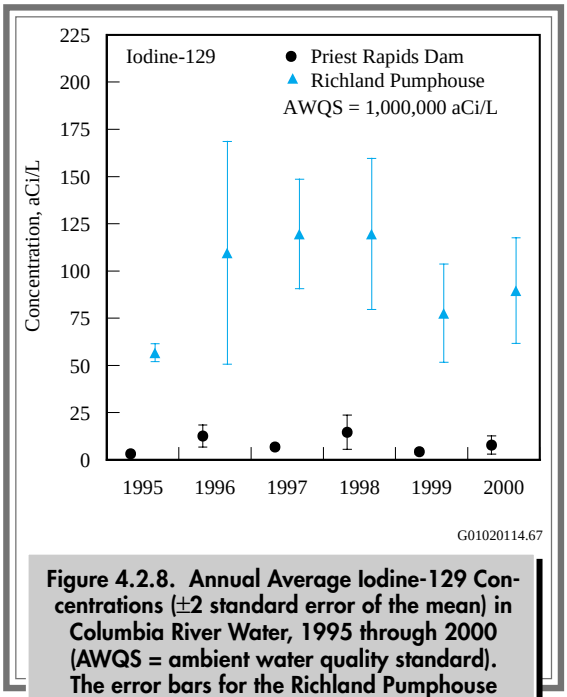


Figure 4.2.8. Annual Average Iodine-129 Concentrations (±2 standard error of the mean) in Columbia River Water, 1995 through 2000 (AWQS = ambient water quality standard). The error bars for the Richland Pumphouse 1995 result are ±2 propagated analytical uncertainty because only one sample was collected.

surface-water quality criteria levels directly applicable to uranium. However, total uranium levels in the river during 2000 were well below the U.S. Environmental Protection Agency (EPA) drinking water standard of 30 µg/L (~27 pCi/L, Appendix D, Table D.2).

The annual average iodine-129 concentrations at Priest Rapids Dam and Richland Pumphouse for 1995 through 2000 are presented in Figure 4.2.8. Only one quarterly iodine-129 result was available for the Richland Pumphouse during 1995 because of construction activities at the structure that interfered with sampling. The average iodine-129 concentration in Columbia River water at the Richland Pumphouse was extremely low during 2000 (0.012% of the ambient surface-water quality criteria level of 1 pCi/L [1 million aCi/L]) and similar to levels observed during recent years. The onsite source of iodine-129 to the Columbia River is the discharge of contaminated groundwater along the portion of shoreline downstream of the Old Hanford Townsite (see Section 7.1). 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.

Plutonium-239/240 concentrations were at or near the detection limits for filter (particulate) and resin (dissolved) components for all samples. Average plutonium-239/240 concentrations on filter samples at Priest Rapids Dam and Richland Pumphouse were 20 ± 6.7 and 14 ± 11 aCi/L, respectively. With the exception of one sample each at Priest Rapids Dam and the Richland Pumphouse, plutonium was only detected 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 (see Appendix D, Table D.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, 1.2 million aCi/L

would be the relevant guideline for plutonium-239/240. There were no statistical differences in plutonium-239/240 concentrations for filter samples at Priest Rapids Dam and Richland Pumphouse. Statistical tests for dissolved plutonium concentrations at Priest Rapids Dam and the Richland Pumphouse were not performed because the majority of the concentrations were below the detection limit.

River Transect and Near-Shore Sampling. Radiological results from samples collected along Columbia River transects and at near-shore locations near the Vernita Bridge, 100-F Area, 100-N Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse during 2000 are presented in Appendix B (Tables B.3 and B.4) and PNNL-13487, APP. 1. Sampling locations were documented using a global positioning system. Constituents 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 September 2000 are depicted in Figure 4.2.9. The results are displayed such that the observer's view is upstream from the Richland Pumphouse. Vernita Bridge is the most upstream transect. Stations 1 and 10 are located along the Benton County and Franklin/Grant Counties shorelines, respectively. The 100-N Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse transects have higher tritium concentrations at the Hanford shore compared to the opposite

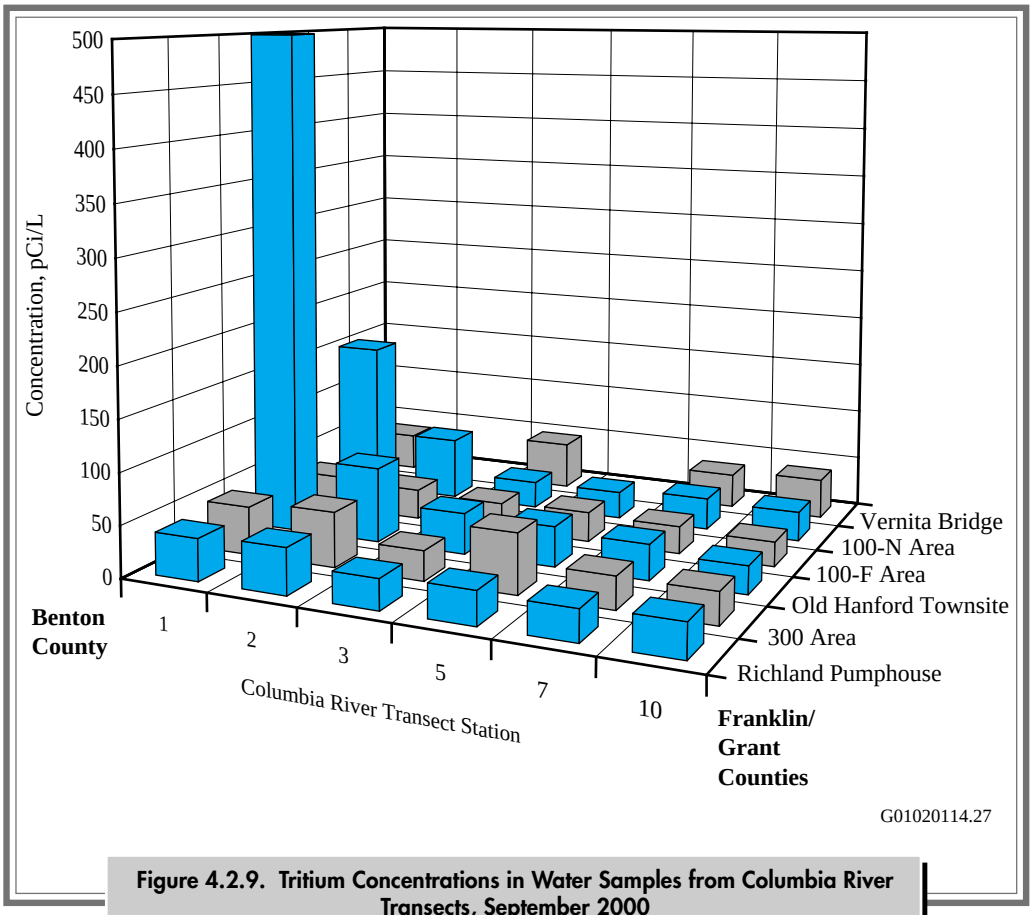


Figure 4.2.9. Tritium Concentrations in Water Samples from Columbia River Transects, September 2000

shore. 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 river flow. As noted since transect sampling was initiated in 1987, the mean tritium concentration 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. The highest tritium concentration observed in 2000 for cross river transect water samples was 500 ± 45 pCi/L (see Table B.3), which was detected along the shoreline of the Old Hanford Townsite. This is a location where groundwater containing tritium levels over 2,000 pCi/L is known to discharge to the river (see Section 7.1.6.1).

Tritium concentrations for near-shore water samples collected at the Hanford shoreline during September 2000 are shown in Figure 4.2.10. The near-shore sampling locations are identified according to Hanford River Markers, which are a series of signpost markers (~1.6 kilometers [1 mile] apart) that originate at Vernita Bridge (Hanford River Marker #0) and end just upriver from the Richland Pumphouse (Hanford River Marker #46). The concentrations of tritium in near-shore water samples

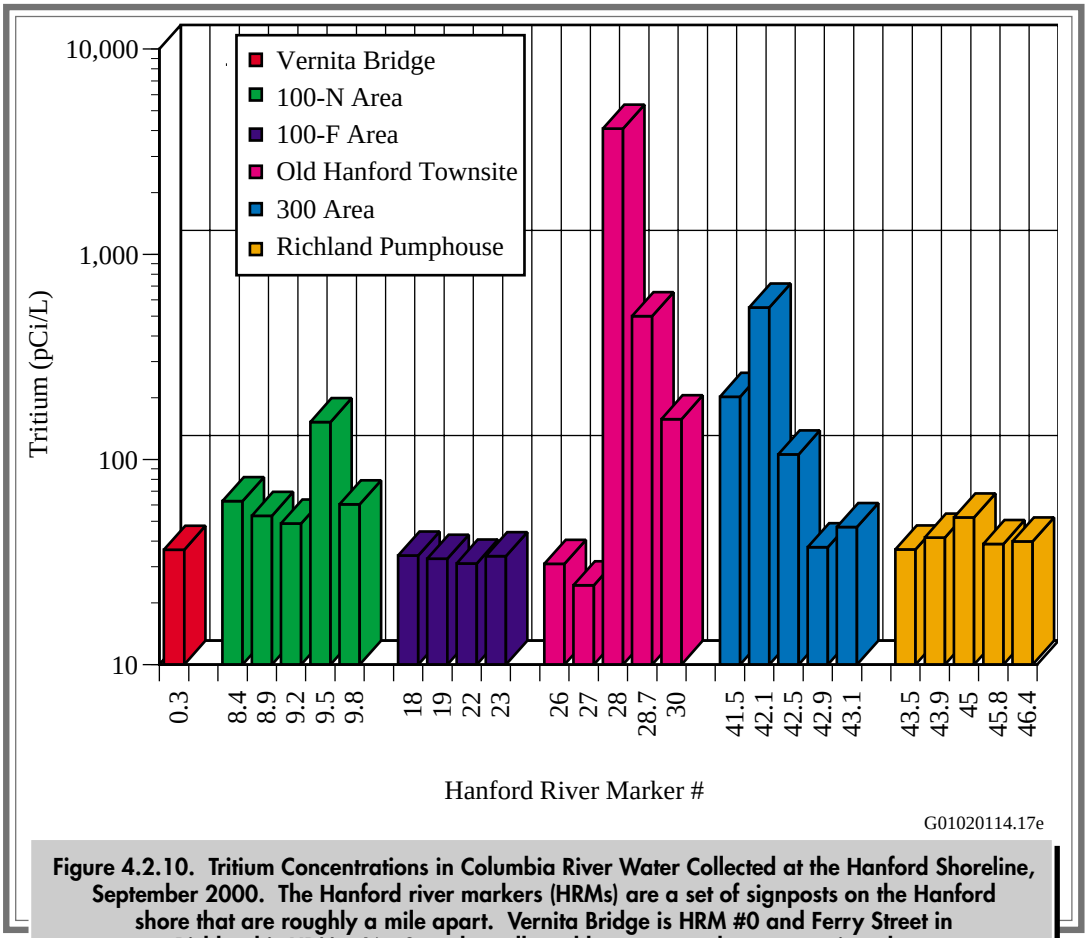


Figure 4.2.10. Tritium Concentrations in Columbia River Water Collected at the Hanford Shoreline, September 2000. The Hanford river markers (HRMs) are a set of signposts on the Hanford shore that are roughly a mile apart. Vernita Bridge is HRM #0 and Ferry Street in Richland is HRM #46. Samples collected between markers are assigned a decimal (e.g., halfway between HRM #12 and HRM #13 is HRM #12.5).

collected at the 100-N Area, Old Hanford Townsite, and 300 Area were elevated, compared to concentrations in samples collected near the Vernita Bridge. There was a wide range of tritium concentrations measured for the shoreline samples with the concentrations increasing near discharge points for the groundwater tritium plume (see Section 7.0, Figures 7.1.11, 7.1.12, and 7.1.19). The tritium concentrations in near-shore samples collected from the Richland shore were only slightly higher that those measured at Vernita Bridge. The highest tritium concentration observed in 2000 for near-shore water samples was 4,100 ± 310 pCi/L (see Appendix B, Table B.4), which was detected along the shoreline of the Old Hanford Townsite.

In 2000, strontium-90 concentrations in Hanford Reach river water for both transect and near-shore samples were similar to background concentrations for all locations, except for the 100-N Area. The 100-N Area had elevated strontium-90 concentrations in some samples obtained at near-shore locations and the near-shore location for the transect samples. The mean strontium-90 concentration found during transect sampling at the Richland Pumphouse was similar to that measured in monthly composite samples from the pumphouse; indicating that strontium-90 levels in water collected from the fixed-location monitoring station are representative of the average strontium-90 concentrations in the river at this location.

Total uranium concentrations in Hanford Reach water in 2000 were elevated along the Franklin County shoreline in both the 300 Area and Richland Pumphouse transects. The highest total uranium concentration was measured near the Franklin County shoreline of the Richland Pumphouse transect and likely resulted from groundwater seepage and water from irrigation return canals on the Franklin County 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.

4.2.1.3 Chemical and Physical Results for River-Water Samples

The U.S. Geological Survey and the Pacific Northwest National Laboratory compiled chemical and physical water quality data during 2000. 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 4.2.11 shows U.S. Geological Survey results for the Vernita Bridge and Richland Pumphouse for 1995 through 2000 (2000 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-13487, APP. 1 and is summarized in Appendix B (Table B.5). Final results are published annually by the U.S. Geological Survey (e.g., Zembrzuski et al. 1999). The 2000 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 2000, there was no indication of any deterioration of water quality resulting from site operations along the Hanford Reach of the Columbia River (see Appendix D, Table D.1).

River Transect and Near-Shore Samples. Results of chemical sampling conducted by Pacific Northwest National Laboratory along transect and near-shore locations of the Columbia River in 2000 at Vernita Bridge, 100-F Area, 100-N Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse are provided in PNNL-13487, APP. 1. The concentrations of metals and anions observed in river water in 2000 were similar to those observed in the past. Several metals and anions were detected in

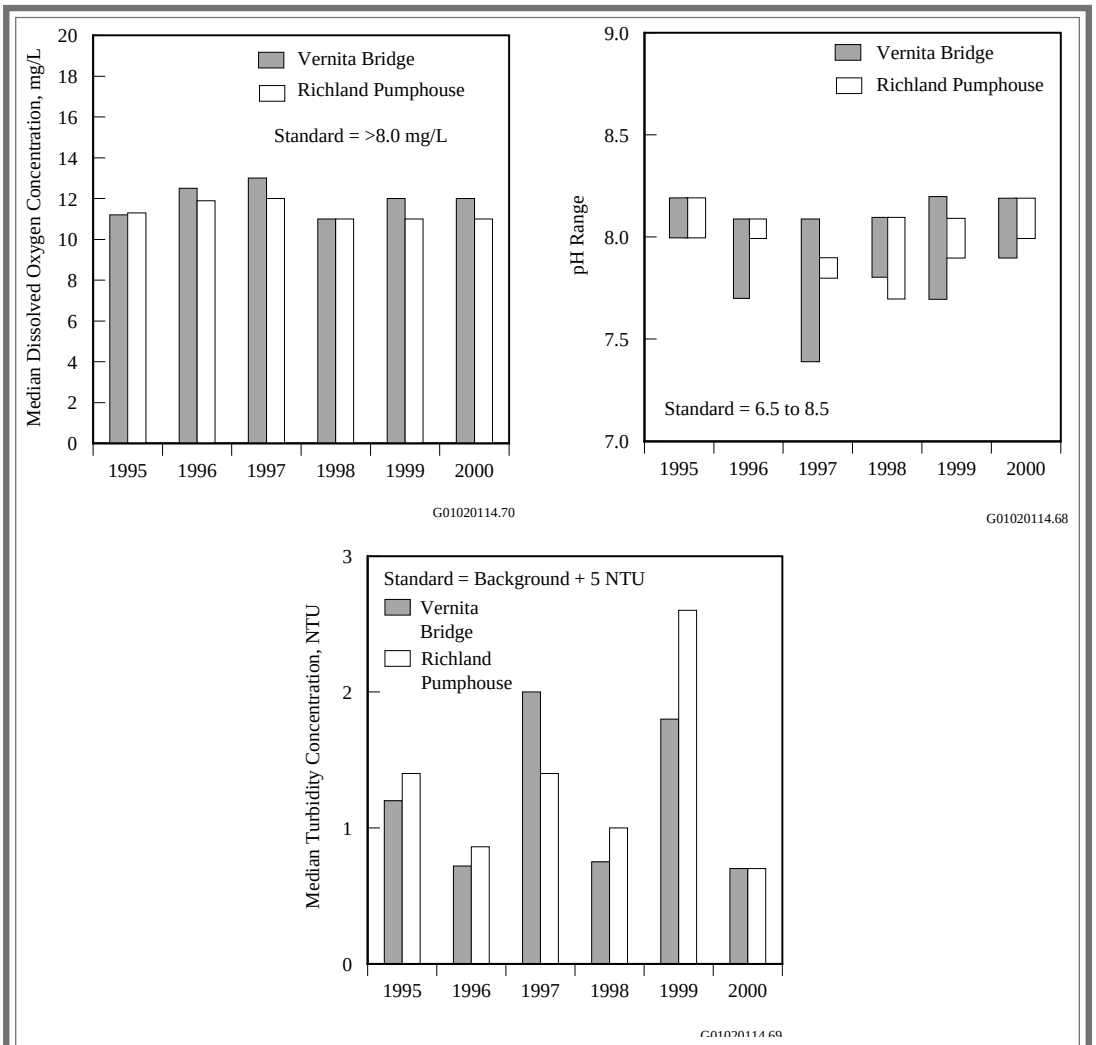


Figure 4.2.11. U.S. Geological Survey Columbia River Water Quality Measurements, 1995 through 2000 (2000 results are preliminary; NTU = nephelometric turbidity unit)

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 for water samples from the Benton County shoreline near the Richland Pumphouse were similar to mid-river samples. Nitrate, sulfate, and chloride concentrations were slightly elevated, compared to mid-river samples, along the Franklin County shoreline at the 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 in agricultural areas. Numerous wells in western Franklin County exceed the EPA maximum contaminant level for nitrate (40 CFR 141; USGS Circular 1144). Average nitrate, sulfate, and chloride results were slightly higher for average quarterly concentrations at the Richland Pumphouse transect compared to the Vernita Bridge transect. Nitrate, chloride, and sulfate concentrations were slightly elevated, compared to mid-river,

for both shorelines at the 300 Area. There were no apparent concentration gradients for anions measured in transect samples collected at Vernita Bridge, 100-N Area, 100-F Area, and Old Hanford Townsite.

Washington State ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; see Appendix D, Table D.3). Criteria for Columbia River water were calculated using a total hardness of 47 mg/L as 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 7 years. The total hardness reported by the U.S. Geological Survey at those locations from 1992 through 2000 ranged from 47 to 77 mg/L as calcium carbonate. All metal and anion concentrations in river water were less than the ambient surface-water quality criteria levels for the protection of aquatic life from both acute and chronic toxicity levels (see Appendix B, Table B.6 and Appendix D, Table D.3). Arsenic concentrations exceeded EPA standards; however, similar concentrations were found at Vernita Bridge and the Richland Pumphouse (see Appendix D, Table D.3).

4.2.2 Columbia River Sediment

Upon release to the Columbia River, radioactive and non-radioactive materials were dispersed rapidly, sorbed onto detritus and inorganic particles, incorporated into aquatic biota, deposited on the riverbed as sediment, or flushed out to sea. The concentrations of the radioactive material decreased as it underwent radioactive decay. 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 sediment (DOE/RL-91-50). Sediment in the Columbia River contains 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 sediment 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 by ingestion of aquatic organisms, 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).

Since the shutdown of the last single-pass reactor in the early 1970s, the contaminant burden in the surface sediment 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) and via contaminated groundwater seepage (see Section 4.2.3).

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). Physical and chemical 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 sediment containing higher total organic carbon and finer grain-size distributions.

4.2.2.1 Collection of Sediment Samples and Analytes of Interest

During 2000, samples of Columbia River surface sediment were collected at depths of 0 to 15 centimeters (0 to 6 inches) from six river locations that are permanently submerged and six riverbank springs that are periodically inundated (see Figure 4.2.1 and Table 4.2.2). Sediment sampling locations were documented using a global positioning system. 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, irrigation water returns, and factories in these drainages may also contribute to the contaminant load found in McNary Dam sediment; thus, sediment samples were taken at Ice Harbor Dam in 1998 and 1999 to assess Snake River inputs. 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 the publicly accessible Richland shoreline.

Monitoring sites at McNary and Priest Rapids Dams consisted of two stations spaced equidistant (approximately) on a transect line crossing the Columbia River; the samples were collected near the boat exclusion buoys at each dam. All other monitoring sites consisted of a single sampling location. Samples of permanently inundated river sediment were collected using a clam-shell style sediment dredge. Samples of periodically inundated river sediment, (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. All sediment samples were analyzed for gamma emitting radionuclides (see Appendix F), strontium-90, uranium-235, uranium-238, and metals (DOE/RL-91-50). Selected river sediment samples were also analyzed for plutonium-238, plutonium-239/240, metals, and simultaneously extracted metals/acid volatile sulfide (SEM/AVS) (PNNL-13417). The specific analytes selected for Columbia River sediment samples were 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 Samples from River Sediment

Results of the radiological analyses on river sediment samples collected during 2000 are reported in PNNL-13487, APP. 1 and summarized in Appendix B (Table B.7). Radionuclides consistently detected in river sediment adjacent and downstream of the Hanford Site during 2000 included potassium-40, cesium-137, uranium-238, plutonium-238, and plutonium-239/240. The concentrations of all other radionuclides were below detection limits for most samples. Cesium-137 and plutonium isotopes 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 levels between sediment sampling locations are made below. Because of variations in the bioavailability of contaminants in various sediment, no federal or state 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 2000 were similar to those reported for previous years (see Appendix B, Table B.7). Median, maximum, and minimum concentrations of selected radionuclides measured in Columbia (1995 through 2000) and Snake River sediment from 1995 through 2000 are presented in Figure 4.2.12. Sampling areas include stations at Priest Rapids, McNary, and Ice Harbor Dams as well as the Hanford Reach stations (White Bluffs, 100-F Area and Hanford Sloughs, and the Richland Pumphouse). Strontium-90 was the only radionuclide to exhibit consistently higher median concentrations at McNary Dam from 1995 through 2000; however, many of the recent values were below the detection limit. No other radionuclides measured in 2000 exhibited appreciable differences in concentrations between locations.

4.2.2.3 Radiological Results for Sediment Samples from Riverbank Springs

Sampling of sediment from riverbank springs was begun in 1993 at the Old Hanford Townsite and

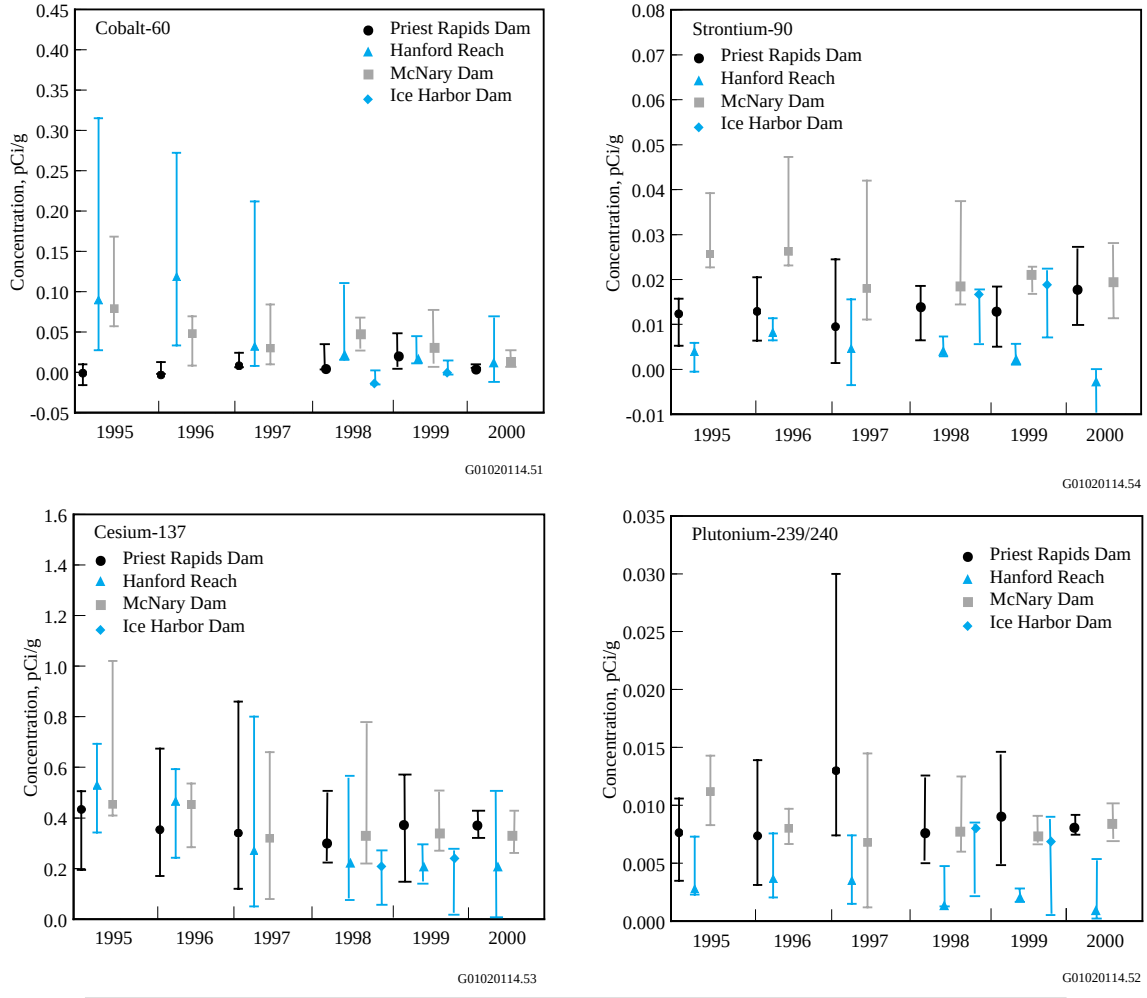


Figure 4.2.12. Median, Maximum, and Minimum Concentrations of Selected Radionuclides Measured in Columbia and Snake River Sediment, 1995 through 2000

300 Area. Sampling of the riverbank springs in the 100-B, 100-F, and 100-K Areas was initiated in 1995. Substrates at all other riverbank springs sampling locations consist of predominantly large cobble and are unsuitable for sample collection.

Radiological results for sediment collected from riverbank springs in 2000 are presented in PNNL-13487, APP. 1 and are summarized in Appendix B (Table B.7). Results were similar to those observed for previous years. In 2000, sediment samples were collected at riverbank springs in the 100-B Area, 100-F Area, Old Hanford Townsite, and 300 Area. There were no sediment available for sampling at the 100-K and 100-N Area locations. In 2000, radionuclide concentrations in riverbank spring sediment were similar to those observed in river sediment.

4.2.2.4 Chemical Results for Sediment Samples from the Columbia River and from Riverbank Springs

Metal concentrations (total metals, reported on a dry weight basis) observed in Columbia River sediment in 2000 are reported in PNNL-13487, APP. 1 and are summarized in Appendix B (Table B.8). Detectable amounts of most metals were found in all river sediment samples (Figure 4.2.13). Maximum and median concentrations of most metals were higher for sediment collected at Priest Rapids Dam compared to either Hanford Reach or McNary Dam sediment. The concentrations of cadmium, chromium, lead, nickel, thallium, and zinc had the largest differences between locations. In general, the metals concentrations in Hanford Reach sediment were more similar to McNary Dam sediment than Priest Rapids Dam sediment. Metal concentrations in riverbank spring sediment samples in 2000 were similar to concentrations in Hanford Reach sediment samples. Currently, there are no Washington State freshwater sediment quality criteria for comparison to the measured values.

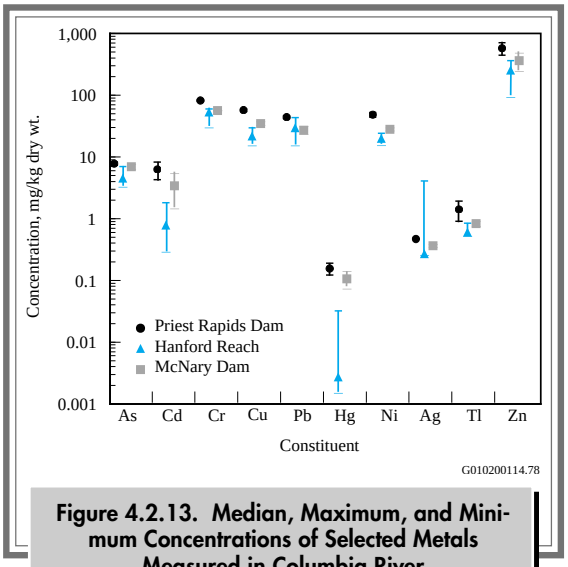


Figure 4.2.13. Median, Maximum, and Minimum Concentrations of Selected Metals Measured in Columbia River Sediment, 2000

From 1997 to 2000, Columbia River sediment also was analyzed for SEM/AVS. This analysis involved a cold acid extraction of the sediment followed by analysis for sulfide and metals. The SEM/AVS ratios are an indicator of potential sediment toxicity (DeWitt et al. 1996; Hansen et al. 1996). Acid volatile sulfide is an important binding phase for divalent metals (i.e., metals with a valance state of 2+, such as Pb^{2+}) in sediment. Metal sulfide precipitates are typically very insoluble, and this limits the amount of dissolved metal available in the sediment porewater. For an individual metal, when the amount of acid volatile sulfide exceeds the amount of the metal (i.e., the SEM/AVS molar ratio is below 1), the metal concentration in the sediment porewater will be low because of the limited solubility of the metal sulfide. For a suite of divalent metals, the sum of the simultaneously extracted metals must be considered, with the assumption that the metal with the lowest solubility will be the first to combine with the acid volatile sulfide.

The SEM/AVS results for the 2000 samples were similar to previous years (Figure 4.2.14), with the exception of the average AVS concentration in the Hanford Reach, which was lower (PNNL-13417).

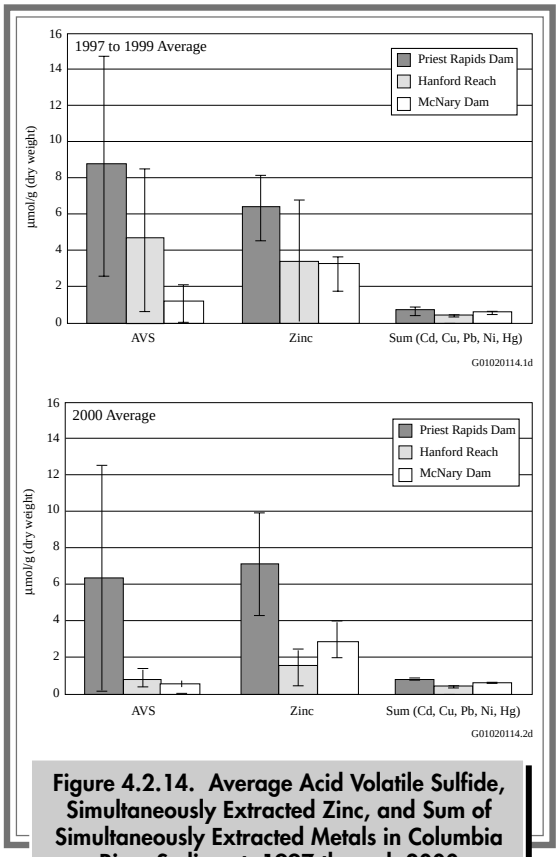


Figure 4.2.14. Average Acid Volatile Sulfide, Simultaneously Extracted Zinc, and Sum of Simultaneously Extracted Metals in Columbia River Sediment, 1997 through 2000 (±1 standard deviation)

For 2000, the acid volatile sulfide values in sediment from the Priest Rapid Dam reservoir had concentrations ranging from 2.0 to 11 µmol/g. Sediment from the Hanford Reach and McNary Dam reservoir had lower concentrations of acid volatile sulfide, with values ranging from 0.50 to 1.7 µmol/g. For 2000, the SEM/AVS molar ratios were near one for Priest Rapids Dam. For 2000, SEM/AVS molar ratios for sediment from the Hanford Reach and McNary Dam were above one, indicating a potential for some metals to be present in the sediment porewater. For all locations, zinc was the primary SEM metal present.

These results reveal an apparent difference in the acid volatile sulfide concentrations in sediment from Priest Rapids Dam reservoir, which had higher concentrations than Hanford Reach and McNary Dam. An apportionment of acid volatile sulfide by divalent metals according to solubility values revealed that sufficient acid volatile sulfide should exist in all locations to limit the porewater concentrations of cadmium, copper, lead, and mercury. For Priest Rapids Dam sediment, average zinc values were of similar magnitude as the average acid volatile sulfide concentrations. For Hanford Reach and McNary Dam sediment, the average zinc concentrations were higher than the available mean acid volatile sulfide pool, indicating the potential for zinc and possibly other metals to be available for biological uptake in the sediment porewater.

4.2.3 Riverbank Spring Water

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site (see Section 7.1.2). 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 the early 1980s, researchers walked the 66-kilometer (41-mile) stretch of Benton County shoreline of the Hanford Reach 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 cessation of 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 7.1). 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 flow, 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 percentage of groundwater in the spring water discharge is believed to increase over time following a drop in river stage. Measuring the specific conductivity of the spring water discharge provides an indicator of the extent of bank storage because the Hanford Site groundwater has higher specific conductivity than the Columbia River.

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 ~66,500 m^3 (2.35 million ft^3) per day.[(a)] This represents only 0.02% of the long-term average flow rate of the Columbia River, which illustrates the tremendous dilution potential afforded by the river. It should be noted that not all of the groundwater discharged to the river contains contaminants originating from Hanford Site operations. Studies of riverbank springs conducted in 1983 (PNL-5289) and in 1988 (PNL-7500) and a near-shore study (PNNL-11933) noted that discharges from the springs 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 compared to the flow of the river and that the impact of groundwater discharges to the river was minimal.

4.2.3.1 Collection of Water Samples from Riverbank Springs and Analytes of Interest

Routine monitoring of selected riverbank springs was initiated in 1988. Currently, riverbank spring water samples are collected for environmental surveillance and to support groundwater operable unit investigations. The locations of all riverbank springs sampled in 2000 are identified in Figure 4.2.1. Sample collection methods are described in DOE/RL-91-50. 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 in late summer/fall.

(a) Personal communication from S. P. Luttrell to G. W. Patton, Pacific Northwest National Laboratory, Richland, Washington, January 1995.

Samples of water from riverbank springs were collected from September to November 2000. All samples collected during 2000 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, and -238. All samples were analyzed for metals and anions, with volatile organic compounds analyzed at selected locations. All analyses were conducted on unfiltered samples, except for metals analyses, which were conducted for both filtered and unfiltered samples.

Hanford-origin contaminants continued to be detected in water from riverbank springs entering the Columbia River along the Hanford Site during 2000. The locations and extent of contaminated discharges were consistent with recent groundwater surveys. Tritium, strontium-90, technetium-99, iodine-129, uranium-234, -235, and -238, metals, and anions (chloride, fluoride, nitrate, and sulfate) were detected in spring water. Volatile organic compounds were near or below the detection limits for most samples. The contaminant concentrations in water from riverbank springs are typically lower than those found in near-shore groundwater wells because of bank storage effects.

Results of radiological and chemical analyses conducted on samples from riverbank springs in 2000 are documented in PNNL-13487, APP. 1. Radiological results obtained in 2000 are summarized in Appendix B (Table B.9) and compared to those reported in 1995 through 1999. In the following discussion, radiological and chemical results are addressed separately. Contaminant concentration trends are illustrated for selected locations.

4.2.3.2 Radiological Results for Water Samples from Riverbank Springs

All radiological contaminant concentrations measured in riverbank springs in 2000 were less than the DOE derived concentration guides (DOE Order 5400.5; see Appendix D, Table D.5). However, the spring at the 100-N Area that has historically exceeded the DOE derived concentration guide for strontium-90 only had observed flow during one (1997) sampling attempt in the last 6 years; thus, an alternative spring was sampled in the 100-N Area. Tritium concentrations in water samples collected in 2000 from riverbank springs at the Old Hanford Townsite exceeded the ambient surface-water quality criteria levels (WAC 173-201A and 40 CFR 141). The tritium concentration in riverbank spring water collected in 2000 at 100-N was 90% of the ambient surface water criteria level (WAC 173-201A and 40 CFR 141), with tritium levels near 50% of the criteria at the 100-D and 300 Area locations. The strontium-90 concentration in riverbank spring water was greater than 50% of the criteria level at the 100-H Area location. There are no ambient surface-water quality criteria levels directly applicable to uranium. However, total uranium concentrations exceeded the EPA drinking water standard (EPA 822-R-96-001) in the 300 Area (see Appendix D, Table D.2). The gross alpha concentration exceeded the ambient surface-water quality criteria level (15 pCi/L, Appendix D, Table D.2) in riverbank spring water at the 300 Area, which is consistent with the elevated uranium levels. All other radionuclide concentrations in 300 Area springs water were less than ambient surface-water quality criteria levels. Gross beta concentrations in riverbank spring water at the Old Hanford Townsite and the 300 Area (22 to 30 pCi/L) were elevated compared to other riverbank spring water locations.

Tritium concentrations varied widely with location. The highest tritium concentration detected in riverbank springs water was at the Old Hanford Townsite (79,000 ± 3,100 pCi/L), followed by the 100-N Area (18,000 ± 800 pCi/L), 300 Area (9,900 ± 510 pCi/L), and 100-D Area (9,800 ± 730 pCi/L). The ambient surface-water quality criteria level for tritium is 20,000 pCi/L. Tritium concentrations in all riverbank springs water samples were elevated compared to the 2000 average Columbia River concentration at Priest Rapids Dam (35 ± 5.6 pCi/L).

Samples from riverbank springs in the 100-B, 100-H, 100-K, and 300 Areas and the Old Hanford Townsite were analyzed for technetium-99. All results were below the EPA drinking water standard (see Appendix D, Table D.2). The highest technetium-99 concentration was found in riverbank spring water from the Old Hanford Townsite (80 ± 6.1 pCi/L), in agreement with the observed gross beta concentrations (30 ± 4.9 pCi/L).

Samples from riverbank springs at the Old Hanford Townsite and 300 Area were analyzed for iodine-129. The highest concentration was measured in a water sample from the Old Hanford Townsite spring (0.27 ± 0.029 pCi/L). This value was elevated compared to the 2000 average measured at Priest Rapids Dam (0.0000082 ± 0.0000050 pCi/L) but was below the 1-pCi/L surface-water quality criteria level (see Appendix D, Table D.2).

Uranium was sampled in riverbank spring water in the 100-H Area, 100-F Area, Old Hanford Townsite, and 300 Area in 2000. The highest level was found in 300 Area spring water (130 ± 27 pCi/L), which was collected from a spring located downgradient from the retired 300 Area process trenches. The 300 Area spring had elevated gross alpha concentration (120 ± 29 pCi/L), which paralleled that of uranium.

Samples from riverbank springs were analyzed for strontium-90 in the 100-B, 100-D, 100-F, 100-H, 100-K, and 100-N Areas. The highest strontium-90 concentration detected in riverbank spring water was at the 100-H Area (5.6 ± 1.3 pCi/L). This value was below the ambient surface water quality criteria of 8 pCi/L.

Historically, riverbank seepage in the 100-N Area has been monitored for contaminants by sampling from well 199-N-8T, which is located close to the river; well 199-N-46 (caisson), which is slightly inland from well 199-N-8T (PNNL-11795, Figure 3.2.4); or riverbank springs. Since 1993, 100-N Area seepage samples for the Surface Environmental Surveillance Project have been collected only from riverbank springs. The Near-Facility Environmental Monitoring program (see Section 3.2.2) also collects water samples along the 100-N shoreline at monitoring well 199-N-46 and at shoreline seepage wells. The Near-Facility Environmental Monitoring program reported all strontium-90 concentrations in calendar year 2000 samples were below the 1,000 pCi/L derived concentration guide for shoreline seepage wells near monitoring well 199-N-46 (see Table 3.2.4). For 1993 to 2000, there were no visible riverbank springs directly adjacent to wells 199-N-8T or 199-N-46 during the Surface Environmental Surveillance Project sampling periods; with the exception of one sample collected in 1997. The 100-N Area riverbank springs samples were, therefore, collected from a downstream riverbank spring. Contaminant activities measured in the water from the two riverbank springs locations sampled in previous years were distinctly different from each other (Table 4.2.3). Historically, the concentrations of strontium-90 and gross beta were considerably higher in the riverbank

Table 4.2.3. Selected Radionuclide Concentrations in 100-N Area Riverbank Spring Water, 1995 through 2000

	Concentration, pCi/L[a]		
Year	Tritium	Gross Beta	Strontium-90
1995[b]	12,000 ± 970	1.5 ± 1.5	0.079 ± 0.10
1996[b]	17,000 ± 1,300	4.5 ± 1.8	0.053 ± 0.048
1997[b]	19,000 ± 1,500	3.5 ± 1.6	0.59 ± 0.13
1997[c]	14,000 ± 1,100	16,000 ± 1,400	9,900 ± 1,800
1998[b]	24,000 ± 1,900	2.3 ± 2.1	[d]
1999[b]	14,000 ± 670	2.9 ± 1.7	0.026 ± 0.034
2000[b]	18,000 ± 800	5.9 ± 2.1	-0.0026 ± 0.037

(a) Concentrations are ±2 total propagated analytical uncertainty.
(b) Sample collected from riverbank spring downstream of well 199-N-8T.
(c) Samples collected from spring below well 199-N-8T (100-N Area spring 8-13, see PNNL-11795, Figure 3.2.4).
(d) Sample was lost during processing at the analytical laboratory.

spring directly adjacent to well 199-N-8T than for the downstream spring. Tritium levels in water from riverbank springs are typically elevated at both locations, and the 2000 tritium result for the 100-N riverbank spring was similar to those found in previous years (see Table 4.2.3). Tritium was the only specific radionuclide detected at the 100-N Area riverbank spring in 2000. The tritium concentration was 90% of the ambient surface-water quality criteria level (see Appendix D, Table D.2). The tritium concentration for the samples from 100-N Area riverbank spring was more than 13 times higher than the maximum value reported in Section 3.2, Table 3.2.4.

Concentrations of selected radionuclides in riverbank spring water near the Old Hanford Townsite (spring 28-2) from 1995 through 2000 are provided in Figure 4.2.15. Several of the radionuclides

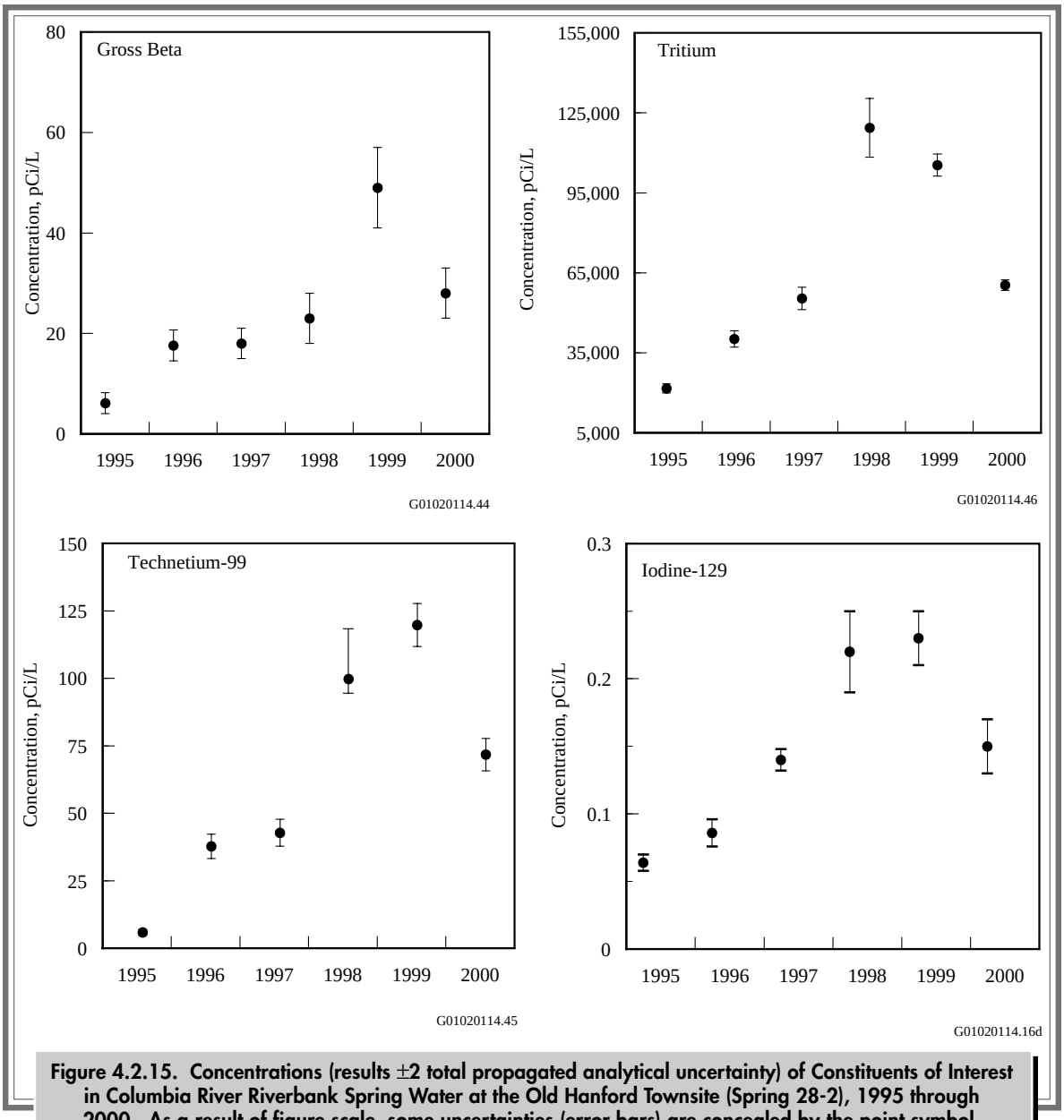


Figure 4.2.15. Concentrations (results ±2 total propagated analytical uncertainty) of Constituents of Interest in Columbia River Riverbank Spring Water at the Old Hanford Townsite (Spring 28-2), 1995 through 2000. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

show what appear to be increasing trends since 1995; however, radionuclide concentrations measured in the early 1990s were similar to the 2000 concentrations (see Figure 4.2.13 in PNNL-11472). Annual fluctuations in these values may reflect the influence of bank storage during the sampling period. The maximum tritium and technetium-99 levels detected in water from Old Hanford Townsite riverbank springs in 2000 were 395% and 93% of their respective ambient surface-water quality criteria levels (see Appendix D, Table D.2). The maximum iodine-129 concentration measured in water from the Old Hanford Townsite riverbank springs for 2000 was 27% of the ambient surface-water quality criteria level (see Appendix D, Table D.2).

Figure 4.2.16 depicts the concentrations of selected radionuclides in the 300 Area riverbank spring (spring 42-2) from 1995 through 2000. Results in 2000 were similar to those observed previously. The elevated tritium levels measured in the 300 Area riverbank springs are indicators of the

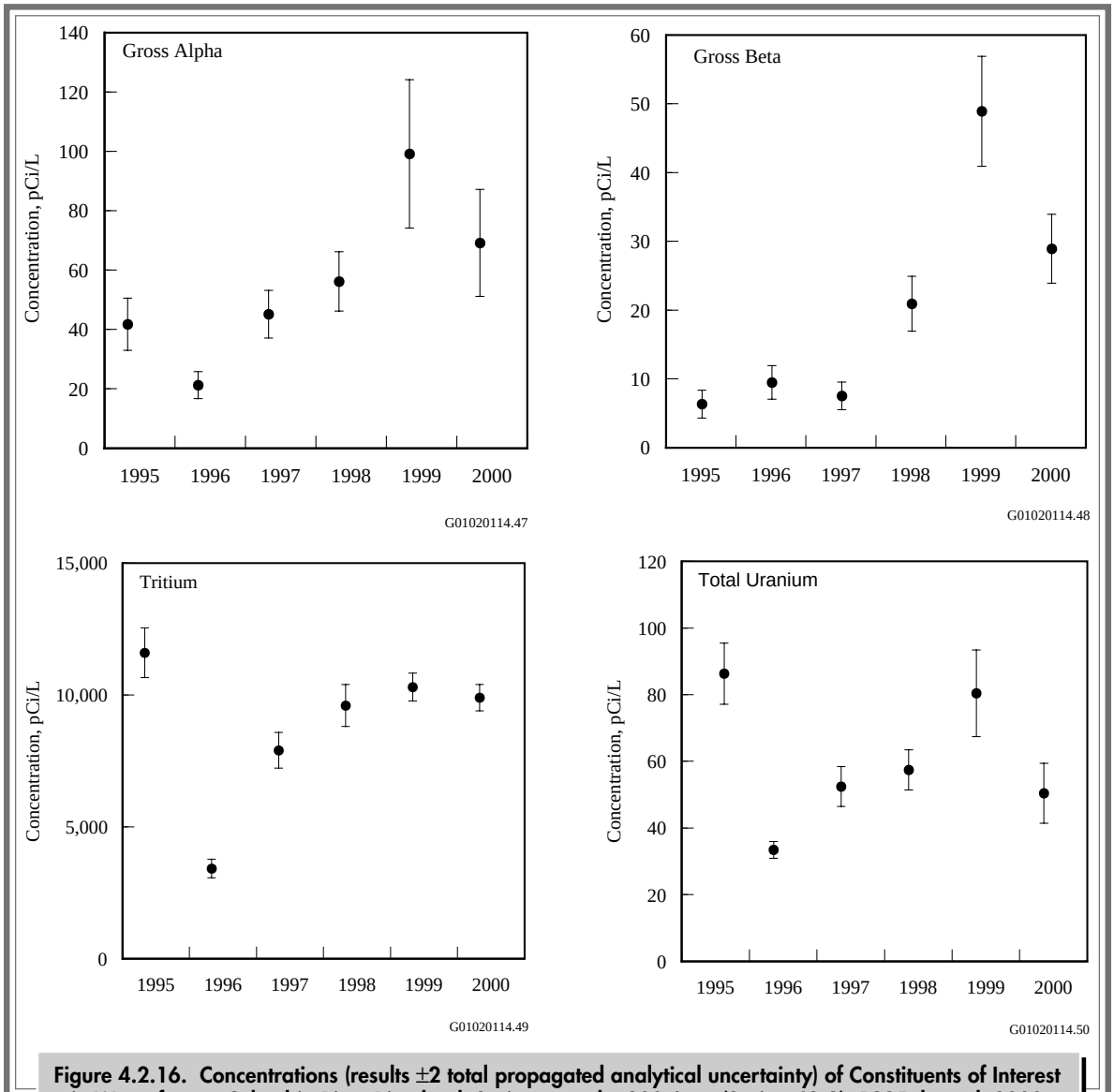


Figure 4.2.16. Concentrations (results ±2 total propagated analytical uncertainty) of Constituents of Interest in Water from a Columbia River Riverbank Spring near the 300 Area (Spring 42-2), 1995 through 2000

contaminated groundwater plume from the 200 Areas (Section 5.9 in PNL-10698). In addition, iodine-129 is also contained in the 200 Areas' contaminated groundwater plume. The maximum tritium and iodine-129 concentrations in water from the 300 Area riverbank springs in 2000 were 50% and 0.57% of their respective ambient surface-water quality criteria levels (see Appendix D, Table D.2). The highest total uranium levels in riverbank spring water from 1995 through 2000 were found in the 300 Area riverbank springs. The 2000 maximum total uranium value was nearly 5 times higher than the EPA drinking water standard (30 μg/L or ~27 pCi/L; see Appendix D, Table D.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. The gross alpha and gross beta concentrations in the 300 Area riverbank springs water from 1995 through 2000 parallel uranium and are likely associated with its presence.

4.2.3.3 Chemical Results for Water Samples from Riverbank Springs

Concentration ranges of selected chemicals measured in riverbank springs water in 1999 through 2000 are presented in Table 4.2.4. For most locations, the 2000 non-radiological sample results were similar to those reported previously (PNNL-12088). Nitrate concentrations were highest in the 100-F and 100-H Areas. Chromium concentrations were highest in the 100-B, 100-D, 100-H, and 100-K Areas' riverbank springs. Hanford groundwater monitoring results for 2000 indicated similar non-radiological contaminants in shoreline areas (see Section 7.1).

The ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; see Appendix D, Table D.3). For comparison purposes, spring water criteria were calculated using the same 47-mg calcium carbonate per liter hardness given in Appendix D, Table D.3. Most metal concentrations measured in water from riverbank springs collected from the Hanford Site shoreline in 1999 through 2000 were below ambient surface-water acute toxicity levels (WAC 173-201A). However, concentrations of chromium in 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F, and 300 Areas spring water were above ambient surface water acute toxicity levels (see Appendix D, Table D.3). Arsenic concentrations in riverbank spring water were well below ambient surface water chronic toxicity levels, but all samples (including upriver Columbia River water samples) exceeded the federal limit (40 CFR 141; see Appendix D, Table D.3). Nitrate concentrations at all spring water locations were below the drinking water standard (see Appendix D, Table D.2).

4.2.4 Onsite Pond Water

Two onsite ponds (see Figure 4.2.1), located near operational areas, were sampled periodically during 2000. The ponds are inaccessible to the public and, therefore, did not constitute a direct offsite environmental impact during 2000. However, they were accessible to migratory waterfowl, creating a potential biological pathway for the dispersion of contaminants (PNL-10174). The Fast Flux Test Facility pond is a disposal site for process water (primarily cooling water drawn from groundwater wells). West Lake, the only naturally occurring pond on the site, is located north of the 200-East Area (ARH-CD-775). West Lake has not received direct effluent discharges from Hanford Site facilities but is influenced by changing water-table elevation as a result of previous discharge of water to the ground in the 200 Areas.

Table 4.2.4. Concentration Ranges for Selected Chemicals in Water from Columbia River Springs, 1999 through 2000

	Ambient Water Quality Criteria Level[a]	Concentration, µg/L							
		100-B Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	Old Hanford Townsite	300 Area
No. of Samples		3	3	2	4	4	2	6	4
Dissolved Metals (µg/L)									
Antimony	NA	0.14 - 0.19	0.15 - 0.22	0.22	0.18 - 0.21	0.23 - 0.28	0.12 - 0.2	0.13 - 0.39	0.20 - 0.36
Arsenic	190	0.93 - 1.6	0.32 - 1.6	2.2 - 2.9	0.66 - 0.94	0.58 - 2.0	1.5 - 2.4	2.6 - 4.8	0.95 - 1.6
Cadmium	0.59	0.010 - 0.012	0.0044 - 0.010	0.011 - 0.031	0.017 - 0.041	0.0044 - 0.034	0.0091 - 0.021	0.020 - 0.051	0.017 - 0.078
Chromium[b]	10	9.8 - 20	2.1 - 49	7.7 - 11	24 - 150	4.0 - 17	14 - 22	1.8 - 4.6	2.6 - 3.7
Copper	6	0.27 - 2.1	0.38 - 0.46	0.25 - 0.28	0.38 - 0.57	0.41 - 5.6	0.37 - 0.42	0.24 - 0.44	0.38 - 0.46
Lead	1.1	0.014 - 0.16	0.0078 - 0.014	0.0050 - 0.0069	0.0073 - 0.017	0.0050 - 0.57	0.0078 - 0.018	0.0049 - 0.058	0.0050 - 0.034
Nickel	83	0.14 - 1.6	0.12 - 1.7	0.2 - 1.0	0.22 - 1.8	0.18 - 1.2	0.12 - 2.2	0.68 - 1.7	1.0 - 2.1
Silver[c]	0.94	0.0053 - 0.014	0.0048 - 0.015	0.0054 - 0.0080	0.0043 - 0.013	0.0052 - 0.0080	0.0043 - 0.042	0.0043 - 0.053	0.0049 - 0.021
Thallium	NA	0.0035 - 0.0072	0.0035 - 0.014	0.011 - 0.014	0.026 - 0.041	0.0085 - 0.026	0.0085 - 0.011	0.013 - 0.020	0.014 - 0.028
Zinc	55	1.1 - 5.0	0.76 - 1.7	2.7 - 3.7	1.7 - 3.4	0.35 - 2.1	1.1 - 1.8	1.3 - 2.9	1.7 - 3.0
No. of Samples		4	3	2	4	4	2	6	4
Total Recoverable Metals (µg/L)									
Chromium[d]	96	11 - 20	2.2 - 48	7.6 - 11	24 - 150	4.0 - 18	17 - 23	1.8 - 4.9	3.2 - 24
Mercury	0.012	0.00098 - 0.0013	0.00086 - 0.0015	0.00044 - 0.0006	0.00086 - 0.004	0.00065 - 0.002	0.0017 - 0.0038	0.00089 - 0.0026	0.00088 - 0.0047
Selenium	5	1.2 - 1.9	0.39 - 2.2	0.88 - 0.96	0.67 - 1.9	0.39 - 0.76	0.94 - 2.3	1.2 - 2.3	2.4 - 3.9
No. of Samples		4	2	2	7[e]	6	4	6	4
Anions (mg/L)									
Nitrate	45[f]	1.8 - 3.4	3.8 - 4.9	3.5 - 4.9	0.84 - 4.5	0.52 - 20	0.58 - 33	3.0 - 8.1	5.1 - 6.4

(a) Ambient Water Quality Criteria Values (WAC 173-201A-040) for chronic toxicity unless otherwise noted.
(b) Value for hexavalent chromium.
(c) Value for acute toxicity; chronic value not available.
(d) Value for trivalent chromium.
(e) One nitrate result of 295 mg/L for riverbank spring (SD-110-2) on October 17, 2000 was not included in the range because it was considered an anomalously high value.
(f) Drinking water standard (WAC 246-290).

4.2.4.1 Collection of Pond Water Samples and Analytes of Interest

In 2000, grab samples were collected quarterly from the Fast Flux Test Facility pond and from West Lake. Unfiltered aliquots of all samples were analyzed for gross alpha and gross beta concentrations, gamma-emitting radionuclides, and tritium. West Lake samples were also analyzed for technetium-99 and uranium-234, -235, and -238. Constituents were chosen for analysis based on their known presence in local groundwater or in effluents discharged to the pond 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 water samples collected during 2000 are reported in PNNL-13487, APP. 1. With the exceptions of uranium-234 and uranium-238 concentrations in samples from West Lake, radionuclide concentrations in onsite pond water were less than the DOE derived concentration guides (DOE Order 5400.5; see Appendix D, Table D.5). The median gross alpha, gross beta, and total uranium concentrations exceeded their ambient surface-water quality criteria in West Lake. The median concentrations of all other radionuclides were below ambient surface-water quality criteria levels (WAC 173-201A; 40 CFR 141; see Appendix D, Tables D.1 and D.2).

Figure 4.2.17 shows the annual gross beta and tritium concentrations in Fast Flux Test Facility pond water from 1995 through 2000. Median levels 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. The use of groundwater well 499-S0-7 during this time is most likely responsible for the high levels of tritium observed in July 1995. Tritium levels in well 499-S0-7 are typically greater than 20,000 pCi/L, reflective of those observed in a portion of the local unconfined aquifer. Median gross beta and tritium concentrations in Fast Flux Test Facility pond water during 2000 were 24% and 18% of their respective ambient surface-water quality criteria. The concentrations of all other measured contaminants in this pond water were below detection limits, except for naturally occurring potassium-40.

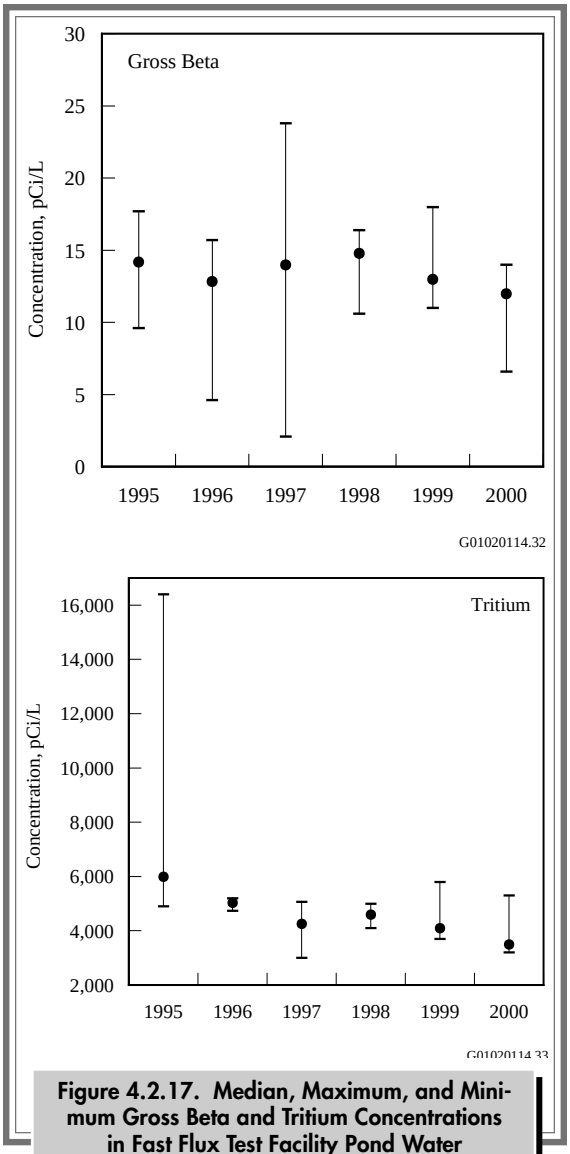


Figure 4.2.17. Median, Maximum, and Minimum Gross Beta and Tritium Concentrations in Fast Flux Test Facility Pond Water Samples, 1995 through 2000

The annual concentrations of selected radionuclides from 1995 through 2000 in West Lake water are shown in Figure 4.2.18. Median radionuclide concentrations in West Lake during 2000 were similar to those observed in the past. The gross alpha and gross beta levels in West Lake water are believed to result from high levels of naturally occurring uranium in the surrounding soil (BNWL-1979; PNL-7662). Annual median total uranium concentrations have remained stable over the last 6 years, but the range is large. The highest concentrations measured in 2000 were in the 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 levels were reported in PNNL-7662 for West Lake samples that contained high concentrations of suspended sediment. Because of the high suspended sediment concentrations, strontium-90 analyses for West Lake water samples were not conducted in 2000. Declines in groundwater levels beneath the 200 Areas have been recorded since the decommissioning of the processing ponds and the shutdown of production facilities (see Section 7.1). As a result, the water

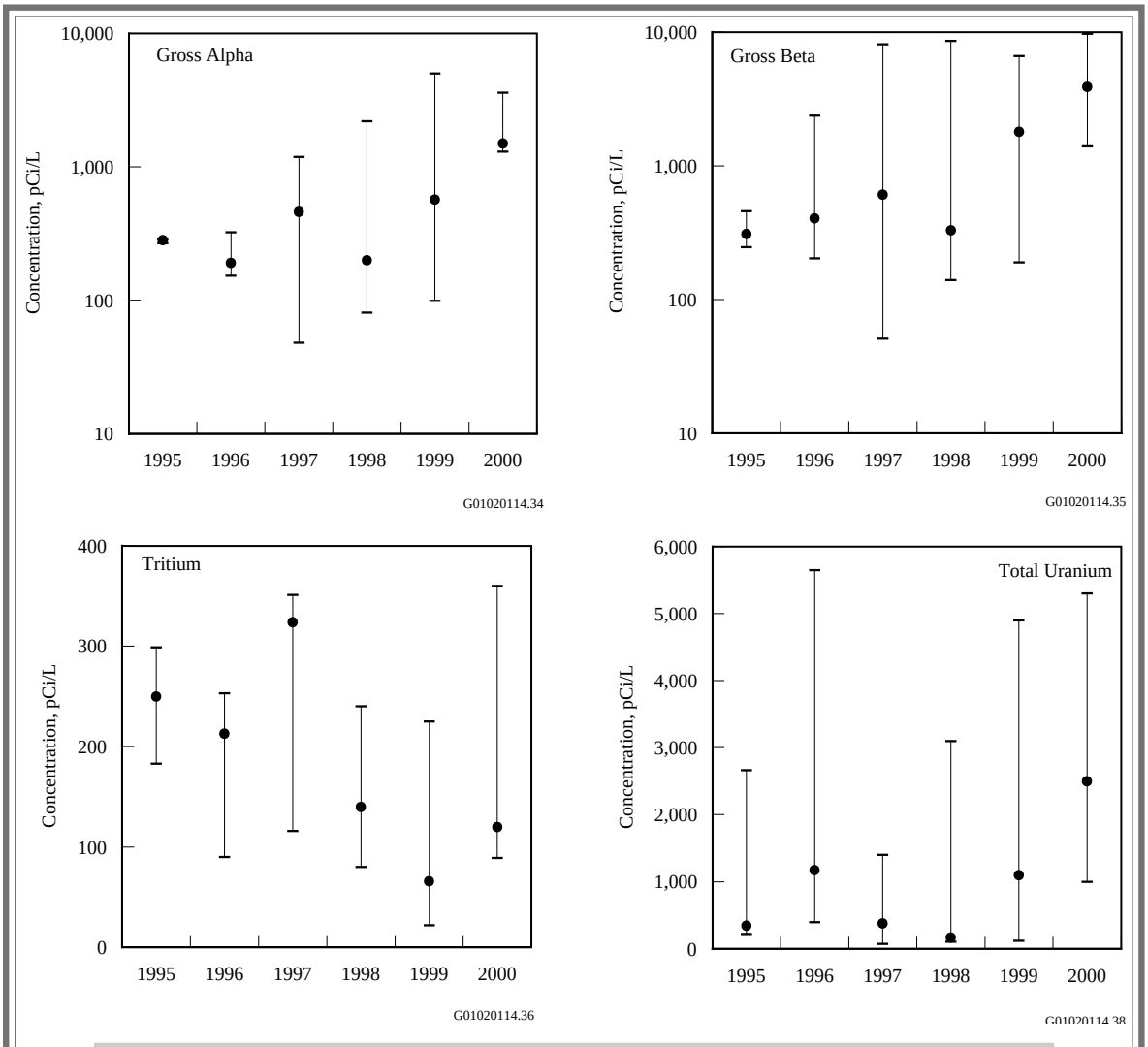


Figure 4.2.18. Median, Maximum, and Minimum Concentrations of Selected Radionuclides in West Lake Water Samples, 1995 through 2000

level in West Lake has dropped. Median concentrations of tritium and technetium-99 in West Lake in 2000 were 0.60% and 44%, respectively, of the ambient surface-water quality criteria levels and reflected local groundwater concentrations. The concentrations of all other measured radionuclides were below their detection limits, except for naturally occurring potassium-40.

4.2.5 Offsite Water

During 2000, water samples were collected from an irrigation canal located across the Columbia River at Riverview and downstream from the Hanford Site. This canal receives water pumped from the Columbia River near Pasco, Washington. In addition, one water sample was collected from the Horn Rapids irrigation pumping station located between the 300 Area and Richland. 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 6.0).

4.2.5.1 Collection, Analysis, and Results for Irrigation Water

Water in the Riverview irrigation canal was sampled three times in 2000 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, and -238. Results are presented in PNNL-13487, APP. 1. In 2000, radionuclide concentrations measured in this canal's water were at the same levels detected 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 173-201A; 40 CFR 141). The strontium-90 levels in the irrigation water during 2000 ranged from 0.040 ± 0.030 to 0.073 ± 0.028 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).

The water sample from the Horn Rapids irrigation pumping station was analyzed for the same analytes as the Riverview irrigation canal, except for tritium. All radionuclide concentrations were below both DOE derived concentration guides and ambient surface-water quality criteria levels (DOE Order 5400.5; WAC 173-201A; 40 CFR 141) and were similar to Columbia River concentrations (see Section 4.2.1).

4.3 Radiological Surveillance of Hanford Site Drinking Water

R. W. Hanf and L. M. Kelly

The quality of drinking water at the Hanford Site is monitored by routinely collecting and analyzing drinking water samples and comparing the resulting analytical data with established drinking water standards and guidelines (WAC 246-290; 40 CFR 141; EPA-570/9-76-003; EPA 822-R-96-001; DOE Order 5400.5; see Appendix D, Tables D.2 and D.5). In 2000, radiological surveillance of drinking water supplied to Hanford Site facilities by DOE-owned pumps and water treatment facilities was conducted by Pacific Northwest National Laboratory for DynCorp Tri-Cities Services, Inc. DynCorp Tri-Cities Services, Inc. conducted routine chemical and microbiological monitoring of these drinking water systems.

The national primary drinking water regulations of the *Safe Drinking Water Act* apply to the drinking water supplies at the Hanford Site. In Washington State, these regulations are enforced by the Washington State Department of Health. Washington Administrative Code (WAC 246-290) requires that all drinking water analytical results be reported routinely to the Washington State Department of Health. In recent years, radiological results for the Hanford Site have been reported to the state through this annual environmental report and through an annual supplemental data compilation (PNNL-13487, APP. 1). Non-radiological data have been reported to the state by DynCorp Tri-Cities Services, Inc. but have not been published.

4.3.1 Hanford Site Drinking Water Systems

Drinking water was supplied to DOE facilities on the site by 11 DOE-owned, contractor-operated, water treatment and distribution systems (Table 4.3.1), and one system owned and operated by the city of Richland. Nine of these systems (including Richland's system) used water pumped from the Columbia River. Two systems used groundwater from beneath the site. In 2000, most of the systems were operated by DynCorp Tri-Cities Services, Inc.; however, Fluor Hanford, Inc. operated two systems in the 400 and 100-K Areas, and Bechtel Hanford, Inc. operated one system in the 100-N Area that was supplied with water from a pumping station operated by DynCorp Tri-Cities Services, Inc. The city of Richland provided drinking water to the 300, 700, and Richland North Areas.

4.3.2 Hanford Site Drinking Water Supply Facilities

In 2000, radionuclide concentrations in onsite drinking water were monitored at the four DOE-owned water supply facilities shown in Figure 4.3.1. 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. Water for the 200-East Area, which formerly came from the 283-E water treatment plant located in the 200-East

Table 4.3.1. DOE-Owned Drinking Water Systems on the Hanford Site, 2000

Location	Source of Supply	Notes
100-D	Columbia River via 181-B or D raw water export	Permanently removed from service on July 12, 2000. Filtered and chlorinated at 183-D Headhouse. Operated by DynCorp Tri-Cities Services, Inc.
100-B	Columbia River via 181-B or D raw water export	Filtered and chlorinated at 182-B Reservoir Pumphouse. Operated by DynCorp Tri-Cities Services, Inc.
100-K	Columbia River via 181-K Pumphouse	Filtered and chlorinated at 185-KE Water Treatment Plant. Operated by Fluor Hanford.
100-N	Columbia River via 181-B or D raw water export	Filtered and chlorinated at 186-N Water Treatment Plant. This is a small skid-mounted package plant that contains three banks of various sized filters and a sodium hypochlorite system for disinfection. Operated by Bechtel Hanford, Inc.
200-E	Normally from the Columbia River via the 283-W Water Treatment Plant. In emergencies, supplied via 181-B or D raw water export and 283-E Water Treatment Plant.	Filtered and chlorinated at 283-W Water Treatment Plant. The clearwells at 283-E serve as reservoirs that supply the 200-East Area distribution system. Under normal conditions, the clearwells are supplied from the 283-W Water Treatment Plant. The 283-E Water Treatment Plant is maintained in standby mode for emergencies. Operated by DynCorp Tri-Cities Services, Inc.
200-W	Columbia River via 181-B or D raw water export	Filtered and chlorinated at 283-W Water Treatment Plant. Operated by DynCorp Tri-Cities Services, Inc.
251 Building (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.
Yakima Barricade	Well 699-49-100C	No treatment provided. Non-potable. Operated by DynCorp Tri-Cities Services, Inc.
609 Building (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.
400 Area	Wells 499-S1-8J, 499-S0-8, and 499-S0-7	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. Wells P-14 and P-15 were not used in 2000. Chlorination only. Operated by Fluor Hanford.
300 Area	Treated Columbia River water via city of Richland	300 Area distribution system. Operated by DynCorp Tri-Cities Services, Inc.

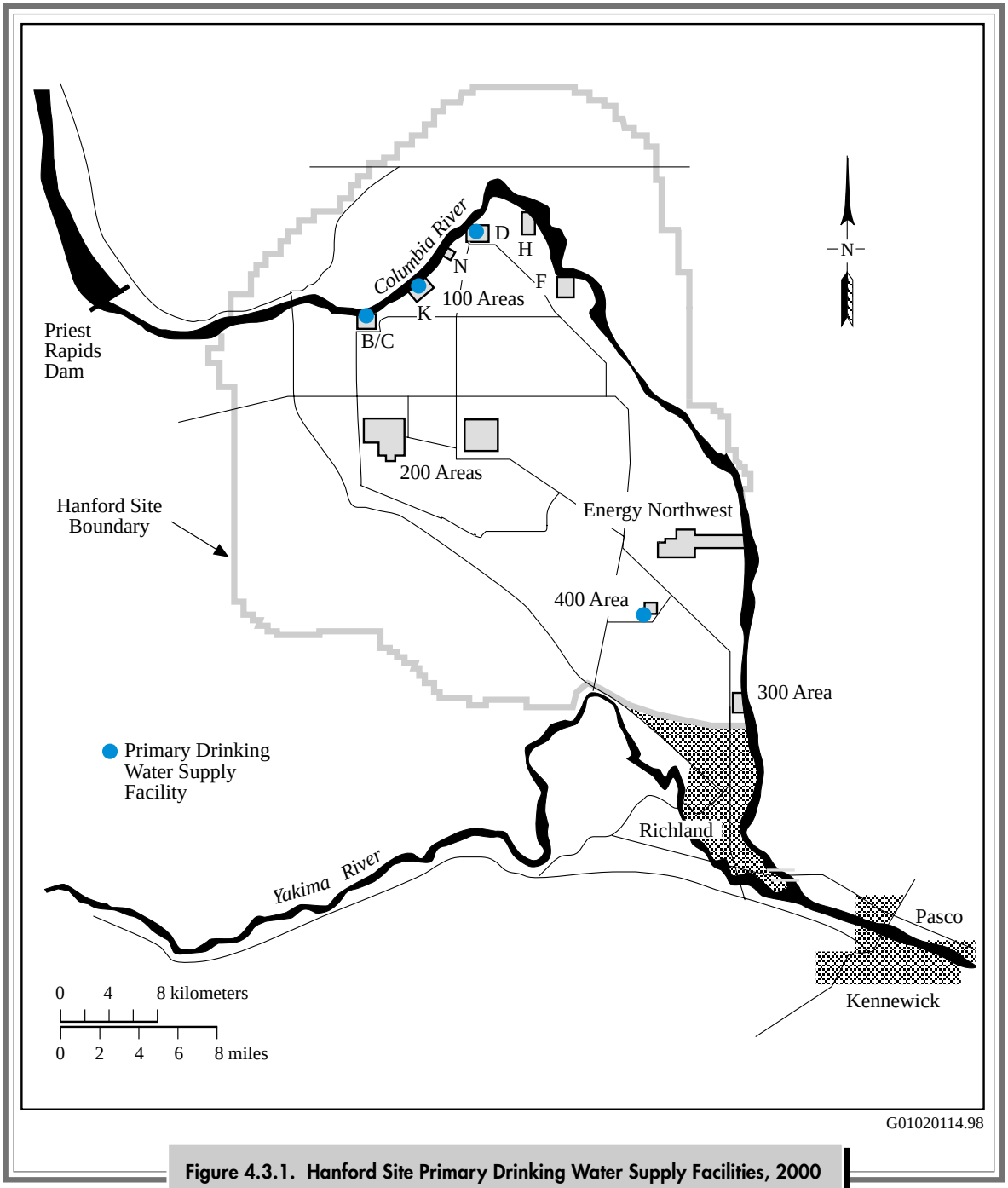


Figure 4.3.1. Hanford Site Primary Drinking Water Supply Facilities, 2000

Area, was supplied by the 283-W water treatment plant (located in the 200-West Area). The 283-E treatment plant was designated as an emergency supply facility in 1999 and was maintained in a standby mode in 2000. The water system at the Yakima Barricade was declared non-potable in 1999 and the well was removed from service on February 13, 2000.

The 400 Area continued to use well 499-S1-8J (P-16) as the primary drinking water supply well, with well 499-S0-8 (P-14) serving as the emergency supply. Well 499-S1-8J is 122 meters (401 feet) deep and was installed in April 1985. Well 499-S0-8 is 90 meters (294 feet) deep and was installed in March 1972. Well 499-S0-7 (P-15), 122 meters (399 feet) deep, was installed in March 1972 and continued to function as the dire emergency supply. Neither well 499-S0-8 nor 499-S0-7 were used as drinking water sources in 2000. In addition to supplying drinking water, these three wells were also important for maintaining fire suppression capabilities within the 400 Area where they are located.

4.3.3 Collection of Drinking Water Samples and Analytes of Interest

Drinking water samples for radiological analyses were collected according to a schedule established at the beginning of the calendar year (PNNL-13109). Samples at all of the locations were collected and analyzed quarterly. Samples from three locations were grab samples of untreated water. The 400 Area samples were grab samples of treated water. The Hanford Groundwater Monitoring Project also collected samples of raw well water from the 400 Area drinking water wells. These samples were analyzed monthly. Drinking water samples obtained from the 400 Area in May 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-13487, APP. 1.

In the 300 Area, water from the city of Richland's system was not monitored for radiological contaminants through the site drinking water surveillance project; however, personnel from Pacific Northwest National Laboratory's Surface Environmental Surveillance Project routinely collected 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 raw river water samples can be found in Appendix B (Table B.2). Sampling of 300 Area drinking water for non-radiological analyses was routinely conducted by DynCorp Tri-Cities Services, Inc. to monitor the DOE-owned, contractor operated water distribution system within the area. However, as stated earlier, non-radiological data are reported directly to the state and are not discussed in this report.

All 2000 drinking water samples collected for radiological analysis were analyzed for gross alpha, gross beta, tritium, and strontium-90.

4.3.4 Radiological Results for Hanford Site Drinking Water

Results for radiological monitoring of Hanford Site drinking water during 2000 are summarized in Table 4.3.2. Individual analytical results are reported in PNNL-13487, APP. 1. The maximum amount of beta-gamma radiation from manmade radionuclides allowed in drinking water by Washington State and

Table 4.3.2. Selected Radiological Constituents in Hanford Site Drinking Water, 2000 Annual Average Concentrations (pCi/L)[a]

System	No. of Samples[b]	Gross Alpha	Gross Beta	Tritium	Strontium-90
100-B Area	4	0.82 ± 0.16	0.87 ± 0.22	124 ± 24	0.07 ± 0.01
100-D Area	4	0.52 ± 0.16	0.91 ± 0.22	59 ± 17	0.07 ± 0.01
100-K Area	4	0.35 ± 0.28	2.12 ± 1.34	47 ± 3	0.07 ± 0.00
400 Area (FFTF)[e]	4	0.19 ± 0.12	6.11 ± 0.12	3,852 ± 106	0.006 ± 0.01
Standards		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) Untreated raw water.
(d) No sample collected in first quarter of calendar year.
(e) FFTF = Fast Flux Test Facility; samples collected at the tap.
(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.

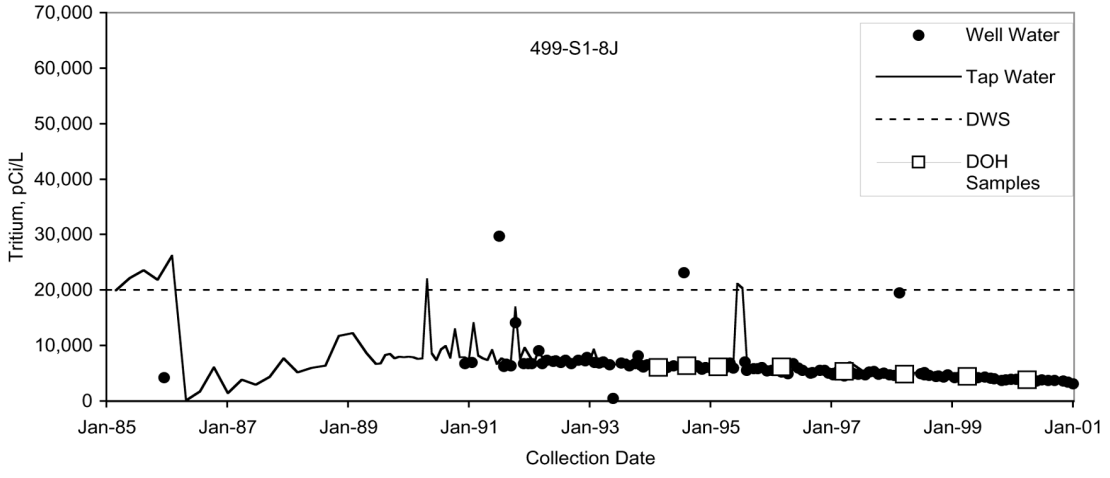
EPA is an annual average concentration that will not produce an annual dose equivalent to the whole body or any internal organ greater than 4 mrem/yr. If both tritium and strontium-90 are present, the sum of their annual dose equivalent to bone marrow must not exceed 4 mrem. Compliance with this standard may be assumed if the annual average concentrations for 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 2000, and results were similar to those observed in recent years (see Section 4.3 in PNNL-12088 and PNNL-13230).

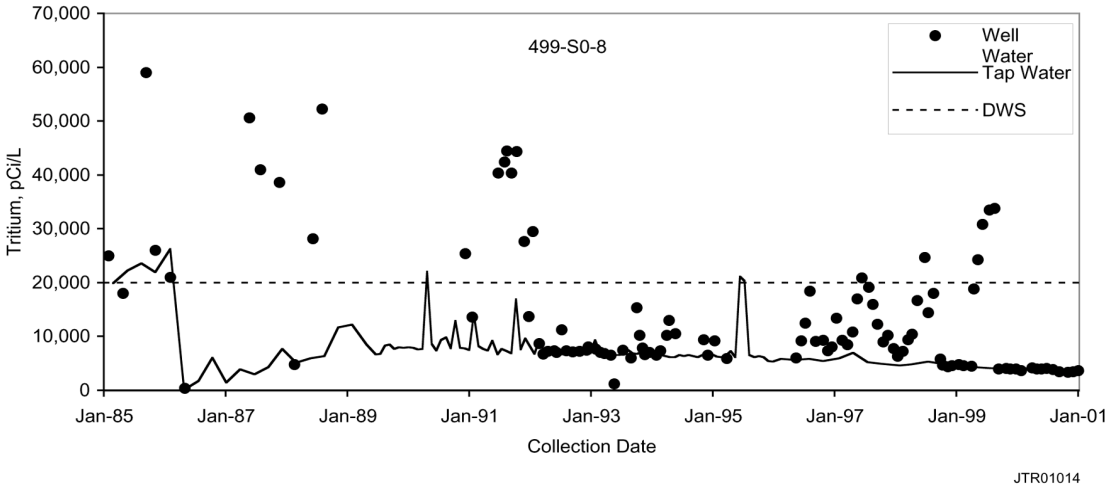
The Hanford Groundwater Monitoring Project collected and analyzed raw water samples monthly from all three 400 Area drinking water wells. Results from these samples show that tritium levels continued to be lowest in well 499-S1-8J and consistently highest in well 499-S0-7 (Table 4.3.3; Figure 4.3.2). A tritium plume that originates in the 200-East Area extends under the 400 Area and has historically affected tritium concentrations in wells 499-S0-7 and 499-S0-8 (see Figure 4.3.2). During 2000, annual average tritium concentrations in both of these wells were below the 20,000 pCi/L state and federal annual average drinking water standard.

Table 4.3.3. Tritium Concentrations (pCi/L) in 400 Area Drinking Water Wells, 2000[a]

Sampling Date	Primary Drinking Water Well 499-S1-8J (P-16)	Emergency Drinking Water Well 499-S0-8 (P-14)	Dire Emergency Drinking Water Well 499-S0-7 (P-15)
January 21, 2000	3,960 ± 420	3,670 ± 410	15,200 ± 950
February 23, 2000	3,800 ± 420	ND[b]	16,000 ± 1,000
March 29, 2000	3,850 ± 470	4,170 ± 470	15,200 ± 1,000
April 25, 2000	3,910 ± 430	4,010 ± 440	16,400 ± 1,000
May 22, 2000	3,610 ± 430	4,030 ± 460	15,600 ± 1,000
June 22, 2000	3,880 ± 440	4,090 ± 450	8,250 ± 660
July 31, 2000	3,700 ± 430	3,870 ± 450	14,800 ± 970
September 7, 2000	3,720 ± 420	3,460 ± 410	14,400 ± 930
October 30, 2000	3,620 ± 450	3,420 ± 440	14,800 ± 990
November 28, 2000	3,440 ± 440	3,530 ± 440	15,100 ± 1,000
December 29, 2000	3,120 ± 410	3,710 ± 440	12,500 ± 880

(a) Reported concentration ±2 total propagated analytical error.
(b) ND = No data.





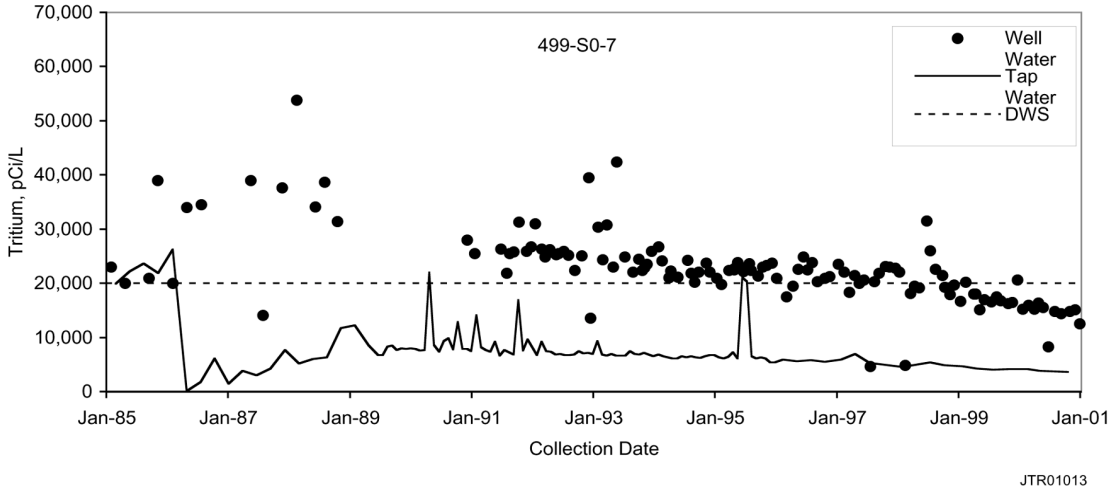


Figure 4.3.2. Tritium Concentrations in Drinking Water from Three Wells in the 400 Area, 1984 through 2000 (DOH = Washington State Department of Health, DWS = drinking water standard)

4.4 Food and Farm Product Surveillance

B. L. Tiller

Foodstuffs, including milk, vegetables, fruits, and wine, were routinely collected in 2000 at several locations surrounding the Hanford Site (Figure 4.4.1). Samples of Yakima Valley hops were collected also at the request of the Washington State Hop Commission. Routine samples were collected primarily from locations in the prevailing downwind directions (south and east of the site) where airborne effluents or fugitive dust from the Hanford Site could be deposited. Samples were collected also in generally upwind directions and at locations somewhat distant from the site to provide information on background radioactivity. Hops were collected upwind of the site near Moxee and Prosser to address a product user's concern about the level of Hanford contaminants in the plants.

Routine food and farm product sampling determines the potential influence of Hanford Site releases in two ways:

- through the comparison of results from downwind locations to those from generally upwind or distant locations
- through the comparison of results from locations irrigated with Columbia River water withdrawn downstream from the Hanford Site to results from locations irrigated with water from other sources.

The food and farm product sampling schedule was modified in 1996 by establishing a 2- or 3-year rotation for sampling certain farm products. Specific details of the 2000 food and farm product sampling, including sampling locations and radionuclides analyzed, are reported in DOE/RL-91-50 and PNNL-13109, and are summarized in Table 4.4.1. Analyses for some radionuclides that historically have not been detected in food or farm products have been discontinued.

Gamma scans (cobalt-60, cesium-137, and other radionuclides; see Appendix F) and strontium-90 analyses were performed for nearly all products. Milk was analyzed for iodine-129 and tritium; wine was analyzed for tritium. In addition, isotopic plutonium was analyzed in routine samples of leafy vegetables in 2000 to examine potential atmospheric deposition as a result of the summer 2000 wildfire. These results are discussed in Section 5.0. Results for fruits and vegetables are reported in picocuries per gram wet weight. Radionuclide levels in hops are reported in picocuries per gram dry weight. Results for tritium are reported in picocuries per liter of liquid distilled from milk and 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 Hanford 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 estimated 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

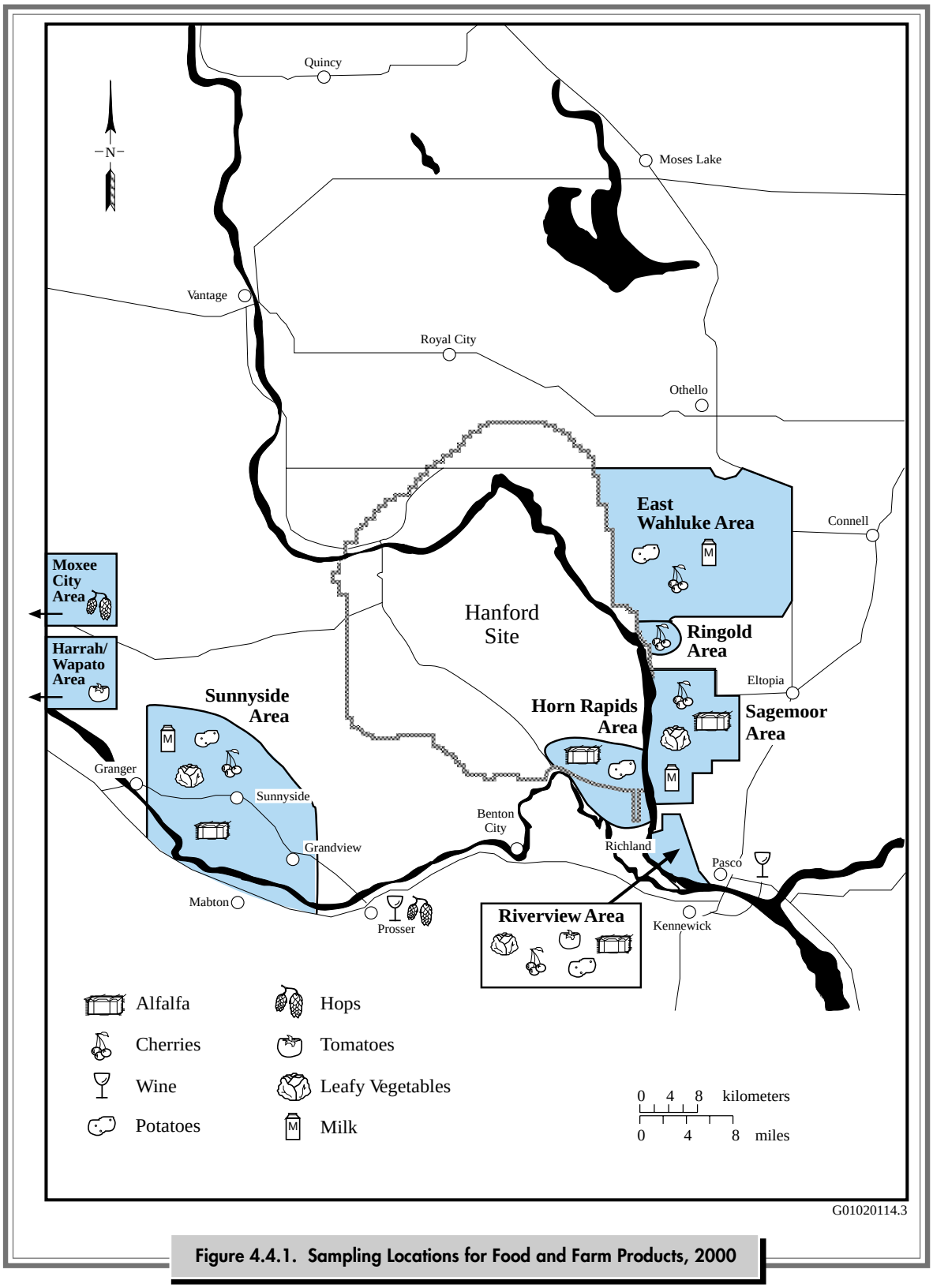


Figure 4.4.1. Sampling Locations for Food and Farm Products, 2000

Table 4.4.1. Locations, Sampling Frequencies, and Analyses Performed for Routinely Sampled Food and Farm Products, 2000[a]

	Number of Locations			Number of Samples Analyzed			
Product	Upwind	Downwind	Sampling Frequency[b]	^{3}H	Gamma	^{90}Sr	^{129}I
Milk	1	2	Q or SA	12	12	12	6
Vegetables	2	2	A	2	6	6	0
Fruit	2	2	A	0	4	4	0
Wine	2	2	A	4	4	0	0

(a) Products may include multiple varieties for each category.
(b) Q = quarterly, SA = semiannually, A = annually.

analytical error associated with the analysis (e.g., counting errors and errors associated with weight and volumetric measurements). Theoretically, re-analysis of the sample should yield a result that falls within the range of the uncertainty 95% of the time. Results and uncertainties not given in this report may be found in PNNL-13487, APP. 1.

4.4.1 Milk Samples and Analytes of Interest

Composite samples of raw, whole milk were collected in 2000 from three dairy farms in the East Wahluke Area and from three dairy farms in the Sagemoor Area. These sampling areas are located near the site perimeter in the prevailing downwind direction (see Figure 4.4.1). Milk samples were also collected from a Sunnyside Area dairy to indicate background radionuclide concentrations at a generally upwind location.

Samples of milk were analyzed for tritium, 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.

Fallout radionuclides in feed and/or drinking water may be a significant source of radioactivity in milk products; however, measured levels of radionuclides in milk from private dairies near the Hanford Site are usually near levels considered to be background. Gamma scans and strontium-90 analyses were conducted quarterly, and iodine-129 analyses were conducted on two semiannual composite samples. Since 1995, tritium concentrations have been below the detection level of standard liquid scintillation counting methods. In 1998, an electrolytic enrichment technique (DOE/RL-91-50) for measuring low levels of tritium in milk samples was instituted. The electrolytic enrichment technique has a detection limit of ~10 pCi/L of water distilled from milk as compared to ~180 pCi/L for the analytical technique used prior to 1996. Milk samples were not analyzed for tritium in 1996 and 1997.

Strontium-90 was detected in 3 of 12 (25%) milk samples analyzed in 2000. These three positive results (0.50, 0.55, and 0.54 pCi/L) were reported in 2 of 4 Sagemoor Area samples and in 1 of 4 Wahluke Area samples. These concentrations are close to the analytical detection limit (0.35 pCi/L) and are consistent with 1 of 12 results found above the analytical detection limit in 1999. While there is no strontium-90 standard for milk, the drinking water standard (based on a 2-liter per day consumption) is 8 pCi/L (40 CFR 141). The maximum milk

consumption rate for estimating dose is ~0.75 liter per day (see Appendix E, Table E.2).

Iodine-129 was quantified for analyses by high-resolution mass spectrometry in six milk samples. In recent years, the levels of iodine-129 in milk collected from generally downwind dairies in the Sagemoor and East Wahluke Areas have persisted at concentrations greater than levels measured upwind in Sunnyside (Figure 4.4.2). Iodine-129 concentrations have declined with the end of nuclear production on the site and contribute less than 1% of the dose to the maximally exposed individual through the consumption of dairy products (see Section 6.0). While there is no iodine-129 standard for milk, the drinking water standard is 1 pCi/L, one thousand times greater than results reported for milk samples from these three areas over the past decade (EPA-570/9-76-003). No other manmade gamma emitters (including cesium-137) were detectable in 2000 milk samples (PNNL-13487, APP. 1).

Tritium was analyzed by an electrolytic enrichment method in quarterly composite milk samples from the Wahluke, Sagemoor, and Sunnyside Areas (see Figure 4.4.1) in 2000. The results indicate Sagemoor Area milk had higher tritium concentrations when compared to milk from both Sunnyside and the Wahluke Areas (Figure 4.4.3). Elevated tritium concentrations in milk from the Sagemoor Area are consistent with results in previous years.

In PNNL-13230, Section 4.4, tritium concentrations in dairy water were reported in conjunction with the milk samples and illustrated the ability to predict tritium concentrations in dairy milk from tritium concentrations in the well water used by the dairies. The dairies in all three areas use well water. The Franklin County aquifers used by the dairies in the Sagemoor and Wahluke Areas have historically been recharged by Columbia River water brought into the areas by the Columbia Basin Irrigation Project. Water for the Columbia Basin Irrigation Project is obtained from the Columbia River upstream of the Grand Coulee Dam. Background tritium levels in Columbia River water in the 1960s ranged from 800 to 5,540 pCi/L. These concentrations were influenced by fallout from worldwide aboveground nuclear weapons testing (Wyerman et al. 1970). Irrigation water from the Columbia River containing these comparatively high tritium levels entered the groundwater aquifers in Franklin County as a result

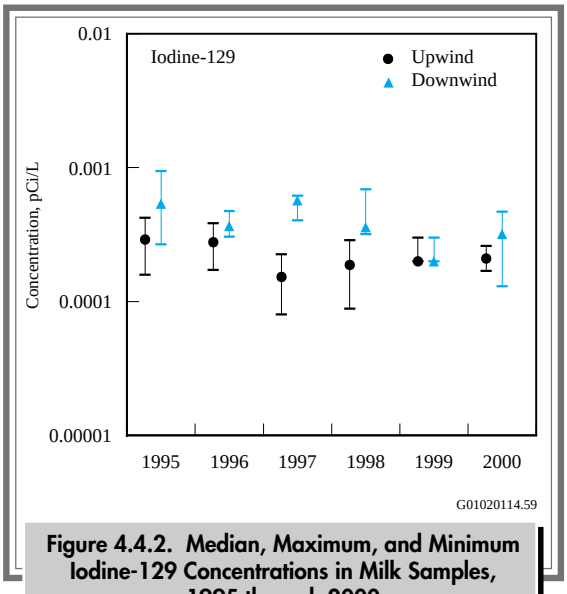


Figure 4.4.2. Median, Maximum, and Minimum Iodine-129 Concentrations in Milk Samples, 1995 through 2000

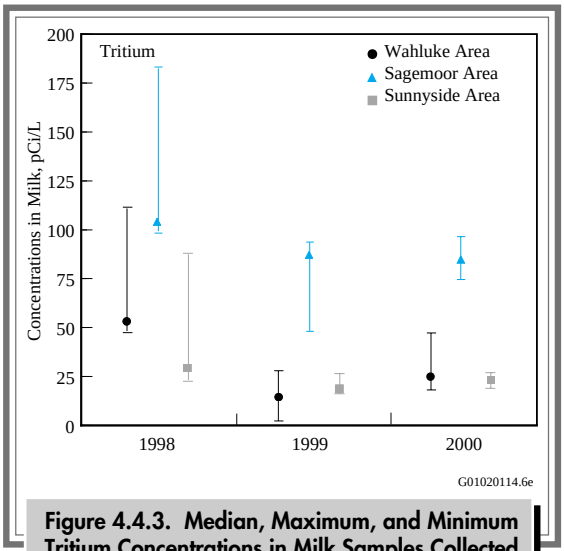


Figure 4.4.3. Median, Maximum, and Minimum Tritium Concentrations in Milk Samples Collected near the Hanford Site, 2000

of overapplication and leaking canals. Over the past 30 years, tritium levels in the aquifer have slowly decreased as a result of radiological decay and possible dilution caused by subsequent recharge with less-contaminated irrigation water. Based on a 12.3-year half-life, if we assume an aquifer having a concentration of 1,000 pCi/L in 1963 (assumes some dilution with natural groundwater), the estimated level after three half-lives in 1999 would be 115 pCi/L. While the relationships between tritium in milk and groundwater used by the dairies are interesting, the actual levels of tritium in milk are a minor contributor to the dose received by those who consume milk (see Section 6.0).

4.4.2 Vegetable Samples and Analytes of Interest

Samples of leafy vegetables (i.e., cabbage and beets) and vegetables (i.e., tomatoes and potatoes) were obtained during the summer from gardens and farms located within selected sampling areas (see Figure 4.4.1). Leafy vegetables are routinely sampled to monitor for the potential deposition of airborne contaminants. Leafy vegetable samples collected downwind of Hanford were of particular interest in 2000 because of a wildfire that burned a large portion of the Hanford Site in late June. The Riverview Area was also sampled because of its exposure to potentially contaminated irrigation water withdrawn from the Columbia River downstream of the Hanford Site. All vegetable samples from all sampling areas were analyzed for gamma-emitting radionuclides and strontium-90.

Measurements of gamma emitters in vegetable and leafy vegetable samples were all less than their respective detection limit (0.02 pCi/g) and were consistent with results seen in recent years (PNNL-13487, APP. 1). Strontium-90 was not detected in any vegetable (potatoes and tomatoes) samples but was detected in 2 of 3 leafy vegetable samples collected in 2000. The results reported above the analytical detection limit were similar between the upwind location (0.012 pCi/g in Sunnyside) and a downwind location (0.018 pCi/g in East Wahluke). Results from another downwind location, the Riverview Area, fell below the analytical detection limit of 0.002 pCi/g.

4.4.3 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. Measurable levels of cesium-137, strontium-90, and other manmade gamma-emitting radionuclides were not detected in apples in 2000. These results are consistent with measurements in grapes, cherries, and melons over recent years (PNL-10575; PNNL-11140; PNNL-11473; PNNL-11796; PNNL-12088; PNNL-13230). The nominal level of detection for cesium-137 was 0.01 pCi/g wet weight.

4.4.4 Wine Samples and Analytes of Interest

Locally produced red and white wines (2000 vintage grapes) were analyzed for gamma-emitting radionuclides and tritium. 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 from each location and analyzed. An electrolytic enrichment method was used for tritium analysis in water distilled from the wine.

Tritium levels in 2000 wine samples were consistent with past results. Tritium concentrations were higher in Columbia Basin wines when compared to Yakima Valley wines (Figure 4.4.4). Red wine from the Columbia Basin contained similar levels of tritium as those found in white wine sampled from the same region. Gamma spectroscopy did not indicate the presence of cesium-137 or any other manmade radionuclide in any of the 2000 wine samples. The observed differences between wines and/or regions are consistent with past results and are likely related to the water sources as discussed with tritium in milk (see Section 4.4.1). While there is no tritium standard for wine, the drinking water standard is 20,000 pCi/L, 500 times greater than maximum concentrations reported in wines from these two areas in 2000 (EPA-570/9-76-003).

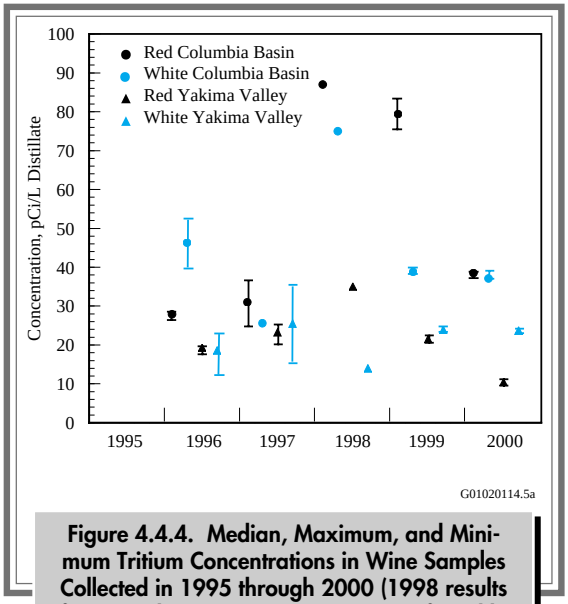


Figure 4.4.4. Median, Maximum, and Minimum Tritium Concentrations in Wine Samples Collected in 1995 through 2000 (1998 results from Washington State Department of Health)

4.4.5 Hop Samples

Four hop samples from two locations (see Figure 4.4.1) were collected in September 2000 and analyzed for gamma-emitting radionuclides, strontium-90, technetium-99, uranium isotopes, and plutonium isotopes. Samples were obtained from the growers and consisted of compressed blocks of commercially packaged hop flowers.

The only radionuclide detected in the four samples was potassium-40. Potassium-40 is a naturally occurring radionuclide and the concentrations were comparable to potassium-40 levels in other vegetation and leafy farm products collected from the Columbia Basin and Yakima Valley.

4.5 Fish and Wildlife Surveillance

B. L. Tiller

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 aquatic organisms 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 or changes in contaminant levels in wildlife over time may indicate that wildlife are entering contaminated areas (e.g., burrowing in waste burial grounds) or that materials are moving out of known contaminated areas (e.g., through blowing dust or food-chain transport). Consequently, fish and wildlife samples are collected at selected locations annually (Figure 4.5.1). More detailed rationale for the selection of specific species sampled in 2000 can be found in DOE/RL-91-50.

Routine background sampling is conducted approximately every 5 years at locations believed to be unaffected by Hanford Site releases. Additional background data also may be donated or collected during special studies or ecological impact monitoring efforts conducted under the Ecosystems Monitoring Project (see Section 8.2).

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 onsite radiological sources 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.

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 have been historically the most frequently measured radionuclides in fish and wildlife.

Strontium-90 is chemically similar to calcium; consequently, it accumulates in hard tissues rich in calcium such as bone, antlers, and eggshells. Strontium-90 has a biological half-life in hard tissue of 14 to 600 days. Hard-tissue concentrations may profile an organism's lifetime exposure to strontium-90. However, strontium-90 generally does not contribute much to the dose humans receive from eating animals because it does not accumulate in edible portions of fish and wildlife. Springs 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 days in muscle; <20 days in the gastrointestinal tract), cesium-137 is an indicator of more recent exposure to radioactive materials. Cesium-137 is also a major constituent of historical fallout.

Fish and wildlife samples were analyzed by gamma spectrometry to detect a number of gamma emitters

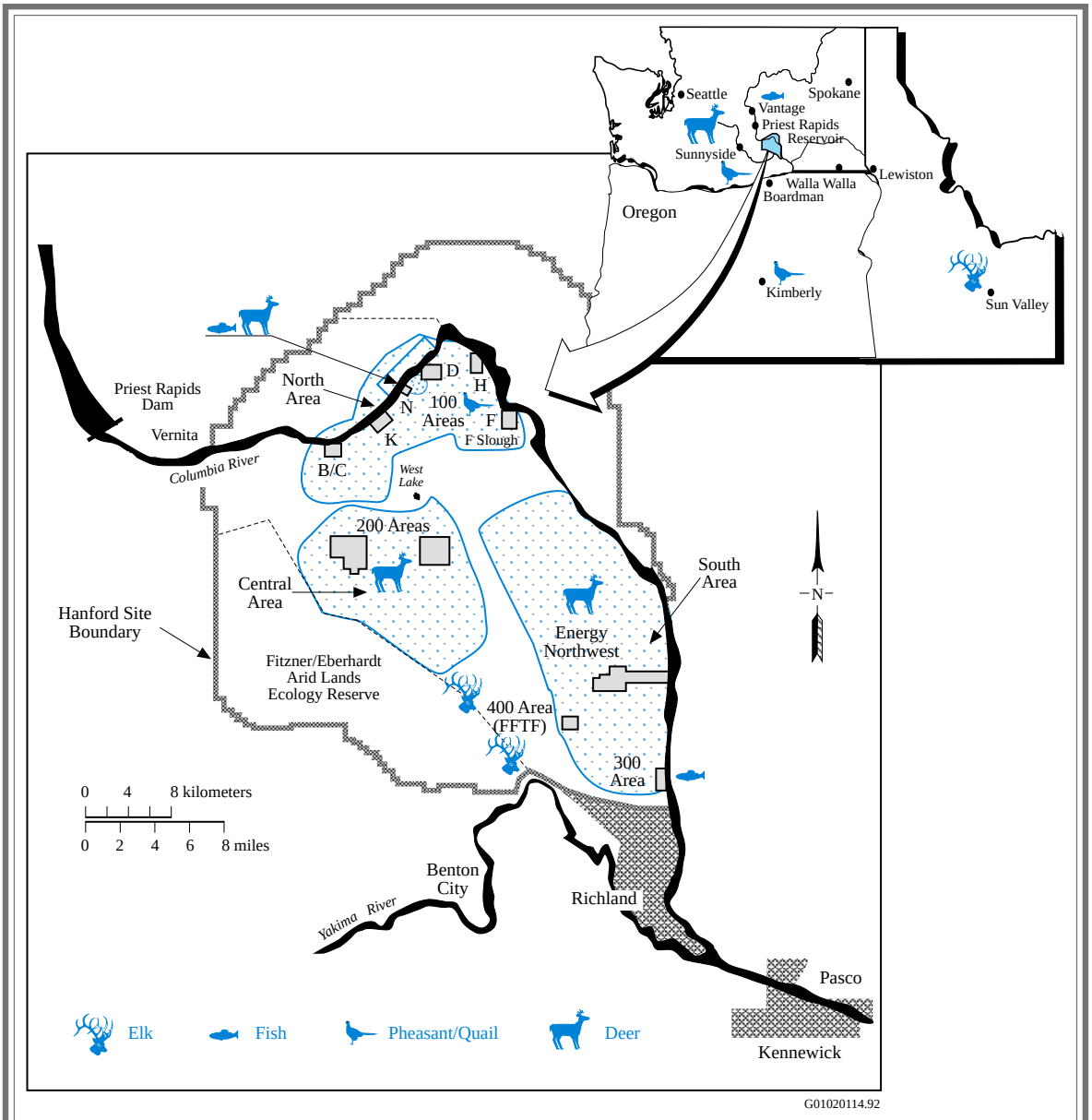


Figure 4.5.1. Sampling Locations for Fish and Wildlife, 2000

(see Appendix F). 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 uncertainty is used as an estimate of the nominal detection level for that analyte and particular medium. The average nominal analytical detection limit for strontium-90 in the bone is 0.04 pCi/g wet

Table 4.5.1. Locations, Species, and Contaminants Sampled for Fish and Wildlife, 2000

Medium	No. of Offsite Locations	No. of Onsite Locations	No. of Analyses		
			Gamma	Strontium-90	Isotopic Plutonium
Fish (carp)	1[(a)]	2[(b)]	14	14	0
Upland game (pheasant, quail)	2	2[(c)]	14	14	0
Mule deer	1	3[(d)]	7	7	2
Elk	0	3[(e)]	3	3	0

(a) Background samples collected from the Columbia River near Vantage, Washington.
(b) Samples collected from 100-N to 100-D Areas and the 300 Area.
(c) Samples collected from 100-D to 100-H Areas and 100-H to 100-F Areas.
(d) Samples collected from the north, south, and central areas populations (see Figure 4.5.1).
(e) Samples collected along Highway 240 .

weight and is 0.04 pCi/g wet weight for cesium-137 in muscle. All analytical results and propagated uncertainties for calendar year 2000 fish and wildlife samples may be found in PNNL-13487, APP. 1.

4.5.1 Fish Samples and Analytes of Interest

Although the amounts of radiological contamination measured in fish samples are well below levels that cause adverse health effects, monitoring fish for uptake and exposure to radionuclides at both nearby and distant locations continues to be important to track the long-term trends of contamination in the Columbia River environment. In 2000, carp were collected from two regions near the Hanford Site as well as from a background sampling area ~80 kilometers (50 miles) upstream of the Hanford Site near Vantage, Washington (see Figure 4.5.1). Fillets and the eviscerated remains (carcass) of fish were analyzed for a variety radiological contaminants and results from the nearby and distant locations were compared and are discussed below. All analytical data for 2000 samples are given in PNNL-13487, APP. 1.

In 2000, fillet (muscle) samples were analyzed with gamma spectrometry for cesium-137 and other gamma-emitting radionuclides (PNNL-13487, APP. 1). Cesium-137 results were below the analytical detection limit (0.04 pCi/g wet weight) in all 14 carp fillet samples collected in 2000. These results are consistent with results from eight carp fillet samples analyzed and reported in 1998 (PNNL-12088) and support results reported throughout the 1990s that indicate a gradual decline in cesium-137 levels in carp. All five samples collected from the upriver control area in 2000 also fell below the analytical detection limit as compared to 14 of 25 (56%) control area results below the analytical detection limit in 1996 and 1992.

Strontium-90 was found in 9 of 14 carp carcass samples collected and analyzed in 2000. Median levels of strontium-90 in carcass tissues collected from the Hanford Reach in 2000 were consistent with those observed in Hanford Reach samples collected over the preceding 8 years, as well as levels observed in five carp from the background area in 2000 (Figure 4.5.2). However, the strontium-90 concentration in one of the five carp samples

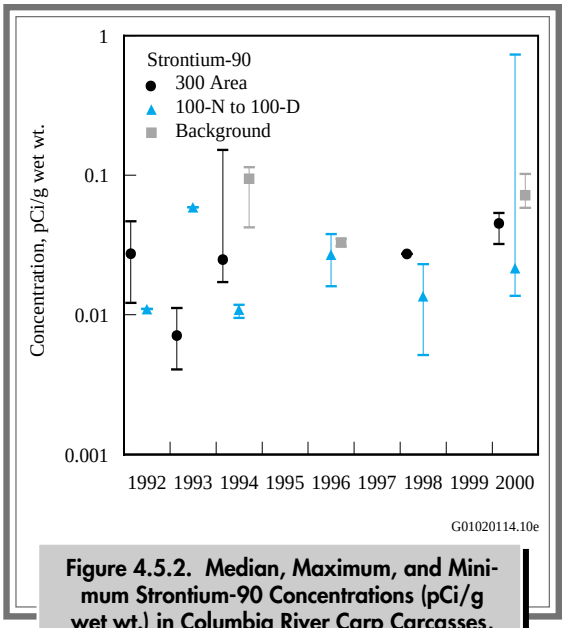


Figure 4.5.2. Median, Maximum, and Minimum Strontium-90 Concentrations (pCi/g wet wt.) in Columbia River Carp Carcasses, 2000 Compared to Previous 8 Years

collected between 100-N and 100-D Areas was over ten times greater than the median concentrations from all three sampling regions, and seven times greater than the highest value reported from the background area. Although this result (0.73 ± 0.17 pCi/g) is the highest reported over the preceding 8-year period, elevated amounts have been measured in carp and other bottom-feeding fishes (suckers and whitefish) collected near the 100-N Area in the past. This maximum-result pattern near the 100-N Area indicates some of the fish have consumed items containing elevated amounts of strontium-90 and have incorporated some strontium into their tissues. However, strontium-90 concentrations in carcass tissue would have to be around 600 pCi/g wet weight to be near the no-effect dose limit of 1.0 rad/day for aquatic organisms (see Section 6.6). The hypothetical dose associated with the consumption of Hanford Reach fish is found in Section 6.0.

4.5.2 Wildlife Sampling

The amount of radiological contamination measured in fish and wildlife samples is well below levels that cause adverse health effects. Monitoring various biota for uptake and exposure to radionuclides both near and distant from Hanford Site operations continues so that long-term trends of contamination in the ecosystem can be tracked. Wildlife sampled and analyzed in 2000 for radioactive constituents included elk, deer, and upland game (pheasants and quail). Wildlife samples were analyzed for gamma emitters, strontium-90, and isotopic plutonium. Three American avocets also were collected in response to a biological dose assessment screening process (see Section 6.6) and samples of bone tissues were analyzed for isotopic uranium.

4.5.2.1 Upland Game Samples and Analytes of Interest

Ten pheasants and four California quail were collected from three selected sampling areas in the fall of 2000 (see Figure 4.5.1). Radionuclide levels found in samples collected onsite in 2000 were compared to levels in samples collected onsite during the previous 8-year period and were also compared to levels found in samples collected from two background locations near Sunnyside, Washington, and Kimberly, Oregon.

Analyses for cesium-137 in muscle tissue require more mass than what is available on a single quail. For this reason, quail collected between the 100-D and 100-H Areas were composited into two samples for the gamma-scan analysis, for a total of two results from that particular area. Cesium-137 was not detected (at or below 0.03 pCi/g wet weight) in any of the five pheasant muscle samples collected between the 100-H and 100-F Areas nor in any of the five samples collected in the background areas (see Figure 4.5.3). These results were consistent with those reported in 1998 (6 of 6 below the analytical detection limit). The number of samples reported at or below the analytical detection limit in both 1998

and 2000 (18 of 18 collectively), reflects the continued downward trend in worldwide levels of cesium-137 fallout. Cesium-137 concentrations in 56% (17 of 30) of upland game muscle samples collected between 1990 and 1997 were reported as at or below the analytical detection limit.

Only 14% (2 of 14) of the upland game bone samples collected and analyzed for strontium-90 in 2000 had concentrations above the analytical detection limit (0.04 pCi/g wet weight). Although both positive results were collected between the 100-H and 100-F Areas along the river shoreline, they are not atypically high compared to results obtained from the background areas and do not indicate elevated levels of strontium-90 in upland game there (see Figure 4.5.3).

4.5.2.2 Deer and Elk Samples and Analytes of Interest

Studies of mule deer populations residing on the central portions of the Hanford Site indicate their division into three distinct groups (Tiller and Poston 2000): 1) the population that inhabits land around the retired reactors in the 100 Areas is designated the north area population; 2) the population that resides from the Old Hanford Townsite south to the 300 Area is designated the south area population; and 3) by default, the deer living around the 200 Areas, away from the river are designated the central area population (see Figure 4.5.1).

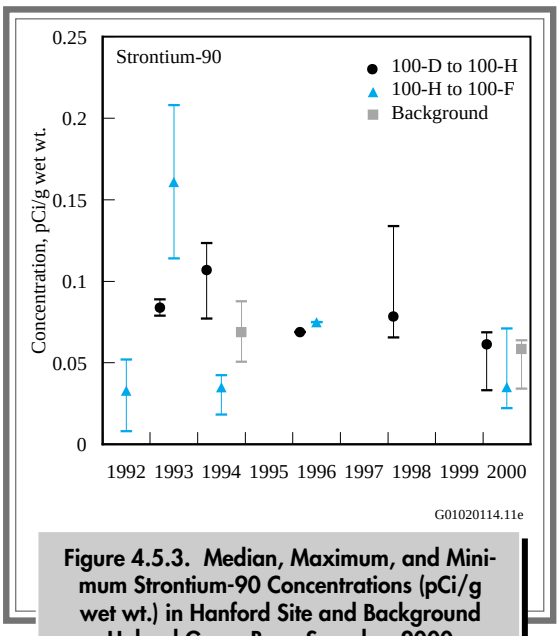


Figure 4.5.3. Median, Maximum, and Minimum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Upland Game Bone Samples, 2000 Compared to Previous 8 Years

Radionuclide levels in deer collected onsite in 2000 were compared to levels in deer collected distant from the site and to results reported for the preceding 8-year period. Background samples were collected between 1992 and 1995 near Boardman, Oregon and in Stevens County, Washington (see PNNL-11472, Section 4.5). In 2000, one background deer sample was obtained from the lower Yakima Valley, near Sunnyside, Washington (see Figure 4.5.1). Additionally, levels in onsite mule deer were compared to levels in a white-tailed deer that was cosampled with the Washington State Department of Health in 1996 from Vail, Washington (see PNNL-12088, Section 4.5). These comparisons with samples from distant locations are useful in evaluating Hanford's impact to deer. The deer collected in Stevens County and Vail, Washington, inhabited mountain regions that received more rainfall (and more atmospheric fallout) than Hanford, increasing background levels of fallout radionuclides there (Tiller and Poston 2000). The climate and precipitation of the Boardman, Oregon, and the Sunnyside, Washington, regions are similar to Hanford.

Until recently, elk have not inhabited areas on the Hanford Site where the potential for uptake of radionuclide contaminants exists (PNNL-13331) and very little data were available about contaminant concentrations in elk residing near or distant from the Hanford Site. In 1999, a baseline assessment of radionuclide levels in elk near and distant from the Hanford Site was conducted (PNNL-13230).

In 2000, elk continued to move across State Highway 240 from the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit to the central portions of the Hanford Site and resulted in three vehicle collisions during the year. Further discussion of elk movements, and the impact to animals from a large wildfire in late June 2000, are discussed in Section 8.2.

Radiological Results for Deer Samples. Cesium-137 was not detected (at or less than 0.02 pCi/g wet weight) in the seven deer muscle samples analyzed in 2000. These results are consistent with a decline in cesium-137 levels in all wildlife examined from 1983 through 1992 (PNNL-10174) and with data obtained over the preceding 8 years. In addition, the levels of cesium-137 in more than 60 Hanford Site deer muscle samples collected during the 1990s were less than the background levels measured in deer samples collected from 1991 through 1995 from Stevens County, Washington, and, in 1996, from Vail, Washington.

Strontium-90 was detected in all seven deer bone samples collected and analyzed in 2000. The lower results found in deer bone from the south and central areas populations are consistent with strontium-90 levels found in deer antlers (Tiller and Poston 2000). Median levels of strontium-90 found in deer bone in 2000 were similar between the three sampling areas onsite and the one background sample (Figure 4.5.4). One sample from the north area contained approximately ten times the amount of strontium-90 (3.54 ± 0.9 pCi/g wet weight) as other samples obtained onsite and was collected near the 100-N Area. Elevated levels of strontium-90 in samples from the north area occurred in about 1 of 3 deer samples collected there throughout the preceding 8-year period, with the highest concentration (20.8 ± 5.2 pCi/g wet weight) reported in 1992 (see Figure 4.5.4). Background samples of deer bone indicate strontium-90 concentrations can be as high as 2.06 pCi/g ± 0.4 pCi/g wet weight. The apparently higher concentrations in deer bone from the north area may indicate some exposure to

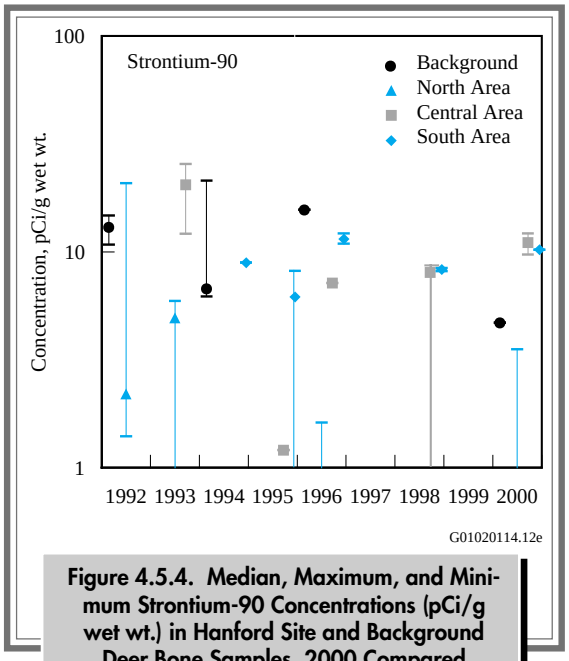


Figure 4.5.4. Median, Maximum, and Minimum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Deer Bone Samples, 2000 Compared to Previous 8 Years

localized, low-level contamination near the N Reactor (Tiller and Poston 2000).

Levels of strontium-90 found in deer bone samples collected between 1992 and 2000 were consistently higher ($p < 0.005$) than levels found in upland game bone or carp collected from the same vicinity (Figure 4.5.5). The diet of upland game primarily includes insects and dry-land grass seeds, whereas deer generally consume riparian and woody plants. Deep-rooted riparian plants can contain higher contaminant levels if their roots are deep enough to reach contaminated groundwater. Strontium-90 concentrations measured in carp and other bottom-feeding fishes (i.e., suckers and whitefish) near the 100-N Area indicates some of the aquatic organisms also have consumed items containing elevated amounts of strontium-90 and have incorporated a portion of the contamination into their tissues.

Plutonium-238 and -239/240 were not found above detection (0.00004 pCi/g wet weight) in two liver samples collected in 2000 from deer that

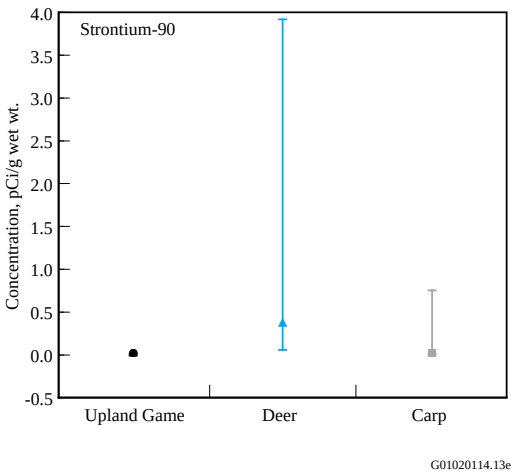


Figure 4.5.5. Comparison of Median, Maximum, and Minimum Strontium-90 Concentrations (pCi/g wet wt.) in the Bones of Deer, Upland Game, and Fish Collected near the 100-N Area, 2000

resided near the 200 Areas. These results are consistent with results reported through the 1990s. Since 1992, only 6% (2 of 34) samples of deer liver were reported above analytical detection for isotopic plutonium.

Radiological Results for Elk Samples. Radionuclide levels were monitored in tissue collected from three road-killed elk along State Highway 240 in 2000 (see Figure 4.5.1). With the exception of strontium-90, concentrations of all manmade radionuclides were reported at or below analytical detection limits. Strontium-90 was detected in bone tissue from all three of the animals (0.32 ± 0.09, 0.33 ± 0.09, and 0.28 ± 0.07 pCi/g wet weight). Figure 4.5.6 depicts strontium-90 concentrations in bone from elk collected between 1998 and 2000 on or near the Hanford Site, and from elk collected in central Idaho in 1999. Median and maximum results illustrate background elk samples contained over twice the amount of strontium-90 as compared to all elk samples that have been collected on or near the Hanford Site. Elk in central Idaho live at higher elevations where higher levels of strontium-90 reflect exposure to fallout contaminants in the atmosphere produced by worldwide weapons testing in the 1950s and 1960s (Tiller and Poston 2000). The median result reported in Hanford Site elk in 2000 (0.32 ± 0.09 pCi/g wet weight) was similar to levels reported in Hanford Site deer inhabiting the south and central areas (see Figure 4.5.4).

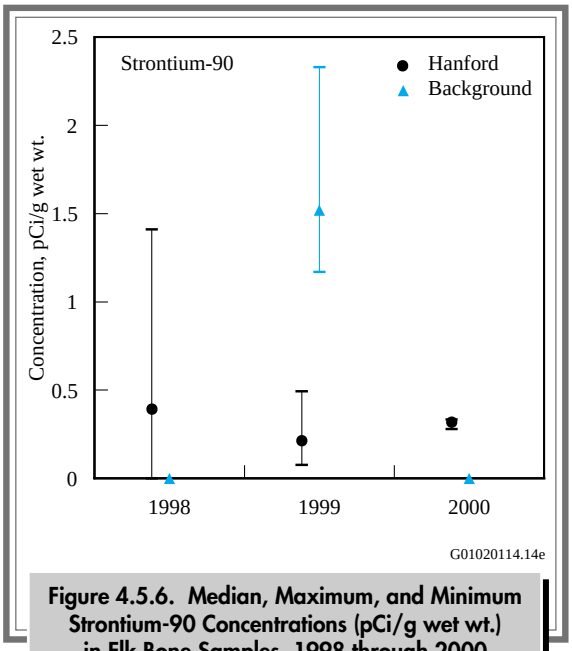


Figure 4.5.6. Median, Maximum, and Minimum Strontium-90 Concentrations (pCi/g wet wt.) in Elk Bone Samples, 1998 through 2000

4.5.3 West Lake Study

In 2000, a special study was initiated to measure uranium concentrations in biota, water and sediment in West Lake. West Lake is located north of the 200-East Area at the base of Gable Mountain. Originally, the site consisted of a small spring but in the 1950s became a small lake (about 7.8 hectares [19.2 acres] in 1979) after discharges of process water in the 200 Areas raised the local water table (PNL-7662). The resulting lake is highly saline and in recent years, has diminished in size (<1 hectare [0.4 acre]) due to reductions in wastewater discharges to the ground in the 200 Areas.

West Lake historically has had elevated uranium concentrations in sediment and most unfiltered water samples (see Section 4.2 and PNL-7662). Water soluble uranium can be distinguished from particulate uranium by filtering the samples. Soluble uranium has the potential to move through the aquatic food pathway to resident, salt-tolerant organisms.

Because of the ponds high salinity, mammals and many birds will not drink West Lake water. However, swallows, bats, and several species of shorebirds forage along the water's edge for saline tolerant black fly larvae (*Ephidridae*) and adults. Biological surveys in 2000 found that small sandpipers, killdeer, and several pairs of American avocet were the most common resident shorebirds at West Lake. Avocets, because of their size, feeding behavior, and relative abundance, were chosen as the best resident bird species to monitor for radiological contaminants and food-chain transfer of contaminants from West Lake water. The foraging patterns of avocets on black fly larvae maximized the potential for uptake of uranium through the water-food pathways. Avocet bone tissue was monitored for the accumulation of uranium-238 because bone tissue is known to absorb heavy metals including uranium (PNL-5484; Hammond and Beliles 1980).

Three adult American avocets were collected for analysis in July 2000. In addition, black fly larvae, black fly adults, pond water (filtered and unfiltered), seep water, and pond sediment were collected and analyzed for uranium-234, uranium-235, and uranium-238. This discussion focuses on uranium-238 (Table 4.5.2). Additional analytical data may be found in PNNL-13487, APP. 1. Uranium-238 concentrations in filtered seep water collected along the West Lake shoreline were above analytical detection limits but well below concentrations in pond water samples. Both filtered and unfiltered pond water samples contained comparable concentrations of uranium-238, indicating the uranium was present in a soluble form and that a food-chain pathway from black flies to shorebirds was likely. Black fly larvae, which are consumed by avocets, contained about twice as much uranium-238 as adult flies. However, uranium-238 concentrations in avocet bone samples (see Table 4.5.2) were one to two orders of magnitude lower than concentrations in blackflies. This indicates that there was no "magnification" of uranium through the food chain. Uranium data collected for this study were also used to evaluate the radiological dose to avocets (see Section 6.0).

Table 4.5.2. Uranium-238 Concentrations in the West Lake Environment

Sample	Concentration[a]
Avocet 1	0.024 ± 0.011 pCi/g wet wt.
Avocet 2	0.007 ± 0.007 pCi/g wet wt.
Avocet 3	0.007 ± 0.006 pCi/g wet wt.
Black fly - larvae	0.55 ± 0.01 pCi/g dry wt.[b]
Black fly - adult	0.25 ± 0.06 pCi/g dry wt.[b]
Filtered seep water	27.7 ± 5.2 pCi/L
Filtered pond water	1,280 ± 220 pCi/L
Unfiltered pond water	1,120 ± 200 pCi/L
Sediment	1.2 ± 0.25 pCi/g dry wt.

(a) ±2 sigma total analytical error.
(b) Wet weight concentrations are 0.16 and 0.073 pCi/g for larvae and adults, respectively.

4.6 External Radiation Surveillance

E. J. Antonio

External radiation is defined as radiation originating from a source external to the body. External radiation fields consist of a natural component and an anthropogenic, or manmade, component. The natural component can be divided into 1) cosmic radiation; 2) primordial radionuclides, 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 historical 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 and Measurements 1987). Moist soil or snow covered soil result in lower levels.

The interaction of radiation with matter results in energy being deposited in that matter. This is why your hand feels warm when exposed to a light source (e.g., sunlight, flame). 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. The International System of Units introduced the gray and is defined as follows: 1 gray is equivalent to 100 rad (American Society for Testing and Materials 1993). For a point of reference, a radiological dose of 100,000 mrem beta/gamma to an 8-ounce cup of water will deposit enough energy in the water to increase the temperature of the water by about 1°F.

One device for measuring radiation absorbed dose is the thermoluminescent dosimeter. This device absorbs and stores energy of ionizing radiation within the dosimeter's crystal lattice. By heating the material under controlled laboratory conditions, the stored energy is released in the form of light, which is measured and related to the amount of ionizing radiation energy stored in the material. Thermoluminescence, or light output exhibited by dosimeters, is proportional to the energy absorbed, which by convention is related 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 (Shleien 1992). 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 unity to obtain dose equivalence (H) measured in rem. The sievert is the International System of Units equivalent of the rem.

$$D\ (rad) = X\ (R) * 1.0$$

$$H\ (rem) = D * N * Q$$

In 2000, environmental external radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters and pressurized ionization chambers. External radiation and surface contamination surveys at specified locations were performed with portable radiation survey instruments.

4.6.1 External Radiation Measurements

Six years ago, in 1995, the Harshaw 8800-series system replaced the former Hanford Standard environmental dosimeter system. The Harshaw environmental dosimeter consists of two TLD-700 chips and two TLD-200 chips and also provides both shallow and deep dose measurement capabilities. Thermoluminescent dosimeters are positioned ~1 meter (3 feet) above the ground at 29 onsite locations (Figure 4.6.1). A former thermoluminescent dosimeter surveillance station, located on the Hanford Site, was re-established in August 2000, following the Hanford wildfire (see station number 11 in Figure 4.6.1). Figure 4.6.2 shows the thermoluminescent dosimeter locations around the site perimeter, in nearby communities, and distant locations. Figure 4.6.3 gives the thermoluminescent dosimeter locations along the Columbia River shoreline. Three thermoluminescent dosimeter surveillance locations were repositioned in 2000 due to vandalism. As a consequence of the repositioning, one location was re-classified from being a perimeter location to a shoreline location. All changes were documented in project files.

All 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 dosimeter was in the field. Quarterly dose equivalent rates (millirem per day) at each location were converted to annual dose equivalent rates (millirem per year) by averaging the quarterly dose equivalent rates and multiplying by 365 days per year. The two TLD-200 chips are included only to determine doses in the event of a radiological emergency.

To determine the maximum dose rate for each distance classification, the annual dose rates, as calculated above for each location were compared and the highest value was reported. The uncertainties associated with the maximum dose rates were calculated as two standard deviations of the quarterly dose rates then corrected to an annual rate.

All community and most of the onsite and perimeter thermoluminescent dosimeter locations are collocated with air monitoring stations. The onsite and perimeter locations were selected based on determinations of the highest potentials for public exposures (i.e., 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.

The shoreline of the Columbia River in the Hanford Reach is monitored by a series of 26 thermoluminescent dosimeters located in the area from Vernita Bridge to downstream of Bateman Island at the mouth of the Yakima River. This includes a new location established in 2000, on the shoreline near 100-H (station number 10) and a repositioned dosimeter at the Vernita Bridge (station number 1).

Ground contamination surveys are also conducted quarterly at 13 shoreline locations. These measurements are made to estimate radiation exposure levels attributed to sources on the Hanford Site, to estimate background levels along the shoreline, and to help assess exposures to onsite personnel and offsite populations. Ground contamination surveys are conducted using Geiger-Müeller meters (Geiger counters) and Bicron® Microrem meters. Results are reported in counts per minute and microrem per hour, respectively. Geiger counter measurements are made within 2.54 centimeters (1 inch) of the ground and cover a 1-square meter (10-square foot) area. The Bicron® measurements are taken 1 meter (3 feet) above the ground surface and at least 10 meters (33 feet) away from devices or structures, which may contribute to the ambient radiation levels.

Pressurized ionization chambers are situated at four community-operated monitoring stations (see

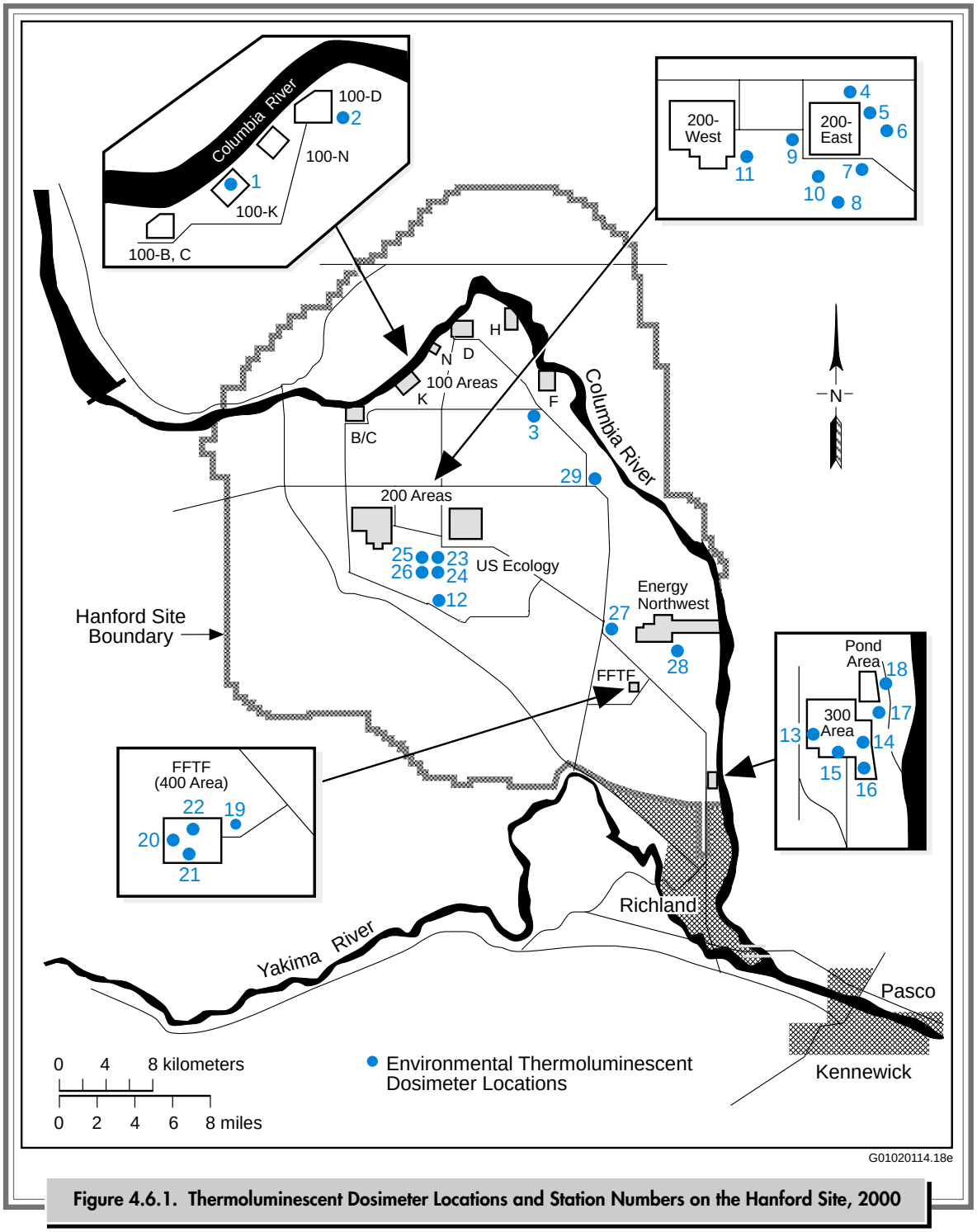


Figure 4.6.1. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 2000

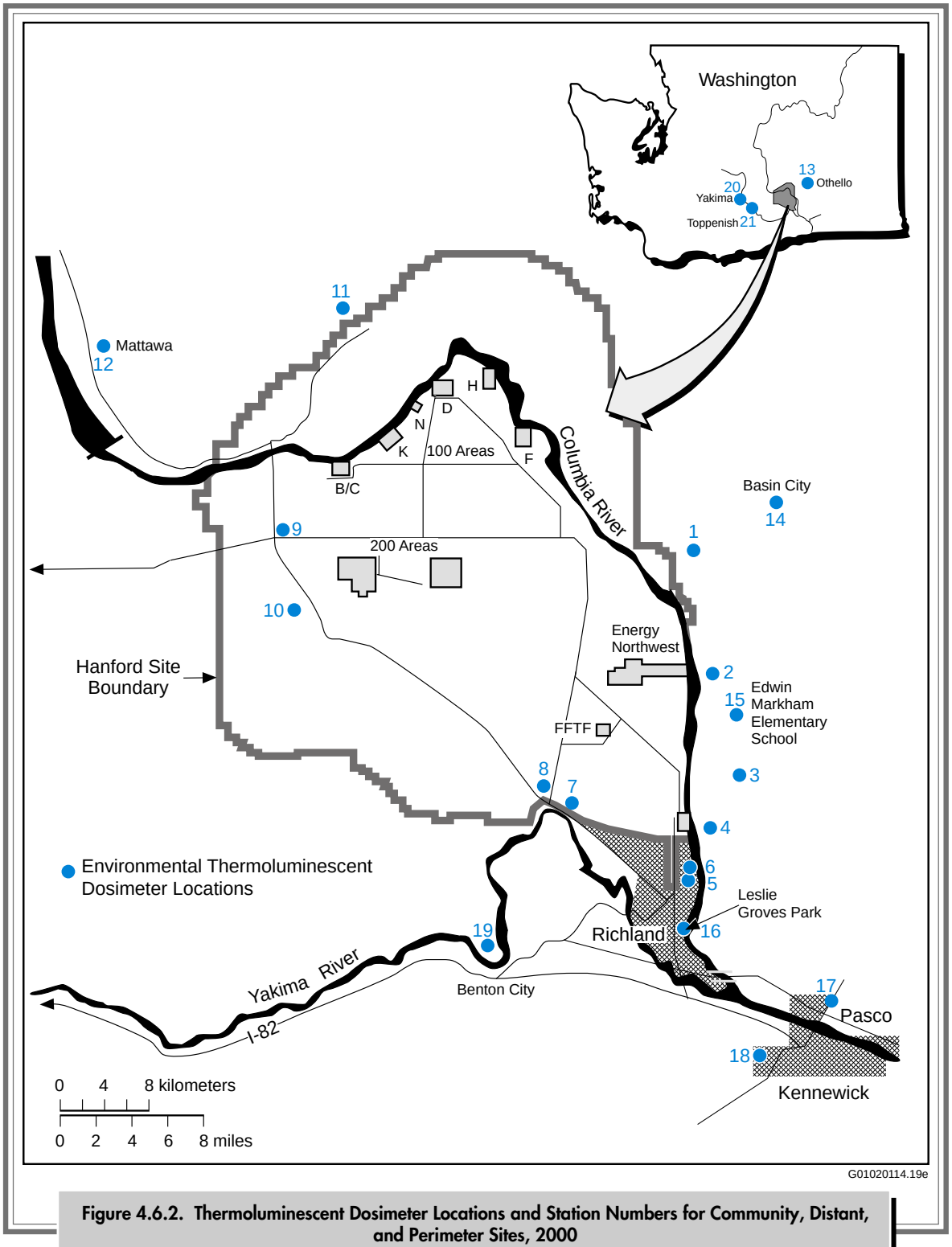


Figure 4.6.2. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 2000

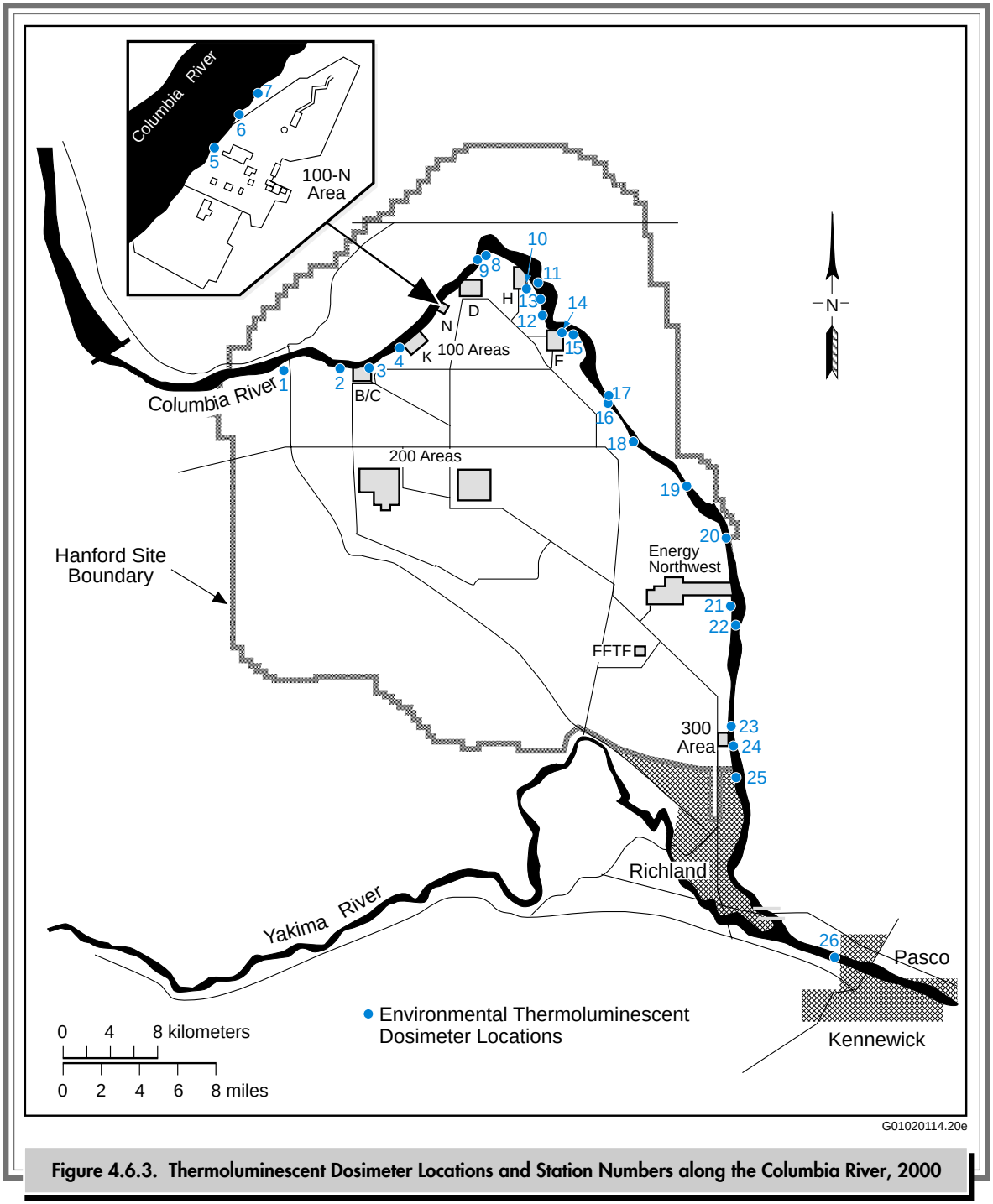


Figure 4.6.3. Thermoluminescent Dosimeter Locations and Station Numbers along the Columbia River, 2000

Section 8.4). These instruments provide a way to measure ambient exposure rates near and downwind of the site and at locations distant and upwind of the site. Real-time exposure rate data are displayed at each station to provide information to the public and to serve as an educational tool for the teachers who manage the stations.

4.6.1.1 External Radiation Results

Thermoluminescent dosimeter readings have been converted to annual dose equivalent rates by the process described above. Table 4.6.1 shows the maximum and mean dose rates for perimeter and offsite locations measured in 2000 and the previous 5 years. External dose rates reported in Tables 4.6.1, 4.6.2, and 4.6.3 include the maximum annual average dose rate (±2 standard deviations) for all locations within a given surveillance zone and the mean dose rate (±2 standard error of the mean) for each distance class or area. Locations were classified (or grouped) based on their proximity to the site.

The annual dose rates measured at perimeter and offsite locations in 2000 and preceding 5 years are given in Table 4.6.1 and Appendix B. The mean perimeter dose rate in 2000 was 89 ± 4 mrem/yr; the maximum was 106 ± 8 mrem/yr. The 5-year perimeter mean dose rate was 88 ± 3 mrem/yr. The mean background dose rate (measured at distant communities) in 2000, was 69 ± 1 mrem/yr, compared to the previous year's mean of 74 ± 2 mrem/yr and the current 5-year average of 71 ± 2 mrem/yr. The variation in dose rates may be partially attributed to changes in natural background radiation that can

Table 4.6.1. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 2000 Compared to Previous 5 Years

		2000		1995-1999		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Perimeter	1 - 12	106 ± 8	89 ± 4	34	98 ± 15	88 ± 3
Community	13 - 19	88 ± 7	78 ± 3	40	90 ± 9	78 ± 2
Distant	20 - 21	69 ± 5	69 ± 1	11	78 ± 3	71 ± 2

(a) ±2 standard error of the mean.
(b) All station locations are shown on Figure 4.6.2.
(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 4.6.2. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters along the Hanford Reach of the Columbia River, 2000 Compared to Previous 5 Years

		2000		1995-1999		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Typical shoreline	1 - 22	96 ± 15	85 ± 3	111	114 ± 12	87 ± 2
100-N shoreline	5 - 7	131 ± 7	112 ± 22	19	187 ± 17	133 ± 14
All shoreline	1 - 25	131 ± 7	88 ± 5	130	187 ± 17	93 ± 4

(a) ±2 standard error of the mean.
(b) All station locations are shown on Figure 4.6.3.
(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 4.6.3. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters on the Hanford Site, 2000 Compared to Previous 5 Years

		2000		1995-1999		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
100 Areas	1 - 3	81 ± 3	79 ± 4	11	88 ± 8	80 ± 5
200 Areas	4 - 12	94 ± 11	87 ± 4	37	98 ± 6	88 ± 2
300 Area	13 - 18	84 ± 7	82 ± 1	30	89 ± 7	82 ± 1
400 Area	19 - 22	85 ± 6	82 ± 2	20	89 ± 7	83 ± 4
600 Area	23 - 29	101 ± 13	87 ± 6	29	138 ± 18	94 ± 7
Combined onsite	1 - 29	101 ± 13	84 ± 2	127	138 ± 18	86 ± 2

(a) ±2 standard error of the mean.
(b) All station locations are shown on Figure 4.6.1.
(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.

occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15% to 25%) (National Council on Radiation Protection and Measurements 1987). Other factors possibly affecting the annual dose rates reported here have been described in PNL-7124 and include variations in the sensitivity of individual thermoluminescent dosimeter zero-dose readings, fading, random errors in the readout equipment, and changes in station locations. Figure 4.6.4 displays a comparison of annual average dose rates between onsite, perimeter, and distant thermoluminescent dosimeter locations from 1995 through 2000.

Table 4.6.2 provides the measured dose rates for thermoluminescent dosimeters positioned along the Columbia River shoreline. Dose rates were highest along the shoreline near the 100-N Area and were ~1.4 times the typical shoreline dose rates. The higher dose rates measured along the 100-N Area shoreline have been attributed to past waste management practices in that area (PNL-3127). The 2000 maximum annual shoreline dose rate was 131 ± 7 mrem/yr, which is not significantly different from the maximum of 143 ± 5 mrem/yr measured in 1999, but is significantly lower than the 5-year maximum of 187 ± 17 mrem/yr. The 5-year maximum was measured in 1995 along the 100-N shoreline. 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 6.0.

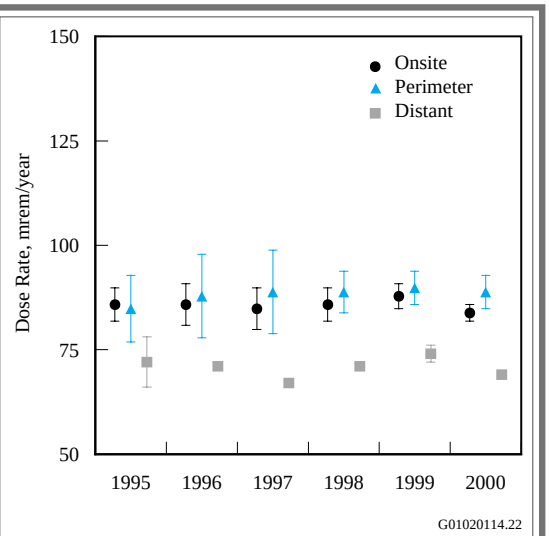


Figure 4.6.4. Annual Average Dose Rates (±2 standard error of the mean), 1995 through 2000

Table 4.6.3 summarizes the results of 2000 onsite measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than average dose rates measured at distant locations. The highest average dose rate on the site (101 ± 13 mrem/yr) was detected in the 600 Area and was due to waste disposal activities at US Ecology, Inc., a non-DOE facility. The 5-year maximum onsite dose rate (138 ± 18 mrem/yr) was measured in 1996, also near the US Ecology facility.

4.6.2 Radiological Survey Results

In 2000, Geiger counters and Bicron® Microrem meters were used to perform radiological surveys at selected Columbia River shoreline locations. These surveys provide a coarse screening for elevated radiation fields. The surveys showed that radiation levels at the selected locations were comparable to levels observed at the same locations in previous years. Historically, the highest dose rate measured with the Bicron® Microrem meter (20 μrem/h) was measured in winter along the 100-N Area shoreline; the lowest dose rate measured was 4 μrem/h and was recorded at other locations in the spring and autumn. The highest reported count rate measured with the Geiger counter in ground level surveys was 100 counts per minute. The lowest ground level count rate (less than 50 counts per minute) was recorded at the same location and on the same day that the lowest Bicron® reading was recorded.

Survey data are not included in the 2000 surveillance data report (PNNL-13487, APP. 1) but are maintained in the Surface Environmental Surveillance Project files at Pacific Northwest National Laboratory and can be obtained on written request.

Gamma radiation levels in air were continuously monitored in 2000 at four community-operated air monitoring stations (see Section 8.4). 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.

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 each station every month because of various problems with equipment and with electrical power. Measurements were not obtained at Basin City or Edwin Markham schools during the year because the data collection systems used at those locations would not work properly after December 31, 1999 (the start of the new millennium). New equipment was ordered for these locations and is scheduled to be installed in 2001. The data collected at Richland and Toppenish each month in 2000 are summarized in Table 4.6.4.

Generally, monthly exposure rates ranged from a maximum of 10.7 μR/h at Leslie Groves Park in October to a minimum of 0.7 μR/h at Toppenish in May (see Table 4.6.4). Median readings at the stations near Hanford were consistently between 8.0 and 8.9 μR/h, and readings at the distant station (Heritage College) ranged between 7.7 and 8.3 μR/h. These dose rates were consistent with those measured by thermoluminescent dosimeters at these locations (Table 4.6.5).

Table 4.6.4. Average Exposure Rates Measured by Pressurized Ionization Chambers at Two Offsite Locations,[a] 2000

Month		Exposure Rate, μR/h (number of readings)[b] Leslie Groves Park[c]		Exposure Rate, μR/h (number of readings)[b] Toppenish[c]	
January	Median	8.1	(744)	7.9	(637)
	Maximum	9.6		10.2	
	Minimum	4.5		7.4	
February	Median	8.0	(696)	7.9	(692)
	Maximum	9.0		9.1	
	Minimum	4.2		7.3	
March	Median	ND[d]		7.8	(764)
	Maximum	ND		8.4	
	Minimum	ND		7.4	
April	Median	ND		7.8	(691)
	Maximum	ND		10.3	
	Minimum	ND		7.4	
May	Median	ND		7.8	(743)
	Maximum	ND		10.5	
	Minimum	ND		0.7	
June	Median	ND		7.7	(720)
	Maximum	ND		8.7	
	Minimum	ND		7.4	
July	Median	8.4	(744)	7.7	(742)
	Maximum	8.8		8.9	
	Minimum	8.4		7.3	
August	Median	8.5	(698)	7.9	(741)
	Maximum	9.0		9.2	
	Minimum	7.7		7.5	
September	Median	8.6	(719)	8.1	(719)
	Maximum	9.7		9.5	
	Minimum	3.6		7.5	
October	Median	8.7	(744)	8.3	(742)
	Maximum	10.7		9.8	
	Minimum	5.4		7.5	
November	Median	8.9	(720)	8.3	(707)
	Maximum	9.9		10.3	
	Minimum	6.1		7.6	
December	Median	8.8	(744)	7.9	(665)
	Maximum	10.2		10.4	
	Minimum	5.4		7.1	

(a) Sampling locations are illustrated in Figure 4.1.1.
(b) Number of 60-minute averages used to compute monthly average.
(c) Readings are stored every 60 minutes. Each 60-minute reading is an average of 360 individual measurements.
(d) ND = No data collected; instrument or power problems.

Table 4.6.5. Quarterly Average Exposure Rates (μR/h[a]) Measured by Thermoluminescent Dosimeters at Two Offsite Locations,[b] 2000

Quarter Ending	Leslie Groves Park	Toppenish
March	9.08 ± 0.417	8.25 ± 0.042
June	7.38 ± 0.125	7.54 ± 0.125
September	NS	7.79 ± 0.542
December	NS	8.04 ± 0.000

(a) ±2 standard deviation of the exposure rate.
(b) Sampling locations shown on Figure 4.1.1.
(c) NS = No sample; thermoluminescent dosimeter missing.

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5.0 The 2000 "24 Command" Hanford Site Wildfire

L. L. Cadwell and T. M. Poston

In early summer 2000, a large wildfire extensively burned federal, state, and private lands on and around the Hanford Site. The wildfire originated near the western boundary of the Hanford Site on State Route 24, ~2 miles west of the junction of State Routes 24 and 240 (Figure 5.1). Dry vegetation was ignited by a vehicle accident that occurred about 1:30 p.m. on June 27, 2000. Throughout the afternoon of June 27 and much of June 28, 2000, light winds pushed the fire mostly south from the point of ignition onto private grazing lands and through the western portion of the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit of the Hanford Reach National Monument (see Figure 1.2). During this time the fire crossed State Route 240, prompting the U.S. Department of Energy (DOE) to declare an alert-level emergency as it approached the 200-West Area. An alert-level emergency activates the Hanford Emergency Operations Center and implements certain emergency responses, protective actions, and authorities. Winds increased out of the northwest in the early evening of June 28, 2000, and rapidly pushed the fire southeast across most of the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit. By late evening on June 28, the fire had moved to the outskirts of Benton City, Washington, where several homes and other structures were burned (see Figure 5.1). On June 29, 2000, the wind changed direction and the fire spread north and east across the Hanford Site toward a non-radiological landfill, the 300 Area, the BC Cribs radiological control area, and the 200-East Area. By June 30, 2000, only a relatively small area of land southwest of the 200-East Area continued to burn. The wildfire was declared out at 4:00 p.m. on July 1, 2000.

Approximately 66,400 hectares (164,000 acres) were burned including ~8,100 hectares (20,000 acres) of private land and 58,300 hectares (144,000 acres) of DOE and U.S. Fish and Wildlife Services managed lands. None of the Hanford Site's operational facilities burned, but the fire approached the boundaries of the 200-East and the 200-West Areas. The fire, formally designated the "24 Command Fire" based on its point of origin on State Route 24, will be referred to as the 2000 Hanford wildfire in the remainder of this chapter.

The following sections describe fire related environmental monitoring activities sponsored by DOE's Richland Operations Office and conducted by Hanford Site contractor personnel. Additionally, monitoring activities undertaken by other federal and state agencies are discussed. DOE has published a detailed report on the fire (DOE/RL-2000-63), which is available on the DOE website at http://www.hanford.gov/docs/rl-2000-63/index.html. The U.S. Fish and Wildlife Service, managers of the Hanford Reach National Monument, which includes the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit, in concert with other federal agencies, documented the wildfire's impact on monument resources and investigated possible wildlife habitat rehabilitation activities (U.S. Department of the Interior 2000). The Washington State Department of Health investigated potential radiological releases from the fire and reported their sample analysis results on their website at http://www.doh.wa.gov/ehp/rp/default.htm. The U.S. Environmental Protection Agency (EPA), at the request of the Washington State Department of Health, collected high-volume air particulate samples in local communities from June 30 through July 3, 2000. The results of EPA sample analysis were

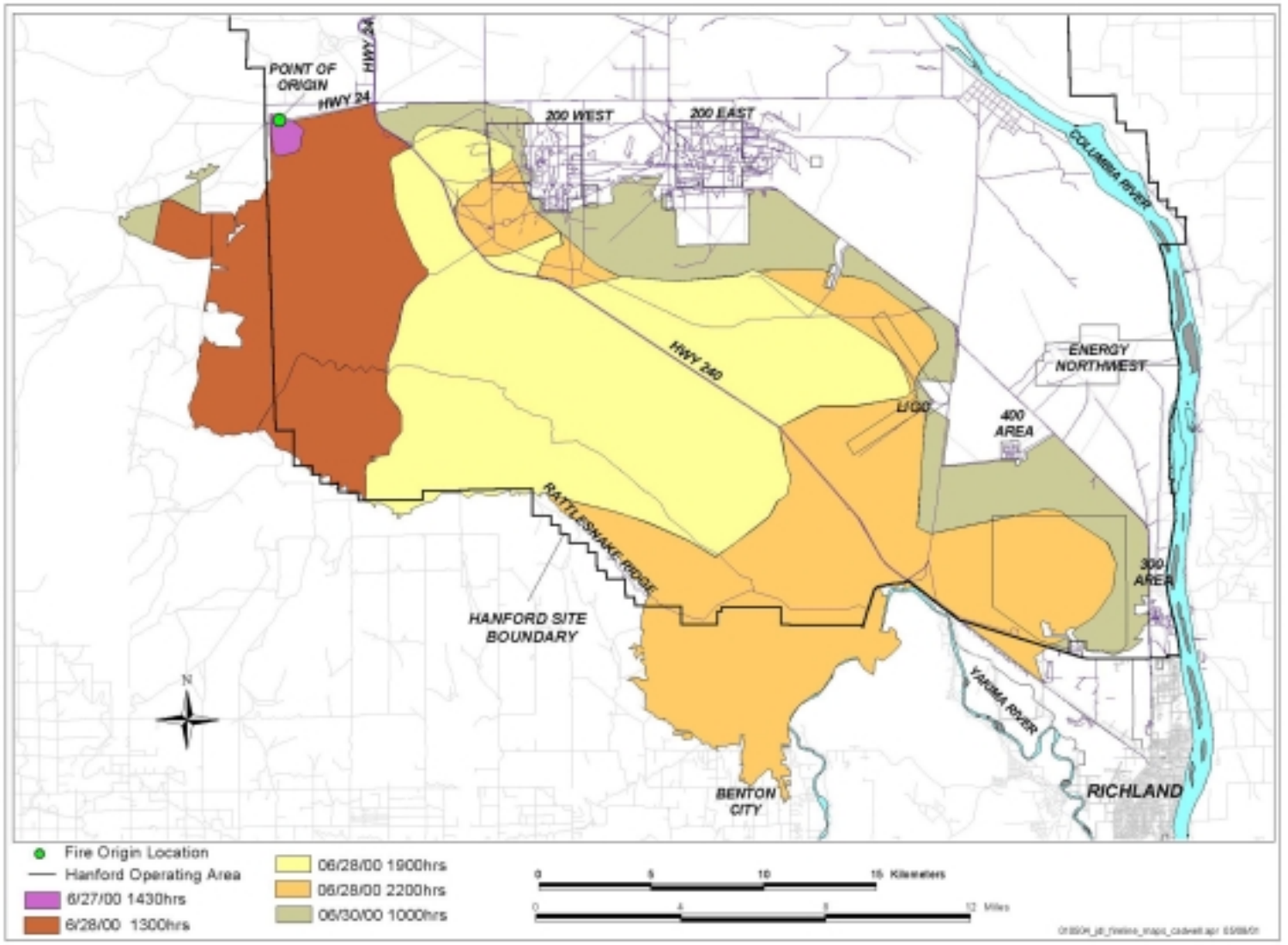


Figure 5.1. Progression of the 2000 Hanford Site Wildfire, June 27 through June 30, 2000

reported on the Washington State Department of Health website at http://www.doh.wa.gov/ehp/rp/epa_data.htm.

The rest of this chapter summarizes air monitoring efforts during and after the fire including post-fire radionuclide monitoring of farm products, soil, ash, and natural vegetation on and around the Hanford Site; brief assessments of the impact to biological and cultural resources; and post-fire soil stabilization and revegetation efforts. Some sampling was conducted at a fire near Mabton, Washington (formally designated the Mule Dry Fire), in late August 2000, to compare monitoring results with those obtained from the 2000 Hanford wildfire. Mabton is a small community located ~32 kilometers (20 miles) southwest of the Hanford Site.

5.1 Air Monitoring

DOE personnel, agency officials, and contractor staff that convened at the Hanford Site emergency center in the late afternoon of June 28, 2000, recognized the potential for airborne suspension of Hanford contaminants if the fire reached waste disposal areas in and near the 200 Areas. This concern became the reason DOE deployed crews to collect environmental samples that evening. The Washington State Department of Health also notified selected staff to report to the emergency center for deployment. Surface Environmental Surveillance Project staff consulted with staff from the Near-Facility Environmental Monitoring Program and personnel from DynCorp, another Hanford Site contractor, to determine where DOE samples should be collected. Hanford meteorology personnel manned the Hanford Meteorology Station near the 200-West Area to monitor changes in weather patterns and were present also at the emergency center throughout the evening. Wind predictions were updated at 15-minute intervals.

During the fire, DynCorp staff collected air samples along fire lines. Washington State Department of Health crews collected samples of airborne dust, smoke, and ash at locations on and off the site. EPA deployed crews to collect air particulate samples in communities at numerous locations around the Hanford Site from the evening of June 30 through July 3, 2000. The Surface Environmental Surveillance Project and Near-Field Environmental Monitoring Program already had continuous air particulate samplers operating on and around the site for their existing programs. Additional onsite air sampling was conducted by personnel from a DOE contractor and the Washington State Department of Health during months following the fire when strong winds suspended dust and ash into the air.

5.1.1 Near-Facility Air Monitoring

C. J. Perkins

Routine monitoring for radioactive particles in air near Hanford Site facilities in 2000 used a network of continuously operating air samplers at 85 locations (see Section 3.2, Table 3.2.2). Filter samples were usually collected biweekly; however, during the fire, the routine sampling schedule was modified (shortened) and samples were collected early so that they could be analyzed immediately. All air filter samples were screened for gross alpha and gross beta activity. They were then grouped (composited) into three sampling periods covering eight geographical onsite locations (Figure 5.2) and analyzed for specific radionuclides. The geographic composite groups and individual sampling locations are listed in Appendix B, Table B.11.

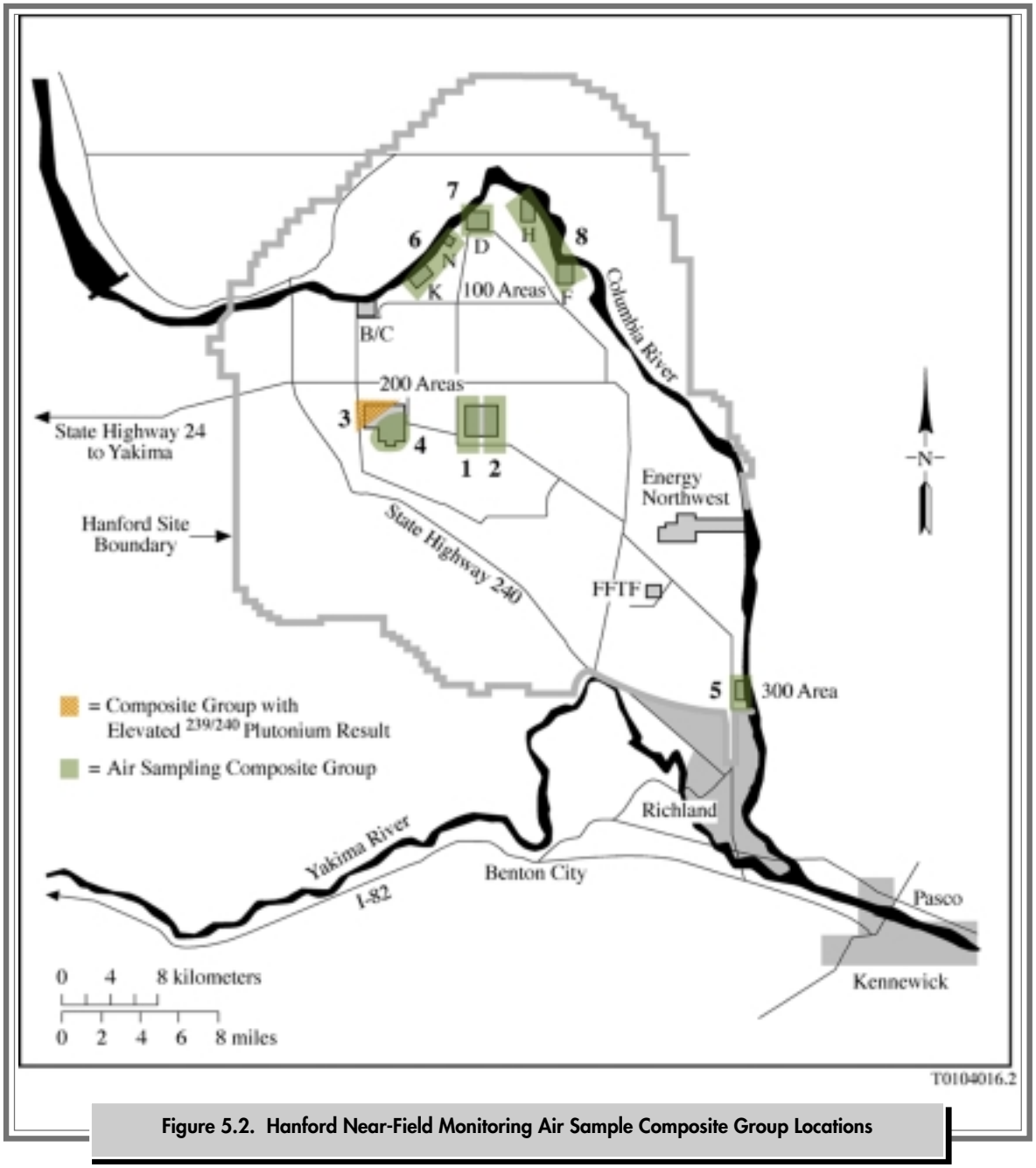


Figure 5.2. Hanford Near-Field Monitoring Air Sample Composite Group Locations

The three sampling periods included:

- June 26 through June 30, 2000. Sampling during the fire ended when the fire was under control and workers were allowed to return to the site
- June 30 through July 10, 2000, immediately following the fire. There were several windstorms during this period that created locally dense levels of airborne dust and ash in the 200 Areas
- July 10 through July 24, 2000.

5.1.1.1 Near-Facility Air Monitoring Results

Radionuclide concentrations in near-facility air samples were compared to the DOE derived concentration guides (see Appendix D, Table D.5). Derived concentration guides are concentrations of radionuclides in air that if continuously inhaled at an annual average rate, would result in an effective dose equivalent of 100 mrem/yr. Results for strontium-90, uranium isotopes, and plutonium-239/240 in samples representing the eight geographic composite groups are shown in Table 5.1 and compared to concentrations from their respective operational areas measured during the time period 1995 through 1999. A complete listing of near-facility air sampling results for 2000 is in PNNL-13487, APP. 2. Analytical results from fire related samples are summarized below.

Gross Alpha and Gross Beta Analyses. Gross alpha concentrations measured in the 200 Areas appeared to be elevated only for samples collected while the fire was burning. Ash and smoke may have contained elevated levels of natural uranium and its short-lived decay progeny that could have increased gross alpha results. The increase in gross alpha, which is common to all range fires where vegetation is burned, was exacerbated when samples were held for just 4 to 5 days prior to analysis to allow the natural activity of uranium progeny to decay away. Routinely collected samples are held for at least 7 days prior to analysis to allow this decay to occur. Gross alpha and gross beta concentrations measured after the fire in the 200 Areas, and for all three sampling periods in the 100 and 300 Areas, were consistent with mean (±2 standard error of the mean) historical levels of 0.0011 ± 0.00004 (alpha) and 0.015 ± 0.0005 (beta) pCi/m^3 (Table 5.2).

Specific Radionuclide Analyses. Samples were analyzed for strontium-90, uranium-234, uranium-235, uranium-238, plutonium-239/240, and gamma-emitting radionuclides (e.g., cesium-137). During the first sampling period (June 26 through 30, 2000), the concentrations of strontium-90 at several locations exceeded the maximum concentration observed over the 5-year period, 1995 through 1999 (see Table 5.1). The maximum strontium-90 value detected during the first sampling period was 0.0029 pCi/m^3 in the 200 Areas and was 3,000 times lower than the DOE derived concentration guide (9 pCi/m^3). Maximum uranium concentrations were detected during the third sampling period (July 10 through 24, 2000) around the 300 Area, but concentrations did not exceed maximum values reported over the preceding 5 years for the same location and were about 100 times lower than the DOE derived concentration guide (0.1 pCi/m^3). The maximum concentration of plutonium-239/240 (0.0016 pCi/m^3) was measured in a sample collected during the second sampling period (June 30 through July 10, 2000) in the 200-West Area. This concentration was greater than the maximum result reported for the site within the past 5 years, but about 12 times lower than the DOE derived concentration guide for plutonium-239/240 (0.02 pCi/m^3). For all three sampling periods, manmade gamma-emitting radionuclides and plutonium-238 concentrations were consistently either below analytical detection limits or at background levels.

5.1.2 Sitewide and Offsite Air Monitoring

B. M. Gillespie

Surface Environmental Surveillance Program staff prepared a special collection and analysis plan for fire-related air particulate samples using existing air particulate sampling stations. The special collection and analysis plan called for the early collection of selected samples at some locations through June 28, 2000, and the collection of an extra sample at several locations during the fire. The plan focused on locations around the Hanford Site perimeter and at nearby communities. Priority handling and analysis of samples at the laboratory

Table 5.1. Summary of Near-Facility Air Sampling Results from the June 2000 Hanford Site Wildfire Compared to Previous Years

Isotope	Composite Group	Location	Sample Period 1[a] Result (pCi/m³)[b]	Sample Period 2[a] Result (pCi/m³)[b]	Sample Period 3[a] Result (pCi/m³)[b]	1995-1999 Average (pCi/m³)[c]	1995-1999 Maximum (pCi/m³)[d]
Strontium-90	1	200-East	0.0018 ± 0.00063	0.00086 ± 0.00026	0.00025 ± 0.00015	0.00038 ± 0.00021	0.0098 ± 0.0012
	2		0.0015 ± 0.0006	0.00056 ± 0.00022	0.0001 ± 0.0001		
	3	200-West	**0.0029 ± 0.00072**	0.00041 ± 0.00025	0.00015 ± 0.00014	0.00031 ± 0.00005	0.0015 ± 0.0003
	4		0.0014 ± 0.00057	0.0007 ± 0.00024	0.00011 ± 0.00013		
	5	300 Area	0.00085 ± 0.00034	0.0013 ± 0.00052	-0.000068 ± 0.00024	0.00029 ± 0.000095	0.00043 ± 0.00031
	6	100-N/100-K	0.0019 ± 0.00061	0.00036 ± 0.0002	0.0002 ± 0.00011	0.0003 ± 0.000068	0.0016 ± 0.00026
	7	100-D	0.0019 ± 0.00076	0.00077 ± 0.00031	0.00043 ± 0.00017	0.00046 ± 0.00018	0.0015 ± 0.00045
	8	100-H/100-F	0.0013 ± 0.0006	0.00083 ± 0.00021	0.000054 ± 0.00012	0.0004 ± 0.00016	0.00089 ± 0.00059
Uranium-234	1	200-East	0.000037 ± 0.000023	0.000051 ± 0.00002	0.000036 ± 0.000014	0.000019 ± 0.0000018	0.000086 ± 0.000048
	2		0.000048 ± 0.000024	0.000034 ± 0.000014	0.000024 ± 0.00001		
	3	200-West	0.00004 ± 0.000031	0.000027 ± 0.000015	0.000026 ± 0.000011	0.000021 ± 0.000003	0.00024 ± 0.000038
	4		0.000064 ± 0.000032	0.000045 ± 0.000018	0.000024 ± 0.000011		
	5	300 Area	0.000055 ± 0.000024	0.000059 ± 0.000028	**0.0002 ± 0.000056**	0.000054 ± 0.00002	0.0001 ± 0.000037
	6	100-N/100-K	0.000036 ± 0.000026	0.000021 ± 0.000011	0.000016 ± 0.0000072	0.000024 ± 0.0000045	0.00012 ± 0.000029
	7	100-D	0.000067 ± 0.000036	0.00003 ± 0.000015	0.000038 ± 0.000014	0.000023 ± 0.0000031	0.000041 ± 0.000018
	8	100-H/100-F	0.000014 ± 0.000017	0.000026 ± 0.000012	0.000026 ± 0.000011	0.000026 ± 0.0000049	0.000052 ± 0.000033
Uranium-235	1	200-East	0.000014 ± 0.000014	0.0000044 ± 0.0000053	0.0000083 ± 0.0000067	0.000012 ± 0.0000019	0.000053 ± 0.000028
	2		0.000006 ± 0.000015	0.0000012 ± 0.000012	0.0000061 ± 0.0000059		
	3	200-West	0.000026 ± 0.000022	0.00001 ± 0.0000096	0.00001 ± 0.0000069	0.000011 ± 0.0000014	0.000052 ± 0.000014
	4		0.000014 ± 0.000017	0.000015 ± 0.0000099	0.0000071 ± 0.0000055		
	5	300 Area	0.0000083 ± 0.000016	0.000015 ± 0.000021	0.000016 ± 0.000014	0.000025 ± 0.000012	0.0001 ± 0.000037
	6	100-N/100-K	0.000024 ± 0.000019	0.0000054 ± 0.0000081	0.0000045 ± 0.0000038	0.000014 ± 0.0000047	0.0001 ± 0.000026
	7	100-D	**0.000028 ± 0.000024**	0.0000062 ± 0.0000062	0.0000083 ± 0.0000065	0.000014 ± 0.0000035	0.000034 ± 0.000024
	8	100-H/100-F	0.000022 ± 0.000018	0.0000048 ± 0.0000058	0.000011 ± 0.0000064	0.000012 ± 0.0000047	0.000026 ± 0.000016

Table 5.1. (contd)

Isotope	Composite Group	Location	Sample Period 1[a] Result (pCi/m³)[b]	Sample Period 2[a] Result (pCi/m³)[b]	Sample Period 3[a] Result (pCi/m³)[b]	1995-1999 Average (pCi/m³)[c]	1995-1999 Maximum (pCi/m³)[d]
Uranium-238	1	200-East	0.000025 ± 0.000018	0.000016 ± 0.00001	0.000022 ± 0.00001	0.000015 ± 0.0000017	0.0001 ± 0.000058
	2		0.00004 ± 0.000024	0.000019 ± 0.000011	0.000016 ± 0.0000077		
	3	200-West	0.000036 ± 0.000025	0.00003 ± 0.000016	0.000034 ± 0.000014	0.000016 ± 0.000003	0.00026 ± 0.000042
	4		0.000035 ± 0.000024	0.000029 ± 0.000015	0.000029 ± 0.000012		
	5	300 Area	0.000028 ± 0.000017	0.000026 ± 0.000019	**0.00015 ± 0.000047**	0.000039 ± 0.000011	0.00011 ± 0.000052
	6	100-N/100-K	0.000022 ± 0.000021	0.000023 ± 0.000011	0.000011 ± 0.0000058	0.000018 ± 0.0000038	0.000083 ± 0.000022
	7	100-D	0.000021 ± 0.000023	0.000024 ± 0.000012	0.000022 ± 0.00001	0.000019 ± 0.0000041	0.000058 ± 0.000031
	8	100-H/100-F	0.000017 ± 0.000015	0.000015 ± 0.0000093	0.000017 ± 0.0000078	0.000026 ± 0.00001	0.000089 ± 0.00005
Plutonium-239/240	1	200-East	0.000024 ± 0.00002	0.000024 ± 0.000017	0.000011 ± 0.0000076	0.00001 ± 0.0000029	0.000064 ± 0.000024
	2		0.0001 ± 0.000044	0.0000095 ± 0.0000074	0.0000048 ± 0.0000044		
	3	200-West	0.000057 ± 0.000044	**0.0016 ± 0.0003**	0.000028 ± 0.000015	0.000018 ± 0.0000037	0.00013 ± 0.000042
	4		0.000039 ± 0.000028	0.000013 ± 0.0000095	0.000023 ± 0.000011		
	5	300 Area	0.000096 ± 0.000035	0.0000054 ± 0.0000076	0.000041 ± 0.000023	0.0000086 ± 0.0000052	0.000012 ± 0.0000068
	6	100-N/100-K	0.000018 ± 0.000016	0.0000036 ± 0.0000043	0.0000074 ± 0.0000056	0.00002 ± 0.0000064	0.00001 ± 0.000035
	7	100-D	0.000044 ± 0.000048	0.0000032 ± 0.000009	0.00001 ± 0.0000088	0.000019 ± 0.0000092	0.000061 ± 0.000027
	8	100-H/100-F	-0.0000092 ± 0.000013	-0.0000046 ± 0.0000074	0.000018 ± 0.0000099	0.000017 ± 0.0000088	0.000042 ± 0.000031

(a) First sample period = June 26-30, 2000; second sample period = June 30 - July 10, 2000; third sample period = July 10-24, 2000.
(b) ± counting error. Bold results indicate maximum values.
(c) ±2 standard error of the mean.
(d) ± counting error.

Table 5.2. Near-Facility Air Monitoring Program Gross Alpha and Beta Results for Air Samples Collected in the 200 Areas during the 2000 Hanford Site Wildfire, and during the Period 1995 through 1999

2000 Hanford Site Wildfire

	Gross Alpha, pCi/m³		Gross Beta, pCi/m³	
Sampling Period	**Mean[a]**	**Maximum[b]**	**Mean[a]**	**Maximum[b]**
June 26 - 30, 2000	0.0043 ± 0.00059	0.0095 ± 0.0031	0.02 ± 0.0013	0.029 ± 0.0055
June 30 - July 10, 2000	0.0013 ± 0.0002	0.0023 ± 0.00097	0.0079 ± 0.00071	0.013 ± 0.0019
July 10 - 24, 2000	0.0011 ± 0.00013	0.002 ± 0.00076	0.011 ± 0.00088	0.016 ± 0.0016

1995 through 1999

	Gross Alpha, pCi/m³		Gross Beta, pCi/m³	
Sampling Period	**Mean[a]**	**Maximum[b]**	**Mean[a]**	**Maximum[b]**
January 1995 - December 1999	0.0011 ± 0.000035	0.049 ± 0.014	0.015 + 0.00048	0.49 ± 0.04

(a) ±2 standard error of the mean.
(b) ±2 sigma total propagated analytical error.

were requested for some samples collected during and shortly after the wildfire. The modified sampling schedule is listed in Appendix B, Table B.12.

During and after the fire, the analytical laboratory was directed to provide priority turnaround times for samples from specific locations for a quick evaluation of public exposure to radioactive materials released during the fire. Selected samples were individually analyzed for gamma emitters prior to compositing. These results were then compared to results from samples collected and analyzed by other agencies. All samples were analyzed according to contract and laboratory procedures so that results could be compared to historical results.

5.1.2.1 Sitewide and Offsite Air Monitoring Results

There appeared to be no increase in gross alpha or gross beta concentrations in samples collected on the site, at the site perimeter, or at distant sampling locations during the fire (Figures 5.3 and 5.4; also see Section 4.1, Figures 4.1.2 and 4.1.3). The results for samples analyzed for gamma-emitting radionuclides prior to compositing were all below minimum detectable levels. After compositing, gamma results were also below minimum detectable levels (see Section 4.1.2 for discussion of sample results below the minimum detectable level). Strontium-90 concentrations were all within the normal annual range of concentrations recorded for the past 5 years (see Figure 4.1.5). Plutonium levels appeared elevated in five surveillance samples (Table 5.3), however, only the Prosser Barricade and 100 Area samples exceeded the maximum value detected over the preceding 5 years for each specific location. Two slightly elevated uranium-238 concentrations were also seen following the fire (see Table 5.3). The highest was seen at Byers Landing, an offsite station located across the Columbia River from the 300 Area. For all seven samples, the observed concentrations were below DOE derived concentration guides for plutonium-239/240 (0.02 pCi/m³) and uranium-238 (0.1 pCi/m³).

No other radionuclide concentrations were above levels observed in routine samples collected during the past 5 years (see Section 4.1.2 for a comparison of 2000 data with data from previous years).

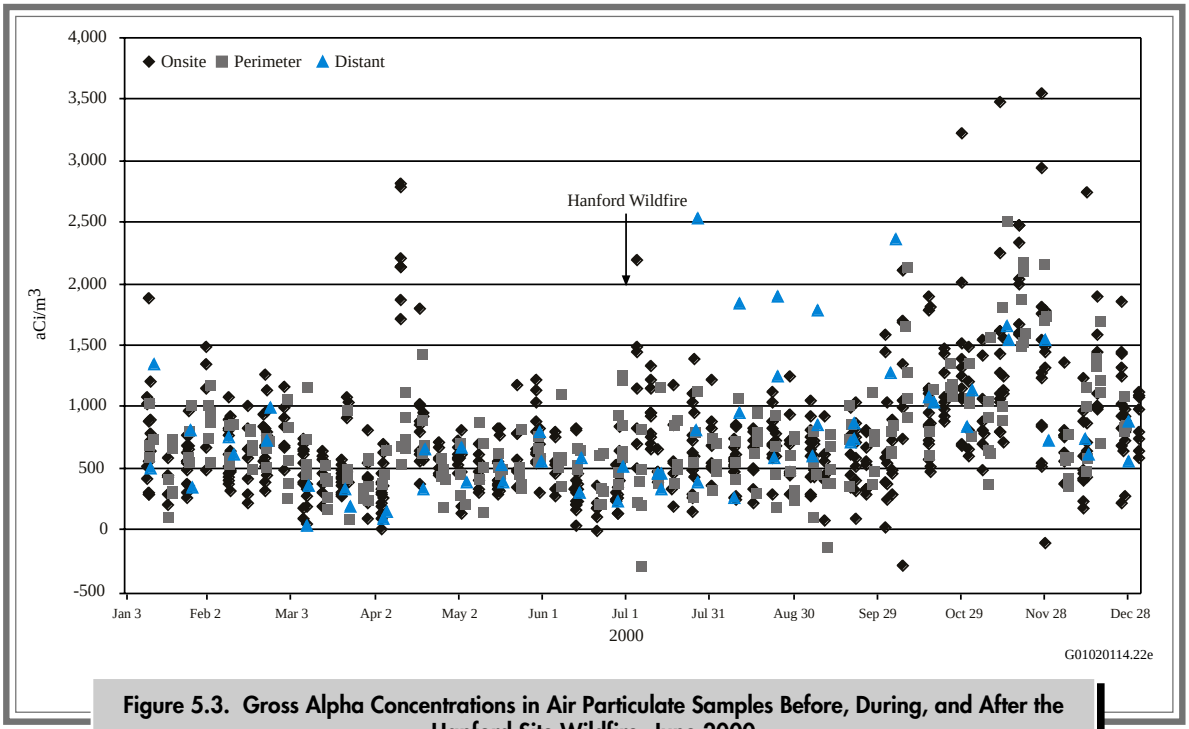


Figure 5.3. Gross Alpha Concentrations in Air Particulate Samples Before, During, and After the Hanford Site Wildfire, June 2000

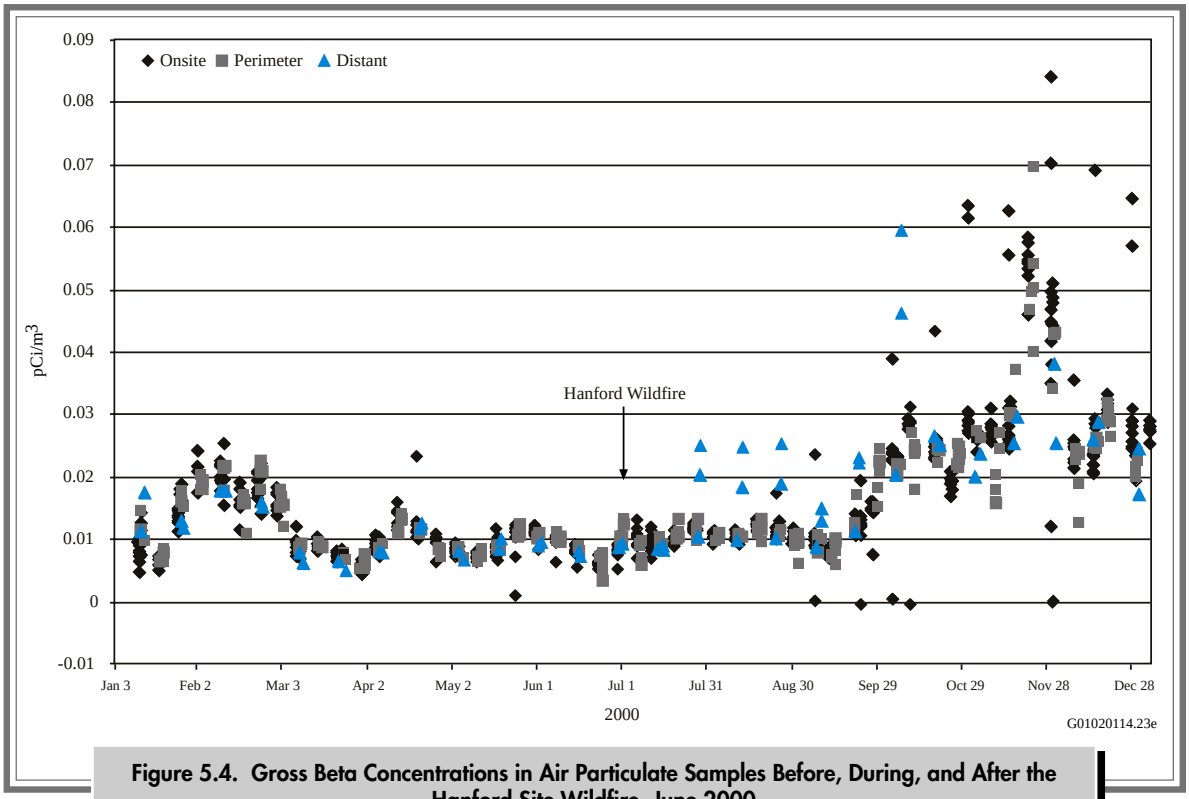


Figure 5.4. Gross Beta Concentrations in Air Particulate Samples Before, During, and After the Hanford Site Wildfire, June 2000

Table 5.3. Elevated Concentrations of Plutonium-239/240 and Uranium-238 Observed in Surveillance Air Samples Collected after the 2000 Hanford Site Wildfire Compared to Maximum and Annual Mean Values from 1995 through 1999

	Following 2000 Hanford Site Fire		1995-1999	
Sample Site (Number)[a]	Collection Date (2000)	Sample Result[b]	Maximum[b]	Mean[c]
		Plutonium-239/240, pCi/m^3		
200-West (14)	July 5	0.000004 ± 0.000003	0.000009 ± 0.000002	0.000003 ± 0.000005
200-West (14)	September 26	0.000006 ± 0.000004	0.000009 ± 0.000002	0.000003 ± 0.000005
200-West Southeast Composite (11, 12, 13)	September 26	0.000003 ± 0.000002	0.000003 ± 0.000001	0.000001 ± 0.000002
100 Areas Composite (1, 2, 3)	October 3	0.000006 ± 0.000002	0.000005 ± 0.000002	0.000002 ± 0.000003
Prosser Barricade (31)	October 6	0.000004 ± 0.000002	0.0000005 ± 0.0000009	0.0000001 ± 0.0000004
		Uranium-238, pCi/m^3		
Byers Landing (28)	September 29	0.00014 ± 0.000003	0.00006 ± 0.00002	0.00004 ± 0.00002
300 Area Trench (18)	October 5	0.00008 ± 0.000002	0.00005 ± 0.00001	0.00003 ± 0.00002

(a) See Figure 4.1.1 for sample site locations.
(b) Value ±2 sigma total propagated analytical error.
(c) Value ±2 standard deviation of the mean for each location.

Comparisons with the Mabton Wildfire. Particulate air samples were collected for DOE on August 25 through 31, 2000, at locations downwind of a wildfire burning near Mabton, Washington, in the southeastern portion of the state (formally designated the Mule Dry Fire based on its point of origin). This fire occurred in an area generally upwind of the Hanford Site. Samples were collected to compare analytical data with data from samples collected on or near the Hanford Site during and after the June wildfire to see if comparable concentrations of strontium-90, plutonium isotopes, and uranium isotopes would be found. A portable high-volume air sampling system was used to filter ~28.3 m^3 (1,000 ft^3) of air over 1-hour sampling periods. The intent was to collect as much particulate matter on the filters as possible so that the detection of radionuclides would be enhanced. Eight filter samples were collected and analyzed for strontium-90, uranium-234, uranium-235, plutonium-238, and plutonium-239/240.

Mabton Fire Monitoring Results. None of the stronium-90, plutonium-238, or plutonium-239/240 results were above minimum detectable levels (about 0.000532 pCi/m^3, 0.000021 pCi/m^3, and 0.000024 pCi /m^3, respectively). Concentrations of uranium-234, uranium-235, and uranium-238 were similar to concentrations obtained during routine air surveillance at the Hanford Site and vicinity (see PNNL-13487, APP.1.). No firm conclusions could be drawn after comparing the Mabton plutonium-239/240 and strontium-90 results to the June wildfire results because all concentrations from the Mabton fire were below minimum detectable levels.

5.1.3 EPA Air Monitoring

T. M. Poston

EPA collected 61 air samples from 23 locations in communities surrounding the Hanford Site. Samples were collected during the latter stages of

and after the fire from June 30 through July 3, 2000. The high-volume air particulate samples were each collected for periods of about 24 hours and analyzed for cesium-137 and other gamma-emitting radionuclides, strontium-90, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240.

5.1.3.1 EPA Air Monitoring Results

Neither gamma emitters (cesium-137) nor strontium-90 were detected in any sample. Uranium-238 was detected in nearly all samples and was determined to represent background concentrations of natural uranium (http://www.doh.wa.gov/ehp/rp/epa_data.htm).

Plutonium-239/240 was detected in six samples collected from 10:00 p.m. June 30 through 8:00 a.m. July 3, 2000. Five of these samples were collected in the Tri-City area (Figure 5.5). Concentrations of plutonium-239/240 in the Tri-City samples ranged from 0.00014 to 0.00042 pCi/m^3 (Table 5.4). The analytical error associated with the measurements ranged from ~9 to 13%. Relatively strong winds (usually greater than 7.2 meters per second [16 miles per hour]) blew across the Hanford Site during three separate periods when EPA was collecting these air samples. The northwesterly winds blew for ~30 to 39% of the times the air samplers were operating and carried suspended dust and ash from burned areas towards the Tri-Cities. The sixth sample was collected in Sunnyside, Washington, and had a plutonium-239/240 concentration of 0.000065 (±60%) pCi/m^3. The relatively high analytical error associated with this analysis suggests that the value was very close to the limits of detection. All other plutonium concentrations collected in the remaining 55 samples were below detection (<0.00005 pCi/m^3).

It is reasonable to conclude that the elevated plutonium concentrations in air samples detected in the Tri-City area were attributable to suspended ash and/or dust carried from the 200 Areas by high winds. Onsite monitoring by Hanford Site contractor personnel also measured elevated levels of plutonium-239/240 on air filters (see Sections 5.1.1.1 and 5.1.2.1). All measured plutonium-239/240 concentrations in samples collected at onsite and offsite locations during and after the fire were well below regulatory limits (e.g., DOE derived concentration guide = 0.02 pCi/m^3). Dose estimates associated with the elevated plutonium levels in the Tri-City area samples are discussed in Section 6.0.

5.2 Special Garden Vegetable and Milk Sampling

B. L. Tiller

Special samples of vegetables (produce) and milk were collected in August 2000 from the gardens of private citizens in the Tri-Cities area (see Figure 5.5). Samples were collected to monitor the radioactive dust and ash deposited from the Hanford wildfire. Five cabbage and four tomato samples were analyzed for plutonium-238 and plutonium-239/240. Twelve milk samples routinely collected each quarter but not usually analyzed for plutonium were analyzed for plutonium-238 and plutonium-239/240. Two samples of goat milk collected from nearby downwind areas also were analyzed for plutonium. Plutonium-238 and plutonium-239/240 concentrations in all produce and milk samples were at or below their analytical detection limits (~0.00003 pCi/g wet weight for milk, or 0.1 pCi/L for produce).

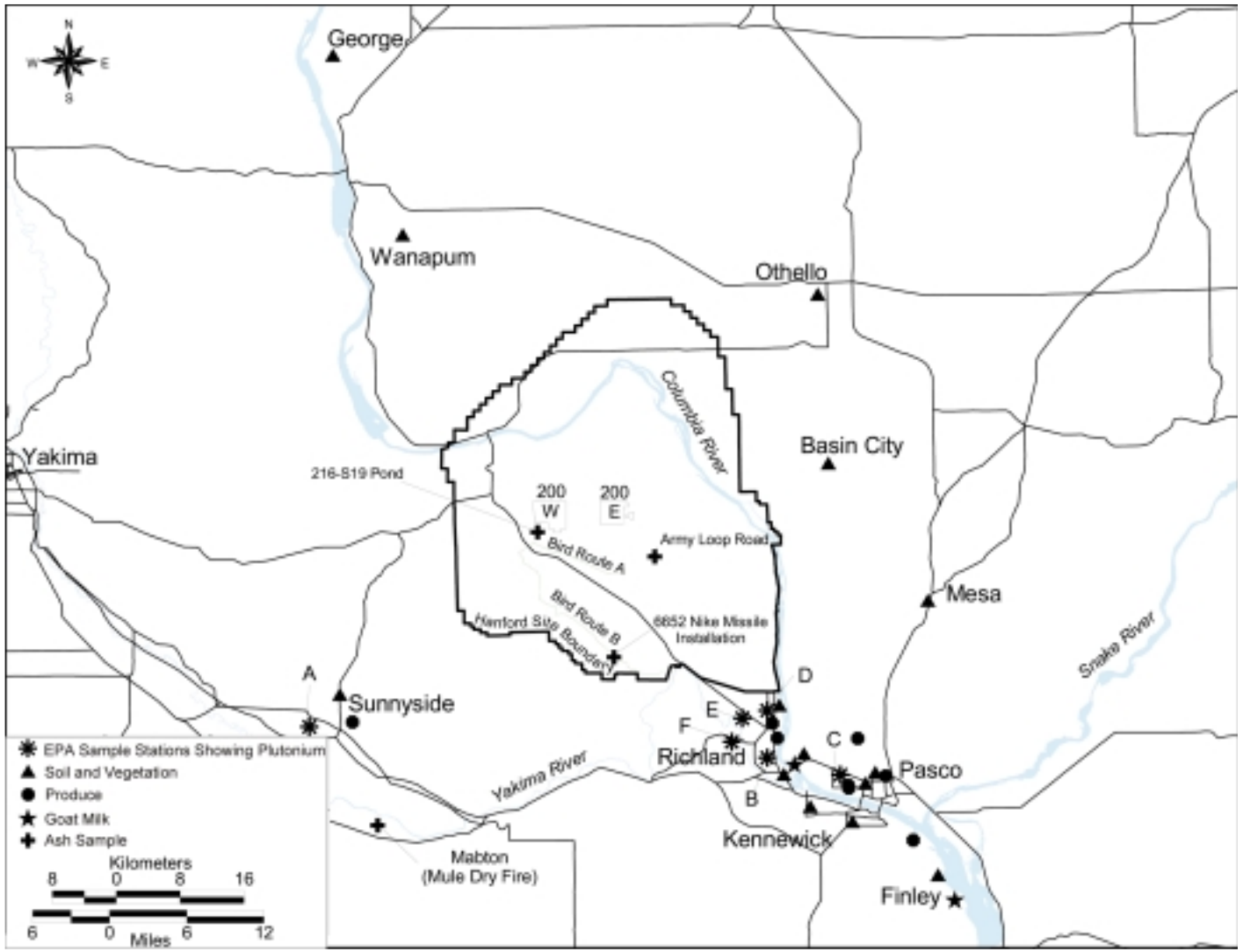


Figure 5.5. Special Air (EPA), Ash, Soil, Vegetation, Milk, and Garden Vegetable Sampling Locations for Post-Fire Collections near the Hanford Site, August 2000

Table 5.4. Comparison of Plutonium-239/240 Concentrations Measured by the U.S. Environmental Protection Agency around the Hanford Site with the Percentage of the Time Northwesterly Winds Crossed the Site

Sample Designation	Location[a]	Date (2000)	Concentration, pCi/m^3[b]	Analytical Error, %	Percentage of Sample Time with Winds >7.2 m/sec (16 mph)[c]
Sunnyside Fire Station	A	July 2-3	0.000065 ± 0.000041	63	NA[d]
Richland #6, Swift Blvd.	B	July 1-2	0.00036 ± 0.000045	13	31
Pasco #8, Road 48	C	July 1-2	0.00042 ± 0.000045	10	39
Richland, Crestview Rd.	D	June 30-July 1	0.00014 ± 0.000012	9	30
Richland, Preswick St.	E	June 30-July 1	0.00023 ± 0.000028	12	30
West Richland, Van Geisen Ave.	F	July 1-2	0.00026 ± 0.000027	10	30

(a) Refer to Figure 5.5 for locations.
(b) Value ±2 total propagated analytical error.
(c) Northwesterly winds blowing across the Hanford Site to the southeast.
(d) Not applicable; Sunnyside is upwind of the Hanford Site.

5.3 Special Soil and Vegetation Sampling

B. L. Tiller

Surface soil and perennial vegetation samples have been collected routinely on and around the Hanford Site for more than 50 years. Routine sampling of surface soil and vegetation was last conducted in 1998 (see PNNL-12088, Section 4.6). Special soil samples collected offsite in August 2000 (see Figure 5.5) in response to the 2000 Hanford wildfire consisted of five plugs of soil, each 2.54 centimeters (1 inch) deep and 10.2 centimeters (4 inches) in diameter, collected within 10 meters (33 feet) of one another and then combined into one bulk sample for analysis (PNL-MA-580). Additional samples consisting of five cores taken from only the top 1 centimeter of surface soil were also collected at each location. Perennial vegetation samples (see Figure 5.5) consisted of the current year's growth of leaves and stems collected from sagebrush and rabbit brush using standard procedures (PNL-MA-580).

5.3.1 Soil Sampling Results

The concentrations of plutonium-239/240 measured in soil are shown in Table 5.5. Concentrations of plutonium-239/240 in soil immediately southeast of the Hanford Site (i.e., Kennewick, Pasco, and Richland) appeared to be marginally elevated compared with samples from locations north and east of the site. Median post-fire concentrations of plutonium-239/240 were lower in all samples from offsite locations than in samples collected around the 200 Areas. Additionally, all plutonium-239/240 concentrations in samples collected offsite following the fire were lower than historic offsite plutonium-239/240 concentrations. All concentrations were well within the range of measurements at offsite locations for the years 1983 through 1998 as noted in Table 5.5. Concentrations of plutonium-239/240 were lower in samples of top 1 centimeter of soil compared to standard surface soil samples. If significant amounts of

Table 5.5. Concentrations of Plutonium-239/240 (pCi/g dry wt.) in Soil from Surveillance Sites Located on and around the Hanford Site, 1983 through 1998, and in Special Samples Collected in August 2000

Location	Mean[a]	Median	Maximum[b]	Minimum[b]	Number of Samples
			1983-1998		
100 Areas	0.013 ± 0.014	0.013	0.030 ± 0.004	0.0008 ± 0.008	42
200 Areas	0.086 ± 0.37	0.013	0.83 ± 0.027	0.0003 ± 0.0004	78
300 Area	0.014 ± 0.014	0.014	0.025 ± 0.004	0.0004 ± 0.0002	21
600 Area	0.010 ± 0.016	0.007	0.034 ± 0.004	0.0007 ± 0.0003	66
Offsite	0.010 ± 0.015	0.008	0.033 ± 0.004	0.00003 ± 0.00017	165
			2000 Special Soil Samples		
Sunnyside	NA[c]	NA	0.0055 ± 0.0011	NA	1
North/East of the Hanford Site	0.004 ± 0.005	0.004	0.0077 ± 0.0017	0.0023 ± 0.0006	5
Tri-City Vicinity	0.007 ± 0.014	0.005	0.018 ± 0.003	0.0002 ± 0.0002	8

(a) ±2 standard deviation.
(b) ±2 total propagated analytical error.
(c) NA = Not applicable.

plutonium-239/240 had been deposited onto the soil from the Hanford wildfire, concentrations of plutonium would have likely been higher in the top 1 centimeter samples.

5.3.2. Vegetation Sampling Results

Fourteen samples of perennial vegetation were collected in August 2000 (see Figure 5.5), and concentrations of plutonium-238/240 in all but one were at or below the level of detection (0.0004 pCi/g dry weight). A sample of gray rabbitbrush collected at the Yakima River delta near Richland had 0.0009 ± 0.0003 pCi/g dry weight of plutonium-239/240. The results overall were consistent with results from past measurements of plutonium-239/240 in vegetation.

5.4 Ash Samples

T. M. Poston

Samples of residual ash (burned natural vegetation) were collected by Surface Environmental Surveillance Project staff from the Mabton wildfire at the same time air samples were collected (see Section 5.1.2.1). Ash samples were collected at the Mabton wildfire to compare with similar samples collected near the 200 Areas by Government Accountability Project personnel and DOE following the 2000 Hanford wildfire. The two 200 Areas samples were collected near Army Loop Road to the southeast of the 200-East Area (see Figure 4.1.1), and close to the retired 216-S19 pond located to the south of the 200-West Area (see Figure 5.5).

A comparison of analytical results from Mabton wildfire samples and results from samples collected in the 200 Areas in July 2000 shows that the ash samples from the 200 Areas were higher in plutonium-238 and plutonium-239/240 (Figure 5.6). Plutonium concentrations were consistent with the historical pattern of contamination measured in vegetation samples collected from the 200 Areas back to 1983 (PNL-10728).

5.5 Biological and Cultural Resource Impacts of the Hanford Wildfire

This section describes some preliminary reviews and assessments of impacts to Hanford Site biological and cultural resources from the Hanford wildfire. A multi-agency report prepared by the U.S. Department of the Interior addresses some of the same issues in more detail (U.S. Department of the Interior 2000).

5.5.1 Habitat Loss

J. L. Downs

The June 2000 Hanford Wildfire has altered the composition of the shrub-steppe habitat in the burned area. The burn intensity of the wildfire was considered to be low, meaning that the soil and

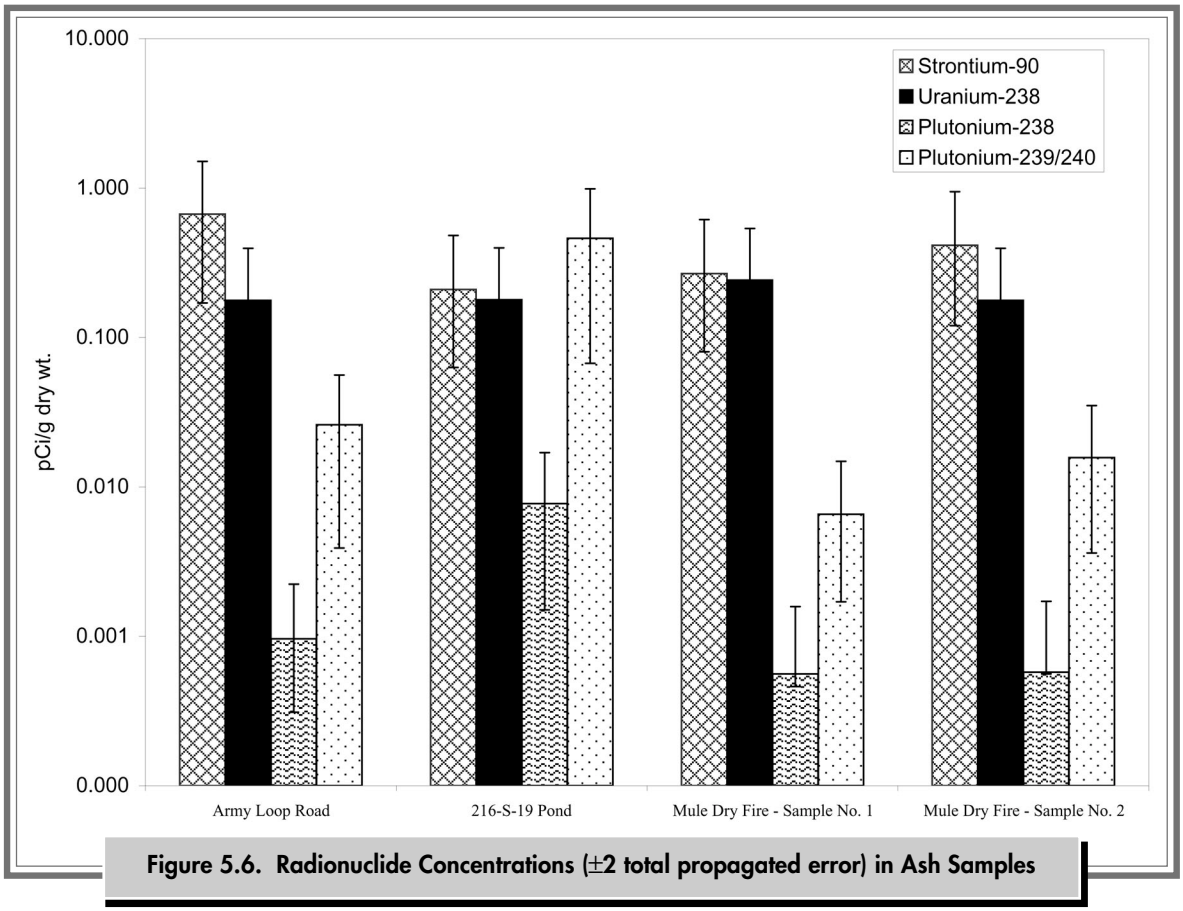


Figure 5.6. Radionuclide Concentrations (±2 total propagated error) in Ash Samples

buried seeds remained intact and the below ground portions of most perennial plants were unharmed and are expected to re-sprout as conditions permit. About 28,700 hectares (71,000 acres) of shrub habitat dominated by big sagebrush and ~13,300 hectares (32,800 acres) of grassland habitat dominated by native grasses were burned in the fire. Most of the vegetation is expected to recover within 1 to 3 years to a configuration resembling the pre-fire conditions, except for sagebrush. The re-establishment of big sagebrush stands is likely to take at least 5 to 10 years, and it potentially could be decades before sagebrush is once again an important feature of the landscape.

5.5.2 Hanford Elk

B. L. Tiller

Elk are mobile animals capable of escaping most wildfires when there is an escape route. Post-fire surveys of adult elk on the Hanford Site suggested very low mortality of adult elk as a result of the June wildfire. However, the wildfire occurred in the middle of the calving season and may play a role in reducing the number of calves that survive to adulthood in the summer of 2001. The long-term impact of the wildfire on the Hanford elk herd is still uncertain.

The wildfire resulted in a temporary relocation of the Hanford elk herd. Figure 5.7 shows post-calving period (July through August) animal locations grouped by decade (1980s and 1990s) and for 2000. Since the 1980s, elk have increased their use of private and Washington State Department of Fish and Wildlife land along the southern boundary of the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit. Data collected after the June 2000 fire indicated that Hanford elk spent a considerable portion of their time foraging on private lands south of the burn area.

5.5.3 Bird Responses to the Fire

W. H. Rickard

Bird use of the shrub-steppe habitat on the Hanford Site has been monitored monthly for the past 12 years. Road surveys were used to cover relatively large areas in a short period of time. Two routes, A and B, were within the area covered by the Hanford wildfire (see Figure 5.5). Birds were identified and counted during 3-minute stops at 0.8-kilometer (0.5-mile) intervals along the survey routes. Surveys were conducted monthly from October 1998 through October 2000. During that time, the vegetation along route A consisted primarily of stands of bluebunch wheatgrass. This area had previously burned and most of the sagebrush had been killed. Along route B, the vegetation consisted of large patches of sagebrush with an understory of cheatgrass. Nearly all vegetation was burned along both routes during the 2000 Hanford wildfire.

The total number of species along both routes decreased after the fire (July 2000) compared to July 1999 (Figure 5.8). The abundance of birds is shown in Figure 5.9. There was a substantial decline in the abundance of birds within the burned-off sagebrush habitat, but the total number of birds counted in the burned-off bunchgrass habitat (Route A) was actually greater in July 2000 following the fire than it was the previous year (July 1999). Species of birds dependent on large sagebrush for habitat will be most severely affected by the fire.

5.5.4 Cultural Resources

D. W. Harvey and L. L. Hale

The Hanford Cultural Resources Laboratory assessed the impact of the June 2000 Hanford

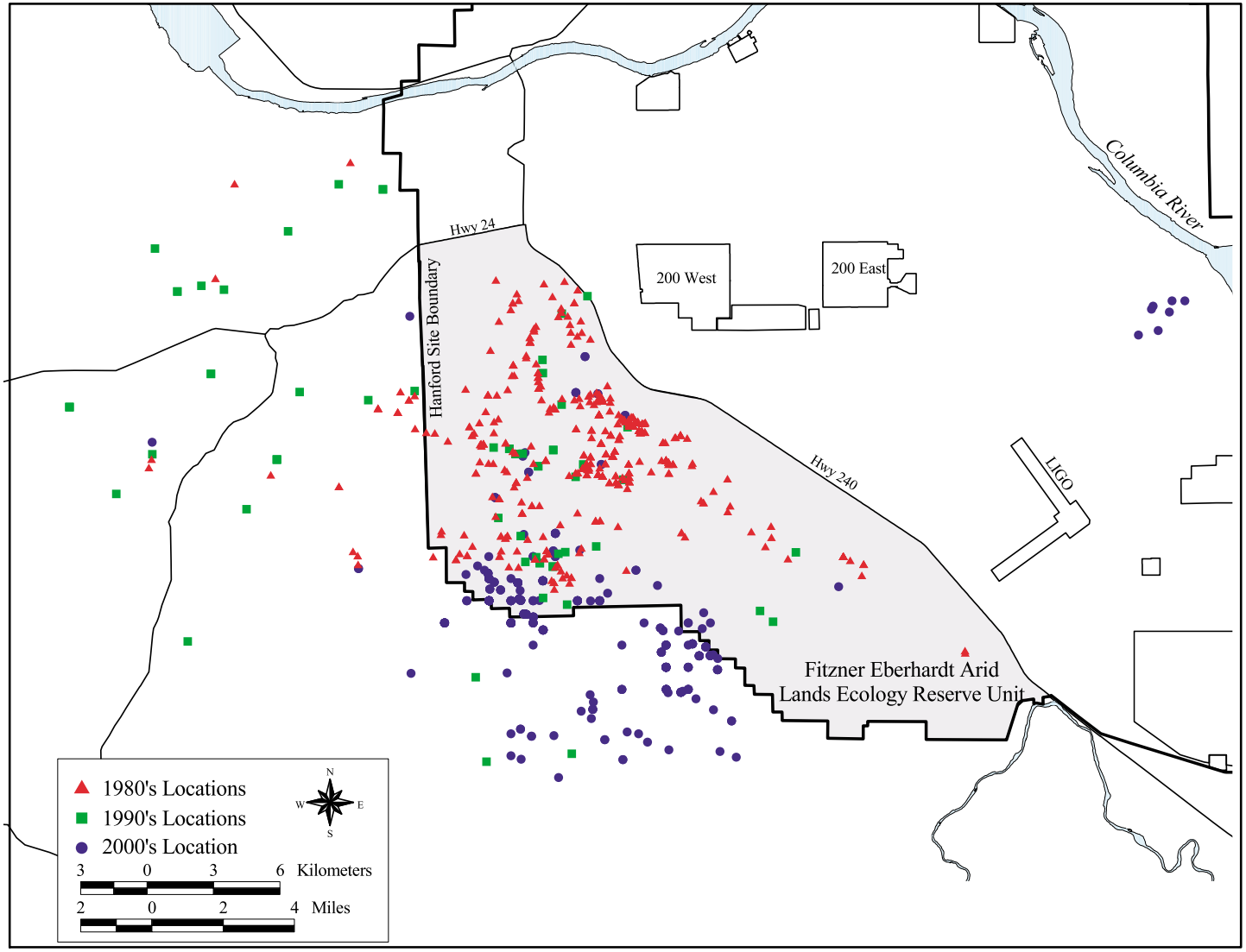
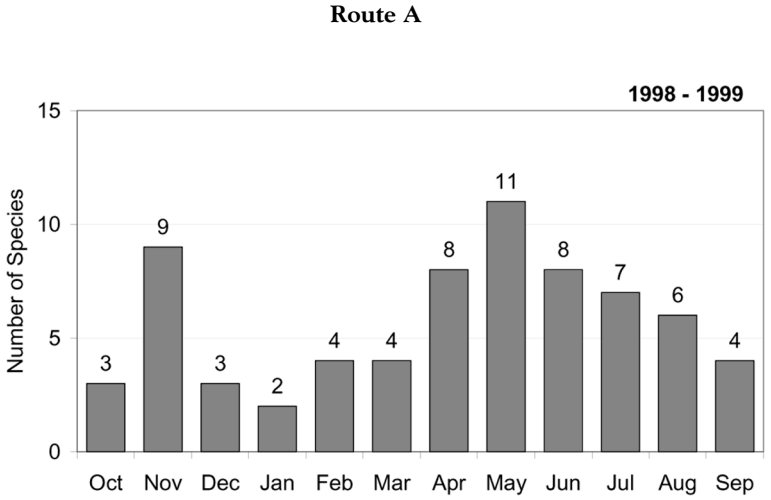
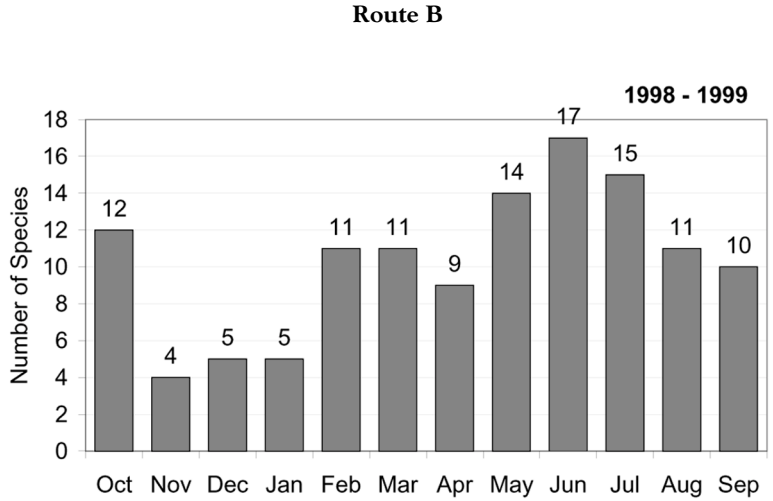
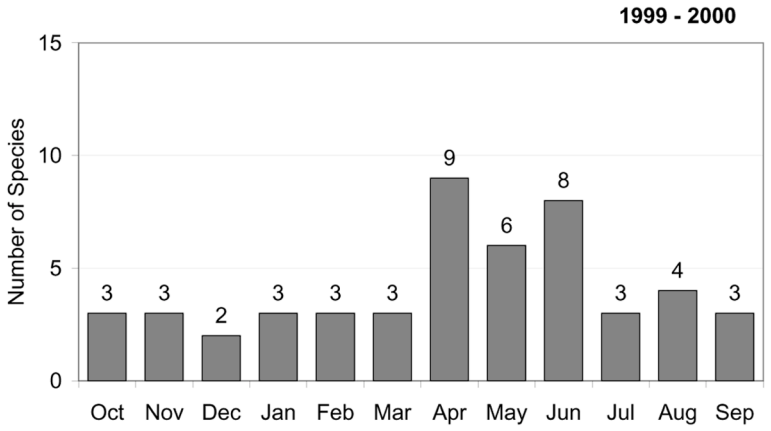


Figure 5.7. Post-Fire (July-August) 2000 Elk Locations Compared with July-August Locations for the 1980s and 1990s







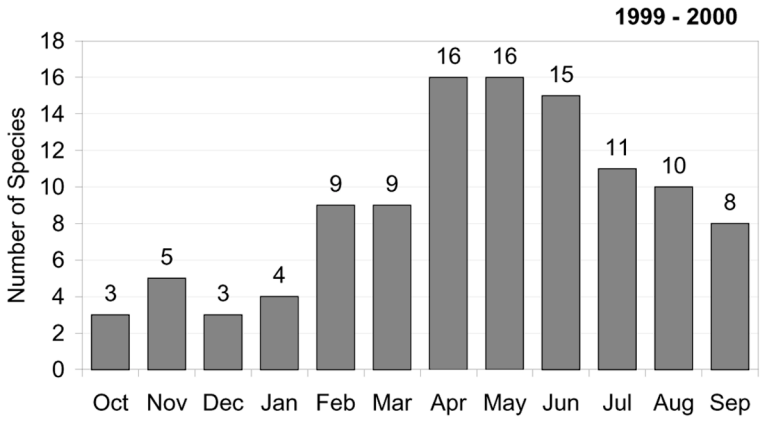


Figure 5.8. Total Number of Bird Species Counted during Roadside Surveys in 1998-1999 and 1999-2000 along Two Routes on the Hanford Site

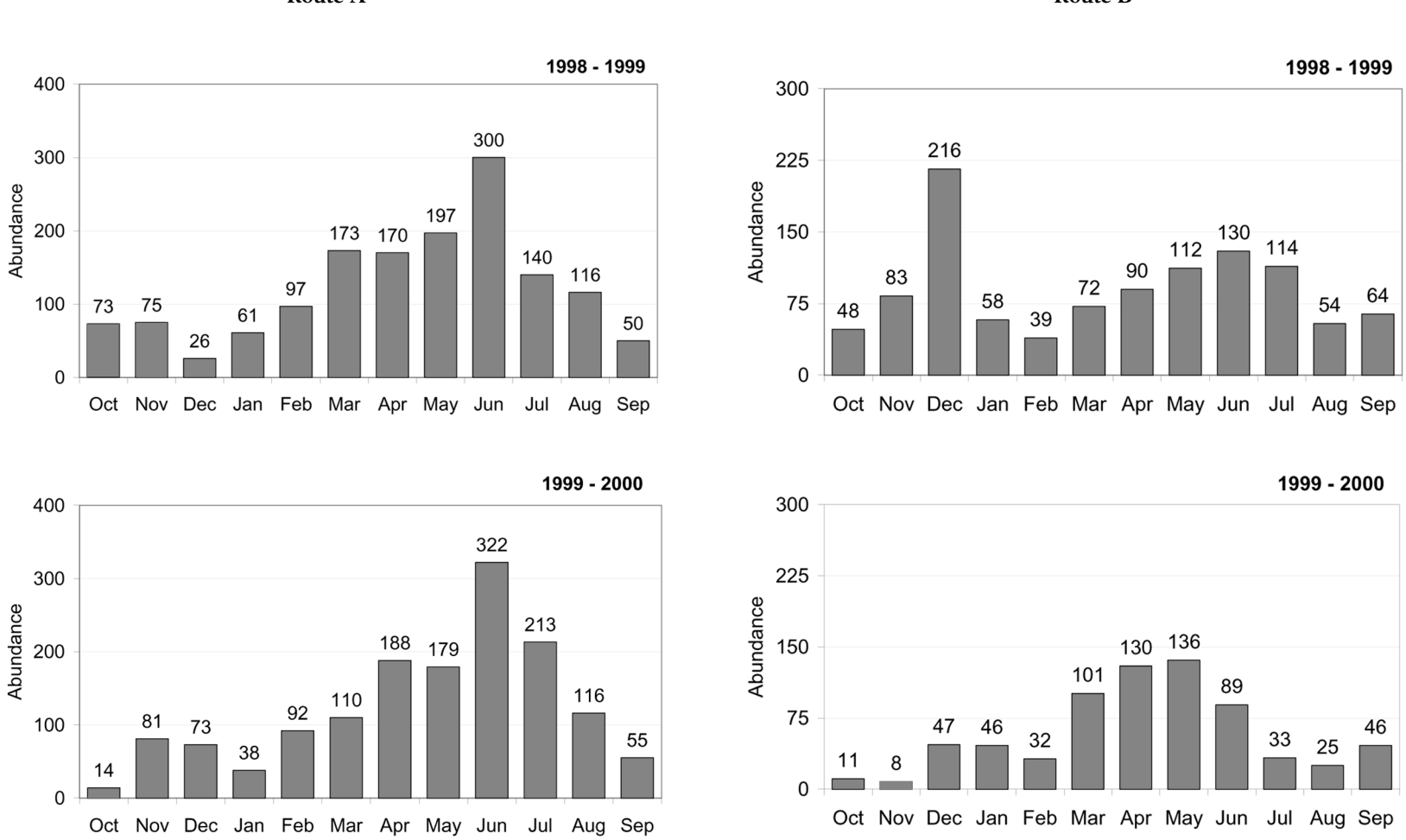


Figure 5.9. Number of Birds Counted during Roadside Surveys in 1998-1999 and 1999-2000 along Two Routes on the Hanford Site

wildfire on cultural resources in the fall of 2000. Members of the Confederated Tribes of the Umatilla Indian Reservation, the Wanapum People, and the Nez Perce Tribe assisted. All previously known archaeological sites, Traditional Cultural Properties, and cold-war era military properties within the burned area on the Hanford Site were located and assessed. If unrecorded sites were located during the course of the assessment, they were noted.

Survey results showed that effects of the wildfire on cultural resources resulted from subsequent soil erosion in some areas. The area along the White Bluffs Road, which was covered over by windblown sand, was the most greatly affected. Other items noted included recreational impacts from dirt bikes near the ethnographic village of Wanawish (Horn Rapids). Several motorcycle tracks were noted in the village area.

The effects of fire suppression activities included vehicle tracks and ruts near cold-war era military properties on site. Bulldozer tracks were noted along the western edge of 200-West Area, along the western edge of Highway 4 South, west of the 200-East Area, and near the former 6652 Nike Missile launch installation (see Figure 5.5). In a few limited areas, most notably on the hill east of the 200-East Area, the fire exposed several building foundations, pads, and sidewalks previously covered by thick vegetation.

The fire consumed all or part of two historic structures at the former 6652 Nike Missile Launch Installation. A 40-foot wooden crow's nest and observation post and the roof of a concrete block guard shack building were destroyed. Most of the wooden light poles, utility poles, and fence posts at the missile installation were also destroyed.

An assessment of the impact to previously known archaeological sites and Traditional Cultural Properties resulted in the discovery of five newly identified archaeological sites and two newly identified finds (e.g., a sheep herders implement and a projectile point). The sites had formerly been obscured by vegetation.

5.6 Soil Stabilization and Revegetation of Burned Areas

A. R. Johnson

A severe windstorm occurred on July 1, 2000, resulting in extensive movement of ash (remains of burned vegetation) and surface soil in areas on the site burned by the Hanford 2000 wildfire and no longer protected by vegetative cover. It was immediately apparent that operations in the 200-West Area were being affected by blowing dust and ash because a vast expanse of native shrub-steppe vegetation west and upwind of 200-West Area had been completely consumed by the fire. A satellite image taken on July 2, 2000, revealed wind erosion of land surfaces previously stabilized by native plants. Within a few weeks following the fire, soil stabilization and re-vegetation efforts were started in selected burned areas to protect workers and facilities from blowing dust. Work progressed throughout the fourth quarter of 2000 to stabilize nearly 400 hectares (1,000 acres) on the west (upwind) side of the 200-West Area. A combination of methods was used that included re-seeding, transplanting shrubs, incorporating hay into the soil, and applying commercial soil fixatives.

5.7 References

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6.0 Potential Radiological Doses from 2000 Hanford Operations

E. J. Antonio, K. Rhoads, L. H. Staven, and W. M. Glines

During 2000, potential radiological doses to the public and biota from Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. The potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, liquid effluents from operating wastewater treatment facilities, and contaminated groundwater seeping into the Columbia River. Other potential sources included fugitive emissions from contaminated soil areas and facilities. The methods used to calculate the potential doses are detailed in Appendix E.

The radiological impact of 2000 Hanford Site operations was assessed in terms of:

- the dose to a hypothetical, maximally exposed individual at an offsite location using a multimedia pathway assessment (U.S. Department of Energy [DOE] Order 5400.5; see Section 6.1)
- the sum of the individual doses to the population residing within 80 kilometers (50 miles) of Hanford Site operating areas (see Section 6.2)
- the dose for air pathways, using U.S. Environmental Protection Agency (EPA) methods, for comparison to the *Clean Air Act* standards in 40 CFR 61, Subpart H (see Section 6.3)
- the maximum dose rate from external radiation at a publicly accessible location at or just within the site boundary (see Section 6.4.1)
- the dose to an avid sportsman who consumes wildlife that may have been contaminated with radionuclides originating on the site (see Section 6.4.2)
- the inhalation dose associated with the Hanford Site wildfire in June 2000 (see Section 6.4.4)
- the absorbed dose received by animals exposed to radionuclide releases to the Columbia River (see Section 6.6).

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations. However, the amounts of most radioactive materials released during 2000 from Hanford Site sources were generally too small to be measured directly once they were dispersed in the offsite environment. For many of the radionuclides present in measurable amounts, it was difficult to separate the contributions from Hanford sources from the contributions from worldwide fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using computer codes and the Hanford Site-specific parameters listed in Appendix E and in PNNL-13487, APP. 1. However, air surveillance data were used to assess the maximum inhalation doses at offsite monitoring stations.

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 on the

Columbia River. During 2000, tritium, technetium-99, iodine-129, and uranium isotopes were found in the Columbia River downstream of Hanford at greater levels than predicted based on direct discharges from the 100 Areas (see Section 4.2 and Appendix B). All other radionuclide concentrations were lower than those predicted from known releases. Riverbank spring water, containing radionuclides, is known to enter the river along the portion of shoreline extending from the 100-B/C Area downstream to the 300 Area (see Sections 4.2 and 7.1). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported in 2000.

6.1 Maximally Exposed Individual Dose

The maximally exposed individual is a hypothetical person who lives at a location and has a lifestyle that makes it unlikely that any other member of the public would receive a higher radiological dose. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides in Hanford Site effluents and emissions using a multimedia pathway assessment (DOE Order 5400.5). 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 (Figure 6.1). In 2000, the Generation II (GENII) computer code Version 1.485 (PNL-6584)

Historically at Hanford, there has been one primary expression of radiological risk to an offsite individual: this is the maximally exposed individual dose. However, the maximally exposed individual dose is currently calculated by two different methods in response to two different requirements.

- One maximally exposed individual dose computation is required by DOE Order 5400.5 and is calculated using the GENII computer code. This calculation considers all reasonable environmental pathways (e.g., air, water, food) that maximize a hypothetical individual offsite exposures to Hanford's radiological effluents and emissions.
- A second estimate of maximally exposed individual dose is required by the Clean Air Act and is calculated using an EPA dose modeling computer code (CAP-88) or other methods accepted by EPA for estimating offsite exposure. This offsite dose is based solely on an airborne radionuclide emissions pathway and considers Hanford's stack emissions and emissions from diffuse and unmonitored sources (e.g., windblown dust).

Because the DOE and EPA computer codes use different input parameters, the location and predicted dose of each agency's maximally exposed individual is usually different. However, the estimated doses from both methods have historically been significantly lower than health-based exposure criteria.

Recently, DOE has allowed private businesses to locate their activities and personnel on the site. This has created the need to calculate a maximum onsite occupational dose for an individual who is employed by a non-DOE business and works within the boundary of the Hanford Site. This dose is based on a mix of air emission modeling data, the individual's exposure at an onsite work location, and the individual's potential offsite exposure.

Another way to estimate risk is to calculate the collective dose. This dose is based on exposure to Hanford radiological contaminants through the food, water, and air pathways and is calculated for the population residing within 80 kilometers (50 miles) of the Hanford Site. The collective dose is reported in units of person-rem, which is the average estimated individual dose multiplied by the total number of people in the population.

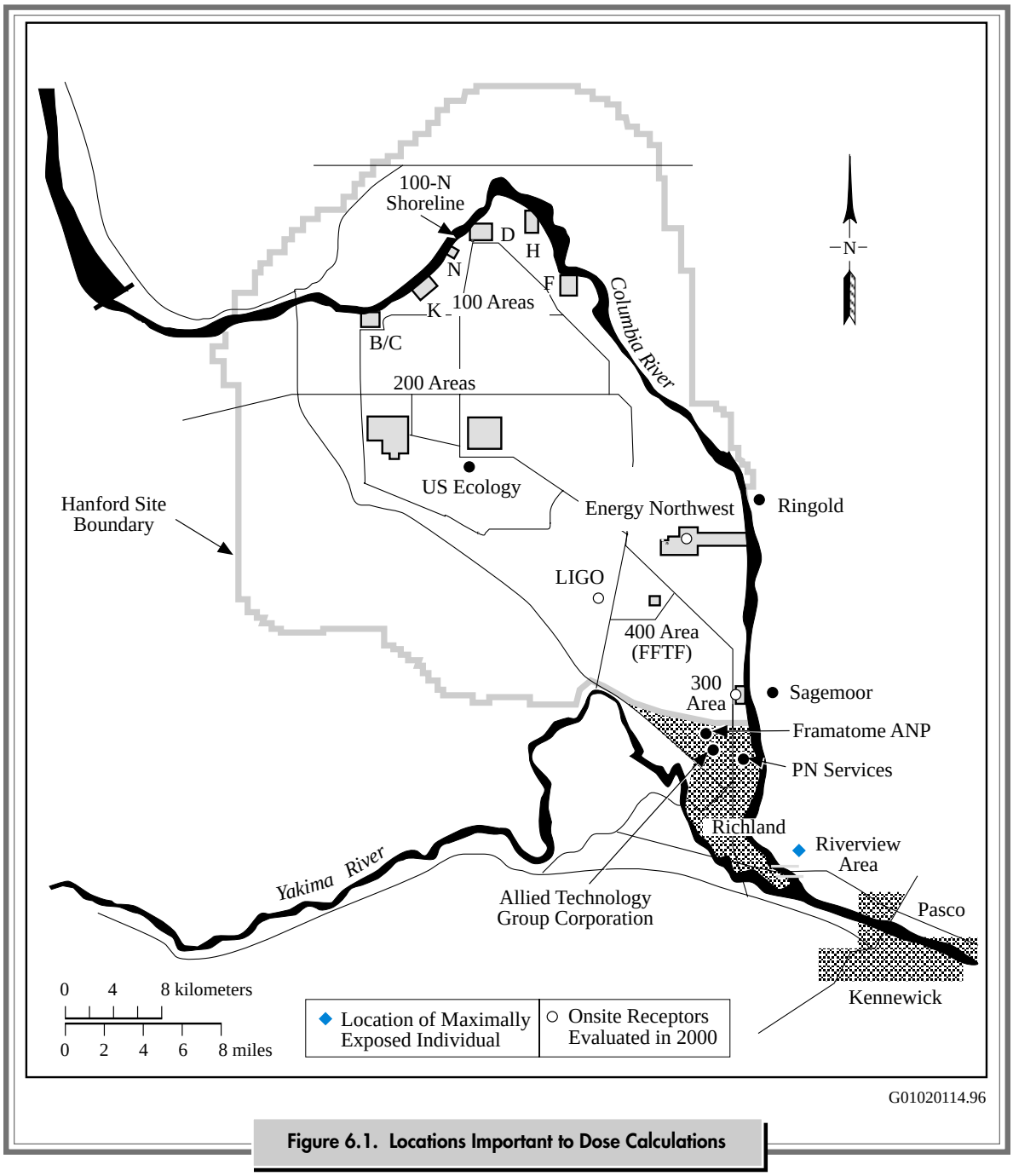

Figure 6.1. Locations Important to Dose Calculations

determined that the DOE maximally exposed individual was located across the Columbia River from Richland, at Riverview (see Figure 6.1). For the calculation, it was assumed that this individual:

- obtained domestic water from a local water treatment system that pumped water from the Columbia River just downstream of the Hanford Site
- received external exposure to radionuclides deposited on the ground
- ingested locally grown food products that had been irrigated with water from the Columbia River (discussed in Section 7.1)
- used the Columbia River for recreational purposes, resulting in direct exposure from water and radionuclides deposited on the shoreline
- ingested locally caught fish.

Doses were calculated using the effluent data in Tables 3.1.1 and 3.1.4 and the calculated quantities of radionuclides assumed to be present in the Columbia River from riverbank springs. 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 100-B/C Area and the 300 Area.

The calculated doses for the DOE maximally exposed individual in 2000 are summarized in Table 6.1. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix E (Tables E.1, E.2, and E.4, respectively).

In 2000, the DOE maximally exposed individual was determined to be at Riverview (see Figure 6.1) and the total dose to that individual was calculated to be 0.014 mrem/yr (1.4×10^{-4} mSv/yr) compared to 0.008 mrem/yr (8×10^{-5} mSv/yr) calculated for 1999. This dose was 0.014% of the 100 mrem DOE limit given in DOE Order 5400.5, but only 0.005% of the 300 mrem/yr received from natural sources by an average individual in the United States (National Council on Radiation Protection and Measurements 1987). The primary

Table 6.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Riverview from 2000 Hanford Operations

		Dose Contributions from Operating Areas, mrem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	9.0×10^{-9}	2.0×10^{-7}	4.5×10^{-10}	3.6×10^{-9}	2.1×10^{-7}
	Inhalation	2.1×10^{-6}	5.9×10^{-4}	1.4×10^{-4}	6.0×10^{-7}	7.3×10^{-4}
	Foods	1.4×10^{-7}	1.4×10^{-4}	1.3×10^{-3}	5.8×10^{-6}	1.4×10^{-3}
	Subtotal air	2.2×10^{-6}	7.3×10^{-4}	1.4×10^{-3}	6.4×10^{-6}	2.2×10^{-3}
Water	Recreation	1.6×10^{-6}	5.3×10^{-5}	0.0[a]	0.0	5.5×10^{-5}
	Foods	7.9×10^{-4}	4.9×10^{-3}	0.0	0.0	5.7×10^{-3}
	Fish	6.4×10^{-4}	2.9×10^{-3}	0.0	0.0	3.5×10^{-3}
	Drinking water	4.8×10^{-5}	2.6×10^{-3}	0.0	0.0	2.6×10^{-3}
	Subtotal water	1.5×10^{-3}	1.0×10^{-2}	0.0	0.0	1.2×10^{-2}
Combined total		1.5×10^{-3}	1.1×10^{-2}	1.4×10^{-3}	6.4×10^{-6}	1.4×10^{-2}

(a) Zeros indicate no dose contribution to maximally exposed individual through water pathway.

pathways contributing to this dose (and the percentage of all pathways) were the following:

- the consumption of food irrigated with Columbia River water (40%), or fish from the Columbia River (25%), or drinking water (19%) derived from the Columbia River, containing principally tritium and uranium isotopes
- the consumption of foods grown downwind of the site (10%), exposed principally to airborne releases of tritium from the 300 and 400 Areas and plutonium from the 100, 200 and 300 Areas.

The dose calculated for the maximally exposed individual for 2000 was 0.01% of the DOE limit of 100 mrem/yr (1 mSv/yr). Thus, the Hanford Site was well within limits specified by applicable federal and state regulations. For comparison purposes, the doses from Hanford operations for the maximally exposed individuals for 1996 through 2000 are illustrated in Figure 6.2.

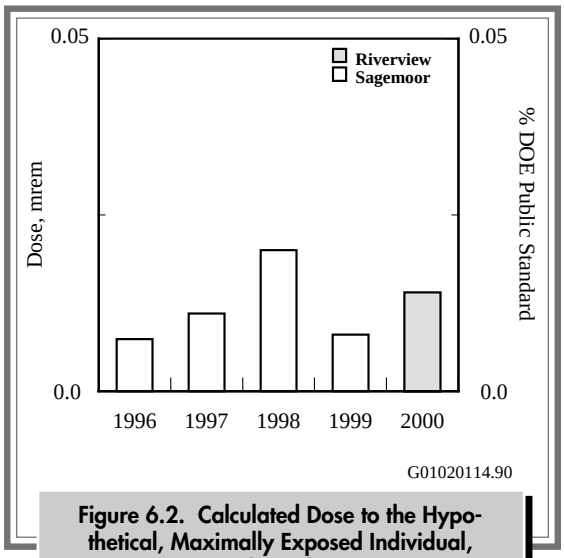

Figure 6.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual, 1996 through 2000

6.2 Collective Dose

The regional collective dose from 2000 Hanford Site operations was estimated by calculating the radiological dose to the population residing within an 80-kilometer (50-mile) radius of the onsite operating areas. Results of the dose calculations are shown in Table 6.2. Summaries of technical details for the calculations of dose from airborne releases are given in Appendix E, Tables E.5 to E.9.

Primary pathways contributing to the 2000 collective dose included:

- consumption of drinking water (37%) contaminated with primarily tritium and uranium released to the Columbia River at Hanford
- inhalation of radionuclides (33%) that were released to the air, principally iodine-129 emitted from 200 Areas stacks
- consumption of foodstuffs (26%) contaminated with radionuclides, principally iodine-129 in gaseous emissions from 200 Areas stacks.

In 2000, the collective dose calculated for the population was 0.3 person-rem/yr (0.003 person-Sv/yr), a slight increase from the 1999 collective dose (0.025 person-rem/yr [0.0025 person-Sv/yr]). The 80-kilometer (50-mile) collective doses attributed to Hanford operations from 1996 through 2000 are compared in Figure 6.3. The average individual dose from 2000 Hanford Site operations based on a population of 380,000 within 80 kilometers (50 miles) was 0.0008 mrem/yr (8×10^{-6} mSv/yr). To place this estimated dose into perspective, it may be compared with doses received from other routinely encountered sources of radiation such as natural terrestrial and cosmic background radiation, medical treatment and x-rays,

Table 6.2. Collective Dose to the Population from 2000 Hanford Operations

Effluent	Pathway	Dose Contributions from Operating Areas, person-rem 100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	2.4×10^{-6}	2.1×10^{-5}	2.4×10^{-8}	3.5×10^{-7}	2.4×10^{-5}
	Inhalation	8.0×10^{-4}	8.7×10^{-2}	1.1×10^{-2}	8.8×10^{-5}	9.9×10^{-2}
	Foods	3.3×10^{-5}	1.5×10^{-2}	6.1×10^{-2}	4.9×10^{-4}	7.7×10^{-2}
	Subtotal air	8.4×10^{-4}	1.0×10^{-1}	7.2×10^{-2}	5.8×10^{-4}	1.8×10^{-1}
Water	Recreation	1.2×10^{-5}	2.9×10^{-4}	0.0[a]	0.0	3.0×10^{-4}
	Foods	8.2×10^{-4}	5.3×10^{-3}	0.0	0.0	6.1×10^{-3}
	Fish	2.5×10^{-4}	1.1×10^{-3}	0.0	0.0	1.4×10^{-3}
	Drinking water	2.0×10^{-3}	1.1×10^{-1}	0.0	0.0	1.1×10^{-1}
	Subtotal water	3.1×10^{-3}	1.2×10^{-1}	0.0	0.0	1.2×10^{-1}
Combined total		3.9×10^{-3}	2.2×10^{-1}	7.2×10^{-2}	5.8×10^{-4}	3.0×10^{-1}

(a) Zeros indicate no dose contribution to the population through the water pathway.

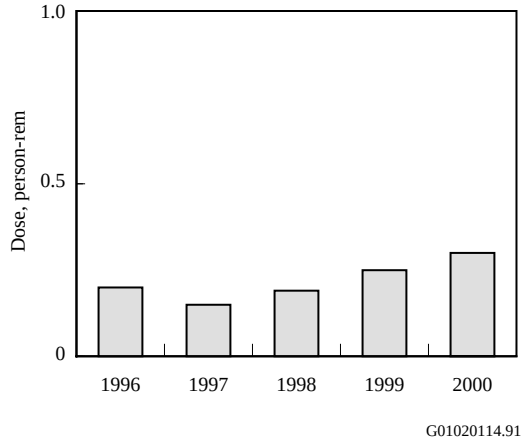

Figure 6.3. Collective Dose to the Population within 80 Kilometers (50 Miles) of the Hanford Site, 1996 through 2000

natural radionuclides in the body, and inhalation of naturally occurring radon. The national annual average radiological dose from these other sources is illustrated in Figure 6.4. The estimated annual average individual dose to members of the public from Hanford Site sources in 2000 was ~0.0003% of the estimated annual individual dose (300 mrem) received from natural background sources.

The doses from Hanford effluents to the DOE maximally exposed individual and to the population within 80 kilometers (50 miles) are compared to appropriate standards and natural background radiation in Table 6.3. This table shows that the calculated radiological doses from Hanford Site operations in 2000 were a small percentage of the standards and of natural background.

6.3 Compliance with Clean Air Act Standards (40 CFR 61, Subpart H)

In addition to complying with the all-pathways dose limits established by DOE Order 5400.5, DOE facilities are required to demonstrate that they comply with standards established by the EPA for airborne radionuclide emissions under the *Clean Air Act* in 40 CFR 61, Subpart H. This regulation specifies that no member of the public shall receive a dose greater than 10 mrem/yr

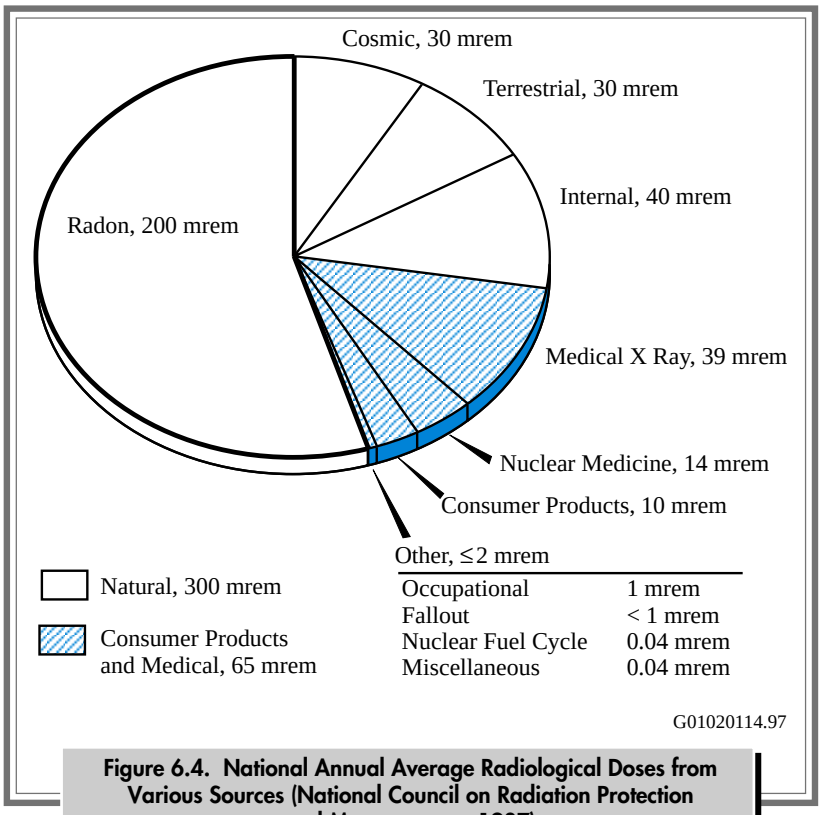

Figure 6.4. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

Table 6.3. Summary of Doses to the Public in the Vicinity of the Hanford Site from Various Sources, 2000

Source	Maximum Individual	Population
All Hanford effluents and emissions	0.01 mrem[(a)]	0.3 person-rem[(a)]
DOE limit	100 mrem	--
Percent of DOE limit[(b)]	0.01	--
Background radiation	300 mrem	110,000 person-rem
Hanford dose percent of background	0.00005	~3 x 10^{-4}
Doses from gaseous emissions	0.046 mrem	--
EPA air standard[(c)]	10 mrem	--
Percent of EPA standard	0.46	--

(a) To convert the dose values to mSv or person-Sv, divide by 100.
(b) DOE Order 5400.5.
(c) 40 CFR 61.

(0.1 mSv/yr) from exposure to airborne radionuclide emissions, other than radon, released at DOE facilities. Whereas DOE uses the GENII computer code for determining dose to the all-pathways maximally exposed individual, EPA requires the use of CAP-88 (EPA 402-R-00-004) or other EPA-approved models to demonstrate compliance with the requirements in 40 CFR 61, Subpart H. The assumptions embodied in this code differ slightly from standard assumptions used with the GENII code. Therefore, air pathway doses calculated by the two codes may differ somewhat. In addition, the maximally exposed individual may be evaluated at a different location from the all-pathways maximally exposed individual because of the relative contributions from each exposure pathway.

The EPA regulation also requires that each DOE facility submit an annual report to EPA that supplies information about atmospheric emissions for the preceding year and their potential offsite dose. For more detailed information about 2000 air emissions on the Hanford Site, refer to DOE's report to EPA (DOE/RL-2001-32).

Maximum Dose to Non-DOE Workers on the Site. The DOE Richland Operations Office recently received guidance from EPA Region 10 and the Washington State Department of Health that, in demonstrating compliance with the 40 CFR 61 standards, it should evaluate potential doses to non-DOE employees who work on the Hanford Site, but who are not under direct DOE control. Accordingly, the doses to members of the public employed at non-DOE facilities that were outside access-controlled areas on the Hanford Site were evaluated for the 2000 EPA air emissions report (DOE/RL-2001-32). These locations included the Columbia Generating Station operated by Energy Northwest, the Laser Interferometer Gravitational Wave Observatory operated by the University of California, a commercial metal extrusion facility in the 313 Building at the north end of the 300 Area, and a research laboratory on the west side of the 300 Area leased to Washington State University (see Figure 6.1). Because 300 Area emissions accounted for the majority of the air pathway dose during 2000, a person working in the Washington State University laboratory in the 300 Area received the highest dose for non-DOE employees who worked on the Hanford Site. The dose was calculated to be 0.046 mrem/yr (4.6×10^{-4} mSv/yr), assuming full-time occupancy at that location for the year. EPA guidance does not currently permit adjustment of doses calculated using CAP-88 to account for less than full-time occupancy at locations within the site boundary. However, if a realistic occupancy period of 2,000 hours per year were assumed for workers at onsite non-DOE facilities, the doses to individuals at any of the locations evaluated would be lower than the dose to the maximally exposed offsite individual that has historically been evaluated for compliance with the EPA standard. Methods to estimate doses to individuals within the site boundary are currently under discussion by DOE and EPA.

Maximum Dose to an Offsite Maximally Exposed Individual. In 2000, the maximally exposed offsite individual for air pathways using EPA specified methods was determined to be at Sagemoor, which is located 1.5 kilometers (1 mile) directly across the Columbia River from the 300 Area (see Figure 6.1). The potential air pathway dose from stack emissions to a maximally exposed individual at that location was calculated to be 0.022 mrem/yr (2.2×10^{-4} mSv/yr), which represented less than 0.3% of the EPA standard. This corresponds to the dose for offsite individuals calculated for previous annual reports to EPA.

The December 15, 1989, revisions to the *Clean Air Act* (40 CFR 61, Subpart H) required DOE facilities to estimate the dose to a member of the public for radionuclides released from all potential sources of airborne radionuclides. DOE and EPA

interpreted the regulation to include diffuse and unmonitored sources as well as monitored point sources (e.g., stacks). EPA has not specified or approved methods to estimate air emissions from diffuse sources, and standardization has been difficult because of the wide variety of such sources at DOE sites. The method developed at Hanford to estimate potential diffuse source emissions is based on environmental surveillance measurements of airborne radionuclides at the site perimeter, as described in DOE/RL-2001-32. During 2000, the estimated dose to a maximally exposed individual at Sagemoor from diffuse sources was 0.052 mrem/yr (5.2 x 10^{-4} mSv/yr). This dose was somewhat higher than the estimated dose from stack emissions. However, the potential combined dose from stack emissions and diffuse sources during 2000 was well below the EPA 10 mrem/yr (0.1 mSv/yr) standard.

6.4 Special Case Dose Estimates

The parameters used to calculate the dose to the DOE maximally exposed individual were selected to provide a scenario yielding a reasonable upper end (or bounding) estimate of the dose. However, such a scenario may not have necessarily resulted in the highest conceivable radiological dose. Other low-probability exposure scenarios existed that could have resulted in somewhat higher doses. Five scenarios that could have potentially lead to larger doses included 1) an individual who spent time at the site boundary location with the maximum external radiological dose rate, 2) a sportsman who consumed contaminated wildlife that migrated from the site, 3) a person who drank water at the Fast Flux Test Facility in the 400 Area, 4) an individual who breathed the maximum measured radionuclide concentrations in air following the Hanford Site wildfire for a period of 30 days, and 5) an individual who breathed the measured radionuclide concentrations in air for an entire year. The scenarios are examined in the following sections.

6.4.1 Maximum "Boundary" Dose Rate

The boundary radiological dose rate is the external radiological dose rate measured at publicly accessible locations at or near the Hanford Site boundary. The maximum boundary dose rate was determined from radiation exposure measurements using thermoluminescent dosimeters at locations where elevated dose rates might be expected on the site and at representative locations off the site. These boundary dose rates were not used to calculate annual doses to the general public because no one could actually reside at any of these boundary locations. However, these rates were used to determine the dose to a specific individual who might have spent some time at that location.

External radiological dose rates measured in 2000 are described in Section 4.6. Radiation measurements made along the 100-N Area shoreline (see Figure 6.1) were consistently above background levels and represented the highest measured boundary dose rates. The Columbia River provided public access to within ~100 meters (330 feet) of the N Reactor and supporting facilities at this location.

The highest dose rate along the 100-N Area shoreline during 2000 was 0.015 mrem/h (1.5 x 10^{-4} mSv/h), or ~1.5 times the average 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 near the 100-N Area shoreline during 2000, the external radiological dose received from Hanford operations was ~0.005 mrem (5 x 10^{-5} mSv) above the average shoreline dose rate. If an individual had spent 3 hours at that location, he or she would have received a higher dose than

the annual dose calculated for the hypothetical maximally exposed individual at Riverview. Members of the public could reach the 100-N shoreline by boat and could have legally occupied the shoreline area below the high water line. However, the topography of the shoreline below the high water line near 100-N is very rocky and visitors are not likely to remain on shore for extended periods.

6.4.2 Sportsman Dose

Wildlife have access to areas of the Hanford Site that are contaminated with radioactive materials. Sometimes wildlife acquire radioactive contamination and migrate off the site. Wildlife sampling was conducted on the site to estimate the maximum contamination levels that might have existed in animals from Hanford that were hunted off the site. Because this scenario had a relatively low probability of occurrence, this pathway was not considered in the maximally exposed individual calculation.

Radionuclide concentrations in most consumable portions of wildlife obtained within the Hanford Site boundary were below contractual detection limits (see Section 4.5) for gamma-emitting radionuclides, except for naturally occurring potassium-40. Strontium-90 was the only radionuclide, possibly of Hanford origin, detected in 2000 and was only found in bone samples. Because bone is not consumed by humans, a dose to a sportsman from this pathway was viewed as relatively implausible and was not included in this report.

6.4.3 Onsite Drinking Water

During 2000, groundwater was used as drinking water by workers at the Fast Flux Test Facility in the 400 Area, and Columbia River water was used as a drinking water source in the 100-B, 100-D, 100-K, and 200 Areas. Therefore, these water supplies were sampled and analyzed throughout the year in accordance with applicable drinking water regulations (40 CFR 141). All annual average radionuclide concentrations measured during 2000 were below applicable drinking water standards. However, tritium in the Fast Flux Test Facility groundwater wells and gross beta concentrations in the 100-K river water samples were detected at levels greater than typical background values (see Section 4.3 and Appendix E).

Based on the measured concentrations, the potential annual dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 liter per day [0.26 gallon per day] for 240 working days) would be ~0.02 mrem (0.0002 mSv). The dose to the hypothetical worker at 100-K was slightly higher than the Fast Flux Test Facility worker's but was still less than 0.02 mrem/yr (0.0002 mSv/yr). These doses were well below the drinking water dose limit of 4 mrem/yr for public drinking water supplies.

6.4.4 Inhalation Doses from the June 2000 Hanford Site Wildfire

During the wildfire on the Hanford Site from June 27 to July 2, 2000, airborne radioactivity was monitored to determine if contaminants were released into the environment (see Section 5.0). Air monitoring data collected by EPA immediately after the wildfire in communities surrounding the Hanford Site were used to calculate a potential radiological dose to the general public. The highest air monitoring result for each radionuclide detected by the EPA above normal background levels was used in the calculation. These maximum results were not all measured at the same location; however, they were assumed to apply to a single individual for the purposes of this calculation. The dose calculation also assumed a 30-day exposure period and an inhalation rate of 23 m^3 per day. These assumptions provided an upper end, or bounding, estimate of the dose to a member of the public due to the wildfire.

The results of the dose calculations for the wildfire are provided in Appendix E, Table E.11, and show an estimated potential maximum dose to a member of the public due to the wildfire of 0.18 mrem (0.0018 mSv) for the 30-day period. In contrast, the national average radiological dose from natural sources is ~300 mrem/yr (3 mSv/yr) (National Council on Radiation Protection and Measurements 1987), or ~25 mrem/month (0.25 mSv/month). Also, the current EPA limit on radiological dose due to airborne emissions is 10 mrem/yr (0.1 mSv/yr) (40 CFR 61). Therefore, the estimated potential maximum dose to a member of the public due to the wildfire represents only 0.7% of the national average monthly dose due to natural sources, and 2% of the annual EPA air emissions limit.

6.4.5 Inhalation Doses for Entire Year

Air surveillance data presented in Section 4.1 (Tables 4.1.2 and 4.1.3) were used to determine radiological doses from inhaling radionuclides in air. A nominal inhalation rate of 23 m^3 per day of air and an exposure period of 8,760 hours (365 days) were assumed for all offsite calculations. For onsite locations, the exposure period was reduced to 2,000 hours (250 8-hour workdays) to simulate a typical work year, and the breathing rate was increased to 28.8 m^3 per day to account for light duty work.

Table 6.4 presents radiological inhalation doses, in millirems per year, to hypothetical offsite individuals modeled to be in the same location for the entire year and to onsite individuals located near air surveillance stations during their workday. The average air concentrations utilized in the calculations were assumed to be constant for the year-long evaluation period.

6.5 Doses from Other than DOE Sources

DOE Order 5400.5, Section II, paragraph 7, has a reporting requirement for combined DOE and other manmade doses exceeding 100 mrem/yr. In 2000, various non-DOE industrial sources of public radiation exposure existed on or near the Hanford Site. These included a commercial low-level radioactive waste burial ground at Hanford operated by US Ecology; a nuclear power generating station at Hanford operated by Energy Northwest; a nuclear fuel production plant operated near the site by Framatome ANP Richland, Inc. (formerly Siemens Power Corporation); a commercial, low-level, radioactive waste treatment facility operated near the site by Allied Technology Group; and a commercial decontamination facility operated near the site by PN Services (see Figure 6.1).

DOE maintains an awareness of these other sources of radiation, which, if combined with the DOE sources, might have the potential to cause a dose exceeding 10 mrem/yr (0.1 mSv/yr) to any member of the public. With information gathered from these companies (via personal communication and annual reporting), it was conservatively estimated that the total 2000 individual dose from their combined activities was on the order of 0.05 mrem/yr (5×10^{-4} mSv/yr). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 2000 was well below any regulatory dose limit.

Table 6.4. Inhalation Doses (mrem/yr) based on 2000 Air Surveillance Data[a]

Radionuclide	Location	Dose Based on Average Air Data[b]
Tritium	Onsite	3.0×10^{-4}
	Perimeter	1.2×10^{-3}
	Nearby communities	1.7×10^{-3}
	Distant communities	7.4×10^{-4}
Strontium-90	Onsite	8.5×10^{-5}
	Perimeter	1.5×10^{-4}
	Nearby communities	3.2×10^{-4}
	Distant communities	6.0×10^{-5}
Iodine-129	Onsite	8.6×10^{-6}
	Perimeter	9.0×10^{-7}
	Distant communities	1.4×10^{-7}
Plutonium-238	Onsite	5.1×10^{-5}
	Perimeter	3.4×10^{-4}
	Nearby communities	0.0×10^{0}
	Distant communities	0.0×10^{0}
Plutonium-239	Onsite	7.9×10^{-4}
	Perimeter	1.3×10^{-3}
	Nearby communities	4.7×10^{-3}
	Distant communities	4.1×10^{-5}
Uranium-234	Onsite	4.9×10^{-3}
	Perimeter	2.9×10^{-2}
	Nearby communities	2.2×10^{-2}
	Distant communities	1.6×10^{-2}
Uranium-235	Onsite	9.6×10^{-5}
	Perimeter	6.9×10^{-4}
	Nearby communities	2.7×10^{-4}
	Distant communities	1.4×10^{-3}
Uranium-238	Onsite	4.0×10^{-3}
	Perimeter	2.6×10^{-2}
	Nearby communities	1.8×10^{-2}
	Distant communities	1.3×10^{-2}
Totals	Onsite	1.1×10^{-2}
	Perimeter	5.9×10^{-2}
	Nearby communities	4.7×10^{-2}
	Distant communities	3.2×10^{-2}

(a) Onsite inhalation dose calculations were based on 2,000 h exposure period and 1.2 m^3/h breathing rate; all offsite inhalation dose calculations were based on a 8,760 h exposure period and a 0.958 m^3/h breathing rate.

(b) Includes contributions from DOE activities as well as contributions from atmospheric fallout, naturally occurring radionuclides, and non-DOE facilities on and near the site.

6.6 Dose Rates to Animals

Conservative (upper) estimates have been made of the radiological dose to native aquatic organisms in accordance with the DOE Order 5400.5 interim requirement for management and control of liquid discharges. The current limit for dose to aquatic biota is 1 rad per day. The proposed limit for terrestrial biota is 0.1 rad per day. Surveillance data from Columbia River shoreline springs, Fast Flux Test Facility pond, and West Lake were evaluated using the Biota Dose Calculator (a screening method to estimate radiological doses to aquatic and terrestrial biota). The Biota Dose Calculator (DOE 2000a and b) is an Excel spreadsheet that initially compares radionuclide concentrations measured by routine surveillance programs to a set of conservative biota concentration guides (e.g., l rad per day for aquatic biota). For samples containing multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to the dose guideline. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded.

The biota concentration guides are very different from the derived concentration guides that are used to assess radiological doses to humans. If the estimated dose exceeds the guideline (sum of fractions >1.0), additional calculations are performed to more accurately evaluate exposure of the biota to the radionuclides. The process may culminate in a site-specific assessment requiring additional sampling and study of exposure.

Maximum concentrations of radionuclides in Columbia River and onsite pond sediment, and riverbank springs and pond water were evaluated using the Biota Dose Calculator. The results indicated that all spring data were below levels of concern. West Lake, an onsite pond created by a rise in the groundwater table due to the discharge of wastewater in the 200 Areas, failed the initial screen (sum of fractions >1.0) prompting additional assessment (Table 6.5). Subsequent evaluations using the Biota Dose Calculator, site-specific concentration factors derived from special surveillance data, and field survey data gathered to document pond use by shorebirds and other wildlife provided a more accurate sum of fractions (0.02). Radiological doses to plants and animals were also evaluated and were determined to be below guidelines based on the available data. The Biota Dose Calculator was a useful tool for initially screening sites for biota doses and then for focusing on those sites where the likelihood of exceeding proposed guidelines was greatest.

Table 6.5. Results of Biota Dose Calculator Screenings

Seep Location	Initial Screen (Sum of Fractions Value)	Pass or Fail
100-B	3.2×10^{-5}	Pass
100-D	4.9×10^{-3}	Pass
100-F	1.2×10^{-2}	Pass
100-H	2.2×10^{-2}	Pass
100-K	7.6×10^{-3}	Pass
100-N	6.7×10^{-5}	Pass
300 Area	4.3×10^{-1}	Pass
Hanford Townsite	1.6×10^{-2}	Pass
West Lake	2.7×10^{-1}	Pass
FFTF Pond	2.0×10^{-5}	Pass
West Lake (1st)	2.5×10^{1}	Fail
West Lake (2nd)	1.3×10^{1}	Fail
West Lake (3rd)	2.0×10^{-2}	Pass

FFTF = Fast Flux Test Facility.

6.7 Radiological Dose in Perspective

This section provides information to put the potential health risks associated with the release of radioactive materials 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) were performed to estimate the possible risk of detrimental health effects from exposure to low levels of radiation. These studies 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, regulatory agencies conservatively (cautiously) assume that the probability of these types of health effects at low doses (down to zero dose) is the same per unit dose as the health effects observed at much higher doses (e.g., in atomic bomb survivors, individuals receiving medical exposures, or radium dial painters). This concept is 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 Site 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 (e.g., Sagan 1987). Because cancer and hereditary diseases in the general population are 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 proven. In developing *Clean Air Act* regulations, EPA uses a probability value of ~4 per 10 million (4×10^{-7}) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 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 operations (e.g., DOE facilities, nuclear power plants, chemical plants, hazardous waste sites). All of these industries are considered beneficial to people in some way such as providing electricity, national defense, waste disposal, and consumer products. Government agencies have a complex task to establish environmental regulations that control levels of risk to the public without unnecessarily reducing needed benefits from industry.

One perspective on risks from industry is to compare them to risks involved in other typical activities. For instance, two risks that an individual experiences when flying on an airplane are added radiological dose (from a stronger cosmic radiation field that exists at higher altitudes) and the possibility of being in an aircraft accident. Table 6.6 compares the estimated risks from various radiological doses to the risks of some activities encountered in everyday life. Table 6.7 lists some activities considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluents in 2000.

Table 6.6. 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	100×10^{-6}[b]
Taking contraceptive pills (side effects)	20×10^{-6}
Drinking 1 can of beer or 0.12 L (4 oz) of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Firearms, sporting (accidents)	10×10^{-6}[b]
Flying as an airline passenger (cross-country roundtrip--accidents)	8×10^{-6}[b]
Eating approximately 54 g (4 tbsp) of peanut butter per day (liver cancer)	8×10^{-6}
Pleasure boating (accidents)	6×10^{-6}[b]
Drinking chlorinated tap water (trace chloroform--cancer)	3×10^{-6}
Riding or driving in a passenger vehicle (483 km [300 mi])	2×10^{-6}[b]
Eating 41 kg (90 lb) of charcoal-broiled steaks (gastrointestinal tract cancer)	1×10^{-6}
Natural background radiation dose (300 mrem, 3 mSv)	0 to 120×10^{-6}
Flying as an airline passenger (cross-country roundtrip--radiation)	0 to 5×10^{-6}
Dose of 1 mrem (0.01 mSv) for 70 yr	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford in 2000 (0.014 mrem, 1.4×10^{-4} mSv)	0 to 0.0070×10^{-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 6.7. Activities Comparable in Risk to the 0.014-mrem (1.4×10^{-4}-mSv) Dose Calculated for the 2000 Maximally Exposed Individual

Driving or riding in a car 0.96 km (0.6 mi)
Smoking less than 1/100 of a cigarette
Flying approximately 2.5 km (1.5 mi) on a commercial airliner
Eating approximately 0.75 tsp of peanut butter
Eating one 0.16-kg (5.75-oz) charcoal-broiled steak
Drinking 0.97 L (approximately 1 qt) of chlorinated tap water
Being exposed to natural background radiation for 18 min in a typical terrestrial location
Drinking approximately 0.17 L (0.6 oz) of wine or 0.05 L (1.75 oz) of beer

6.8 References

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7.0 Groundwater and Vadose Zone Monitoring

D. G. Horton and D. R. Newcomer

7.0.1 Groundwater Monitoring

The Hanford Groundwater Monitoring Project includes sitewide groundwater monitoring mandated by U.S. Department of Energy (DOE) Orders and near-field groundwater monitoring conducted to ensure that operations in and around specific waste disposal facilities comply with applicable regulations.

Collection and analysis of groundwater samples to determine the distribution 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 effects of Hanford Site groundwater contamination. Other work included data management, interpretation, and reporting. The purpose of this section is to provide an overall summary of groundwater monitoring during 2000. Additional details concerning the Hanford Groundwater Monitoring Project are available in PNNL-13404, *Hanford Site Groundwater Monitoring for Fiscal Year 2000*.

Groundwater monitoring was conducted to accomplish the following tasks:

- assess the impact of radiological and hazardous chemicals on groundwater as a result of Hanford Site operations
- evaluate potential offsite effects from the groundwater pathway
- verify compliance with applicable environmental laws and regulations
- evaluate effectiveness of groundwater remediation
- identify and characterize new or existing groundwater quality problems
- evaluate the potential human exposure to contaminants in groundwater.

To assess the effect of Hanford Site operations on groundwater quality, background conditions, or the quality of groundwater on the site unaffected by operations must be known. Data on the concentration of contaminants of concern in groundwater that existed before 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 site operations, including upgradient locations, provide the best estimate of pre-Hanford groundwater quality. Summaries of background conditions are tabulated in several reports (PNL-6886; PNL-7120; DOE/RL-96-61; and Appendix A of WHC-EP-0595).

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-13404) 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 and less frequently than the unconfined aquifer, because it also provides a potential pathway for contaminants to migrate off the site. Some sampling also was conducted at the request of the Washington State Department of Health.

Sitewide groundwater monitoring is designed to meet the project objectives stated in DOE Order 5400.1 and described above. The effects of Hanford Site operations on groundwater have been monitored for more than 50 years under this project and its predecessors. Near-field monitoring of groundwater around specific waste facilities was performed to meet the requirements of the *Resource Conservation and Recovery Act* (RCRA) (40 CFR 265) and Washington Administrative Codes (WAC 173-303 and 173-304) as well as applicable DOE Orders (e.g., 5400.1, 5400.5). Groundwater monitoring was also performed in conjunction with cleanup investigations under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) (40 CFR 300).

To evaluate the effect of remediation efforts on groundwater, groundwater within the contaminant plumes must be monitored to characterize and define flow patterns and trends in the concentrations of radiological or chemical constituents. Monitoring is required to quantify the existing groundwater quality problem and to provide a baseline of environmental conditions against which future changes can be assessed.

New or existing groundwater quality problems must be identified and characterized. Areas that potentially could be a source of contamination were monitored to characterize and define trends in the condition of the groundwater. These areas were monitored to identify and quantify existing, emerging, or potential problems in groundwater quality. Potential source areas included active waste disposal facilities or facilities that had generated or received waste in the past. Most of these facilities are located within the 100, 200, and 300 Areas. However, some sources such as the 618-11 burial ground are located outside these operational areas.

Water supplies on and near the Hanford Site potentially provide the most direct route for human exposure to contaminants in groundwater. In 2000, one of the site's ten DOE-owned, contractor-operated drinking water systems provided groundwater for human consumption on the site. This system supplied water at the Fast Flux Test Facility (see Section 4.3). Water supply wells used by the city of Richland are located near the 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.

Summary results for groundwater monitoring in 2000 are discussed in Section 7.1.

7.0.2 Vadose Zone Monitoring

The vadose zone is defined as the area between the ground surface and the top of the water table. This subsurface zone also is referred to as the unsaturated zone or the 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 industrialized and waste disposal areas at the Hanford Site has been contaminated with large amounts of radioactive and non-radioactive materials through the intentional and unintentional discharge of liquid waste to the soil column, burial of contaminated solid waste, and deposits of airborne contaminants on the ground. Depending on the makeup of the soil, the geology of the area, the nature of the waste, 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 about the effect 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 the Hanford Site, the primary method for monitoring 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 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 conducted as part of an expedited response action in the 200-West Area to remove carbon tetrachloride from the vadose zone.

Results for the 2000 vadose zone activities are discussed in Section 7.2. Section 7.2 has been divided into vadose zone characterization, vadose zone monitoring, and technical demonstrations related to the vadose zone.

7.1 Hanford Groundwater Monitoring Project

D. R. Newcomer and M. J. Hartman

The strategy for managing and protecting groundwater resources at the Hanford Site focuses on protection of the Columbia River, human health, the environment, treatment of groundwater contamination, and limitation of contaminant migration from the 200 Areas (see Groundwater/Vadose Zone Integration Project reports DOE/RL-98-48 and DOE/RL-98-56). To implement this strategy, the Hanford Groundwater Monitoring Project continues to monitor the quality of groundwater. The project, which is conducted by Pacific Northwest National Laboratory for DOE, is designed to detect and characterize new contaminant plumes and to document the distribution and movement of existing groundwater contamination. Monitoring provides the historical baseline to evaluate current and future risk from exposure to groundwater contamination and to decide on remedial options. Hydrogeologic studies are an integral part of the project because the geology and hydrology of the Hanford Site control the movement of contaminants in groundwater.

The effort to protect groundwater quality at the Hanford Site is implemented through programs to minimize and eliminate waste discharged to the soil column and through remediation work on the site. The Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement; Ecology et al. 1998) provided 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 2.3.

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 to treat and dispose contaminated effluents discharged to the soil. Of the 33 major waste streams identified in DOE (1987), the Phase I (high-priority) streams have either been eliminated or are being treated and diverted to the 200 Areas Treated Effluent Disposal Facility. In 2000, the State-Approved Land Disposal Site was the only place on the Hanford Site where liquid effluent containing radionuclide contamination (tritium) discharged to the soil column. The locations of active permitted facilities through which wastewater was discharged to the ground in 2000 are shown in Figures 1.3 and 7.1.1 and are discussed in detail in Section 2.3. In 2000, ~3% of the total volume of wastewater at the Hanford Site was discharged to the State-Approved Land Disposal Site and ~97% was discharged to the 200 Areas Treated Effluent Disposal Facility. All other facilities (e.g., cribs, trenches) where wastewater was historically discharged to the soil column are out of service. The only operational injection wells are associated with pump-and-treat remediation systems. Treated wastewater is re-injected into the unconfined aquifer at these wells.

Groundwater is used for drinking water and other purposes at some facilities on the Hanford Site. Pacific Northwest National Laboratory monitors DOE drinking water supplies for radiological constituents at the source and in one instance, at the point of use. Results of the radiological monitoring are summarized in Section 4.3. The locations of wells completed in the unconfined aquifer that provide water for drinking, fire suppression, and cooling are shown in Figure 7.1.2.

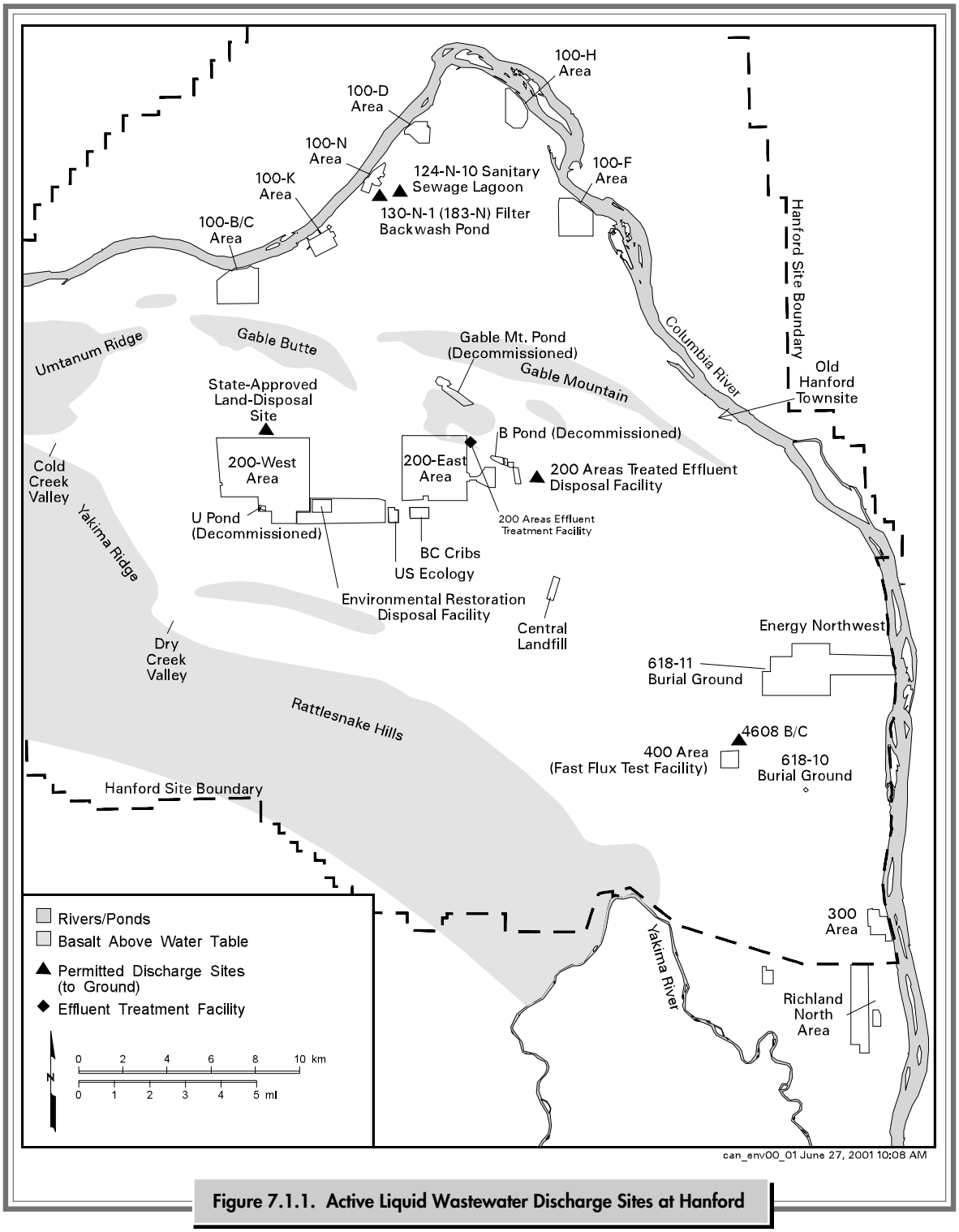

Figure 7.1.1. Active Liquid Wastewater Discharge Sites at Hanford

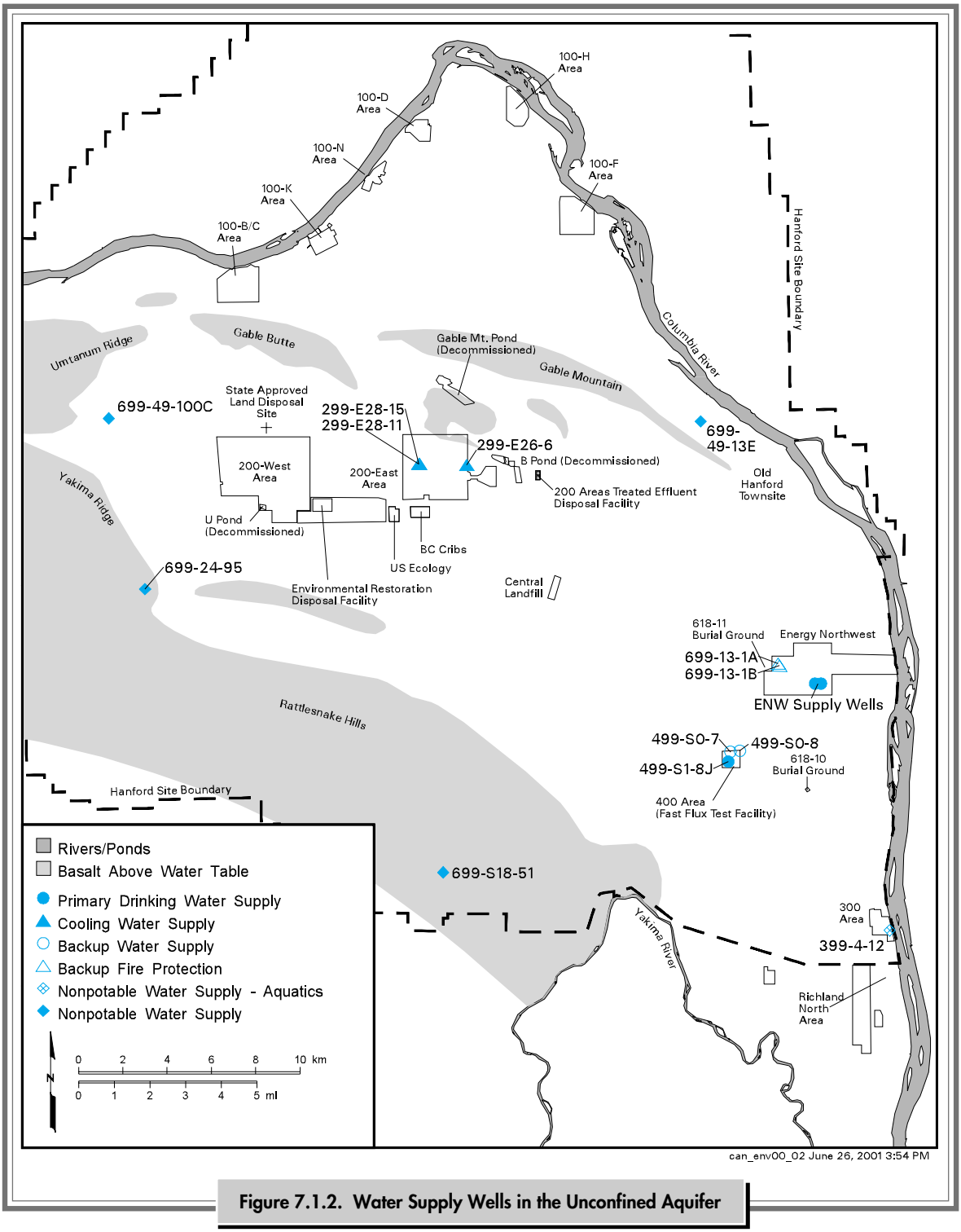

Figure 7.1.2. Water Supply Wells in the Unconfined Aquifer

7.1.1 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 7.1.3).

The Columbia River basalts were formed from lava that periodically erupted from volcanic fissures. The regional river system eroded the basalt and deposited sediment across the basalt surfaces between eruptions. Zones between the basalt flows and the sediment deposited as interbeds between basalt eruptions are frequently zones that are used as water sources in areas around the Hanford Site.

During the period when basalt was deposited, tectonic pressure was slowly deforming the basalt flows into the generally east-west 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 sediment, the Columbia River began to erode, rather than deposit, sediment 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 caliche forms a low-permeability layer that affects migration of water through the vadose zone.

More recently, Hanford formation sediment was deposited by catastrophic ice age floods. Fine sand and silt were deposited in slackwater areas at the margins of the basin. However, primarily sands and gravels were deposited on the Hanford Site. In

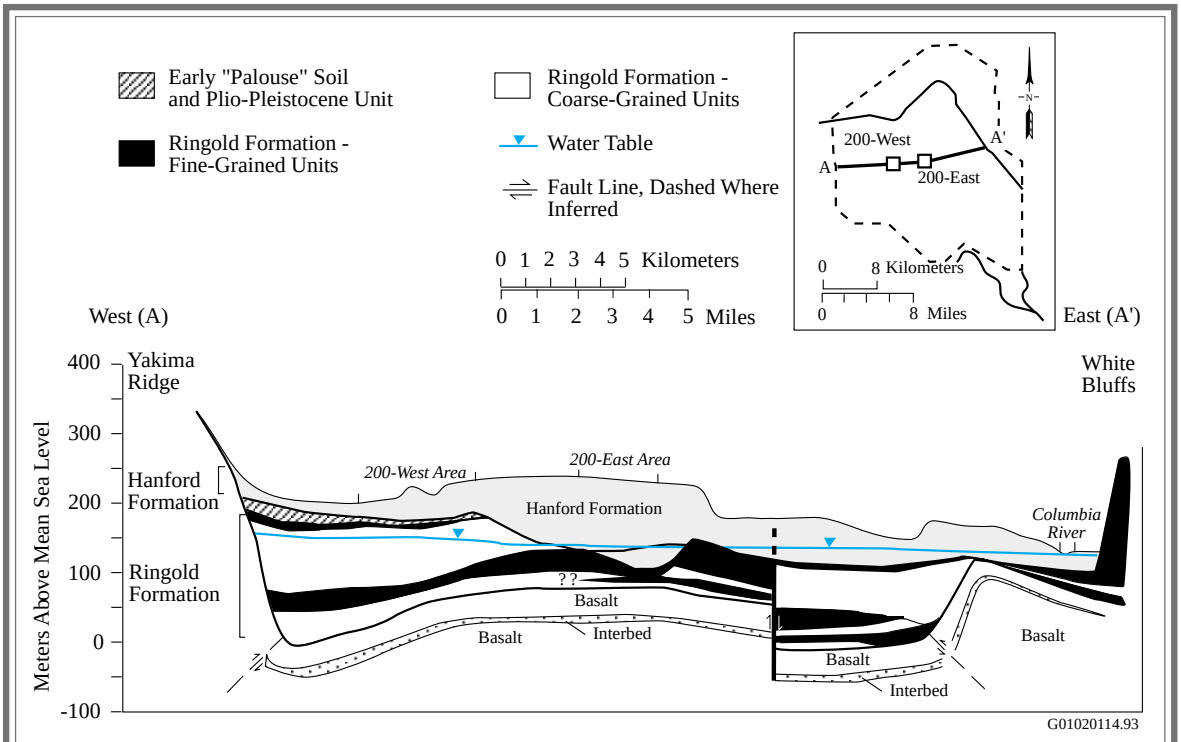

Figure 7.1.3. Geologic Cross Section of the Hanford Site

places, the sediment is covered by up to a few meters of recent stream or windblown deposits.

Detailed information on the geology of the Pasco Basin can be found in BHI-00184, DOE/RW-0164 (Vol. 1), PNNL-13080, WHC-MR-0391, WHC-SD-EN-TI-014, and WHC-SD-EN-TI-019.

7.1.2 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 sediment (i.e., caliche). Extensive, confined aquifers at the site are found primarily within interflows and interbeds of the Columbia River basalts. These are referred to as basalt-confined aquifers. Locally confined aquifers also are found below the clays and silts of the Ringold Formation.

An unconfined aquifer, or water-table aquifer, is overlain by unsaturated sediment. 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. Sand and gravel of the Hanford formation are unconsolidated and are generally much more permeable than the compacted and silty gravel of the Ringold Formation. Clay and silt units and zones of natural cementation form low-permeability zones within the Ringold Formation.

The unconfined aquifer, which forms the uppermost groundwater zone, has been directly affected 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 sediment above the basalt bedrock is greater than 200 meters (656 feet) in some areas of the Hanford Site and thins out along the flanks of the uplifted basalt ridges (Figures 7.1.3 and 7.1.4). Depth from the ground surface to the water table ranges from less than 0.3 meter (1 foot) near the Columbia River to greater than 106 meters (348 feet) in the center of the site. The unconfined aquifer is bounded below either by 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

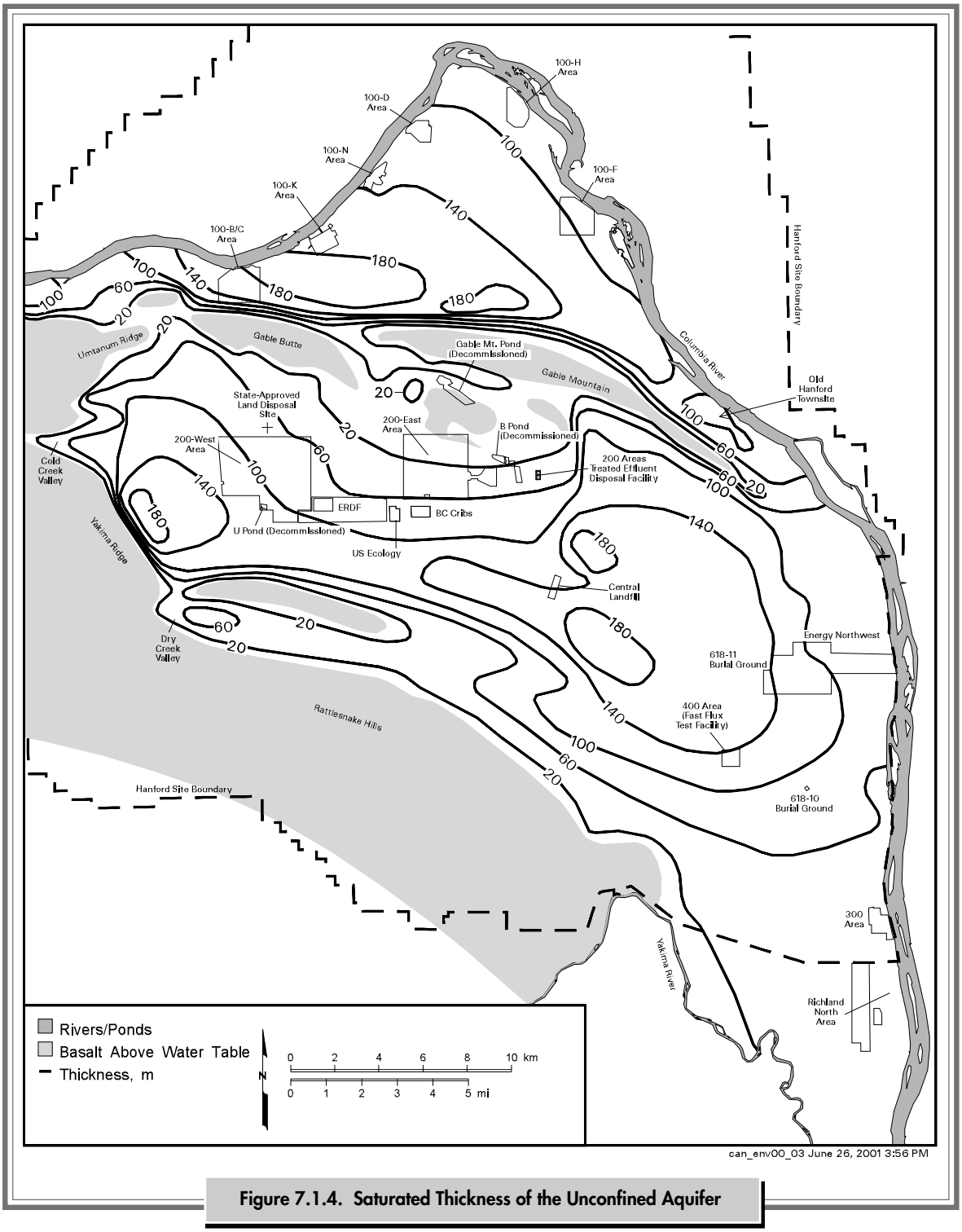

Figure 7.1.4. Saturated Thickness of the Unconfined Aquifer

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).

7.1.2.1 Groundwater Flow

The water-table elevation contours shown in Figure 7.1.5 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 to areas of lower elevation. Areas where the contours are closer together are high-gradient areas, where the "driving force" for groundwater flow is greater. However, because sediment with low permeability inhibits groundwater flow, producing 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 sediment. Figure 7.1.6 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 site. The Yakima River, where it flows along the southern boundary of the 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 temporally. The rate of natural recharge depends primarily on soil texture, vegetation, and climate (Gee et al. 1992; PNL-10285). Natural recharge rates range from near zero, where fine-grained soil and deep-rooted vegetation are present, to greater than 10 centimeters per year (4 inches per year) in areas where soil is coarse textured and bare of vegetation.

Large-scale, artificial recharge to the unconfined aquifer occurred because of past liquid waste disposal in the operating areas and offsite agricultural irrigation to the west and south. Discharge of wastewater caused the water table to rise over most of the Hanford Site. Since the peak discharge in 1984, discharge of wastewater to the ground has been significantly reduced and, in response, the water table subsequently declined over most of the site. The water table continues to decline, as illustrated by Figure 7.1.7. The water table declined up to 0.5 meter (1.6 feet) over most of the site between 1999 and 2000. The largest decline in the water table was 0.75 meter (2.5 feet) near a pump-and-treat system in the 200-West Area.

The decline in the water table has altered the flow pattern of the unconfined aquifer, 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 (see Section 7.1.6).

In the past, two major groundwater mounds formed near the 200-East and 200-West Areas in response to wastewater discharges. The first of these mounds was created by disposal at the 216-U-10 pond (U Pond) in the 200-West Area. After U Pond

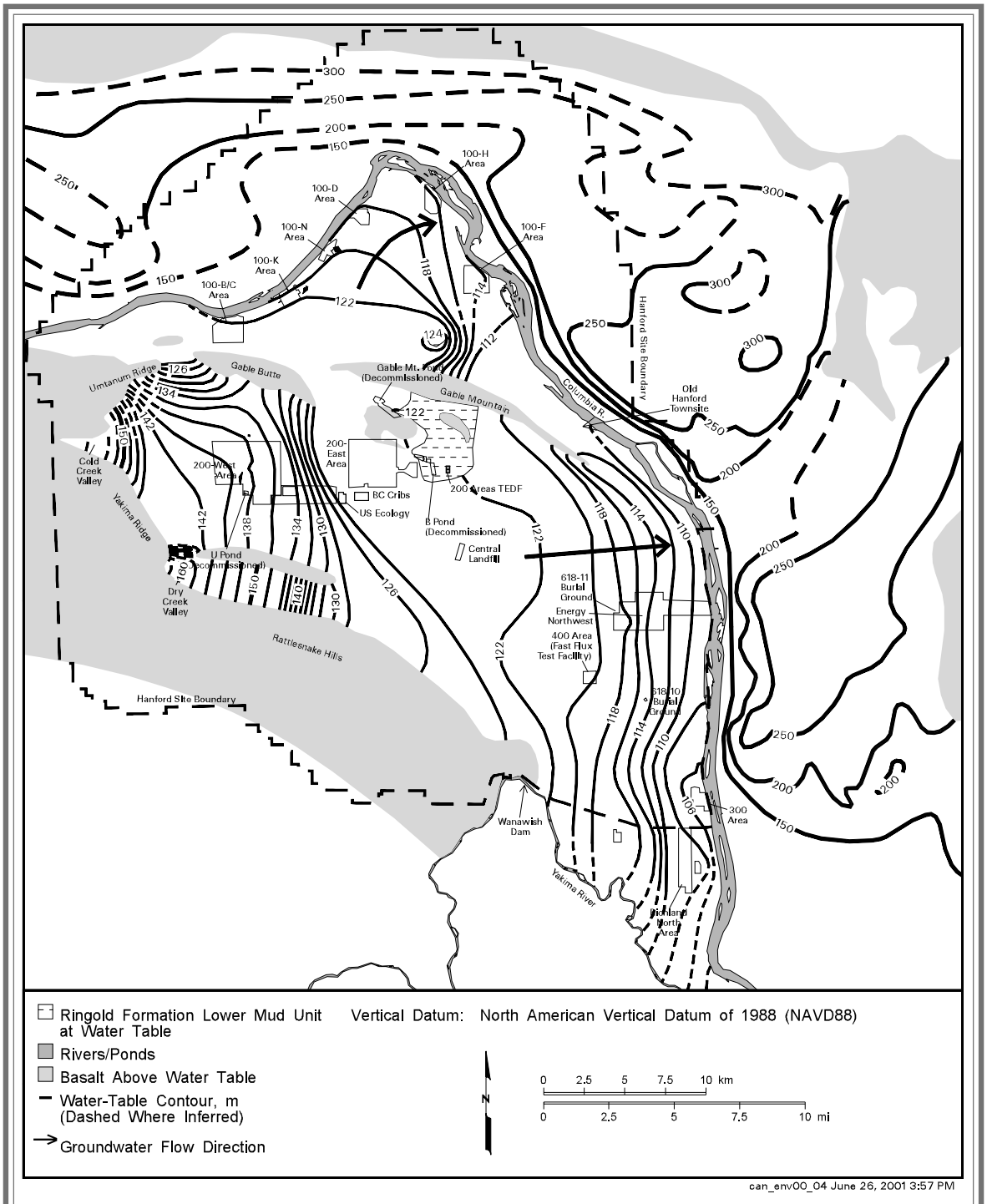

Figure 7.1.5. Water-Table Elevations for the Unconfined Aquifer at the Hanford Site and in Adjacent Areas East and North of the Columbia River, March/April 2000

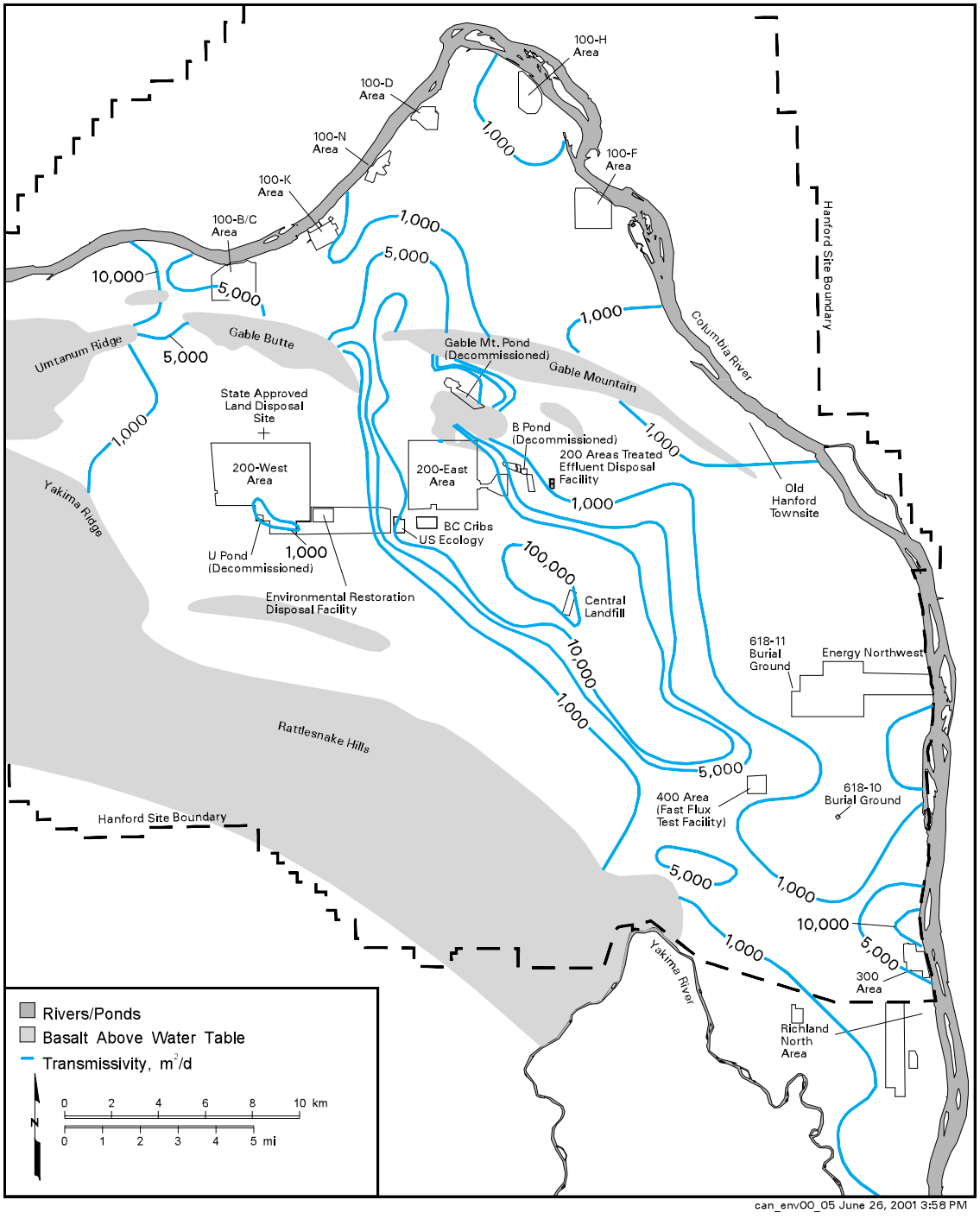

Figure 7.1.6. Transmissivity Distribution in the Unconfined Aquifer

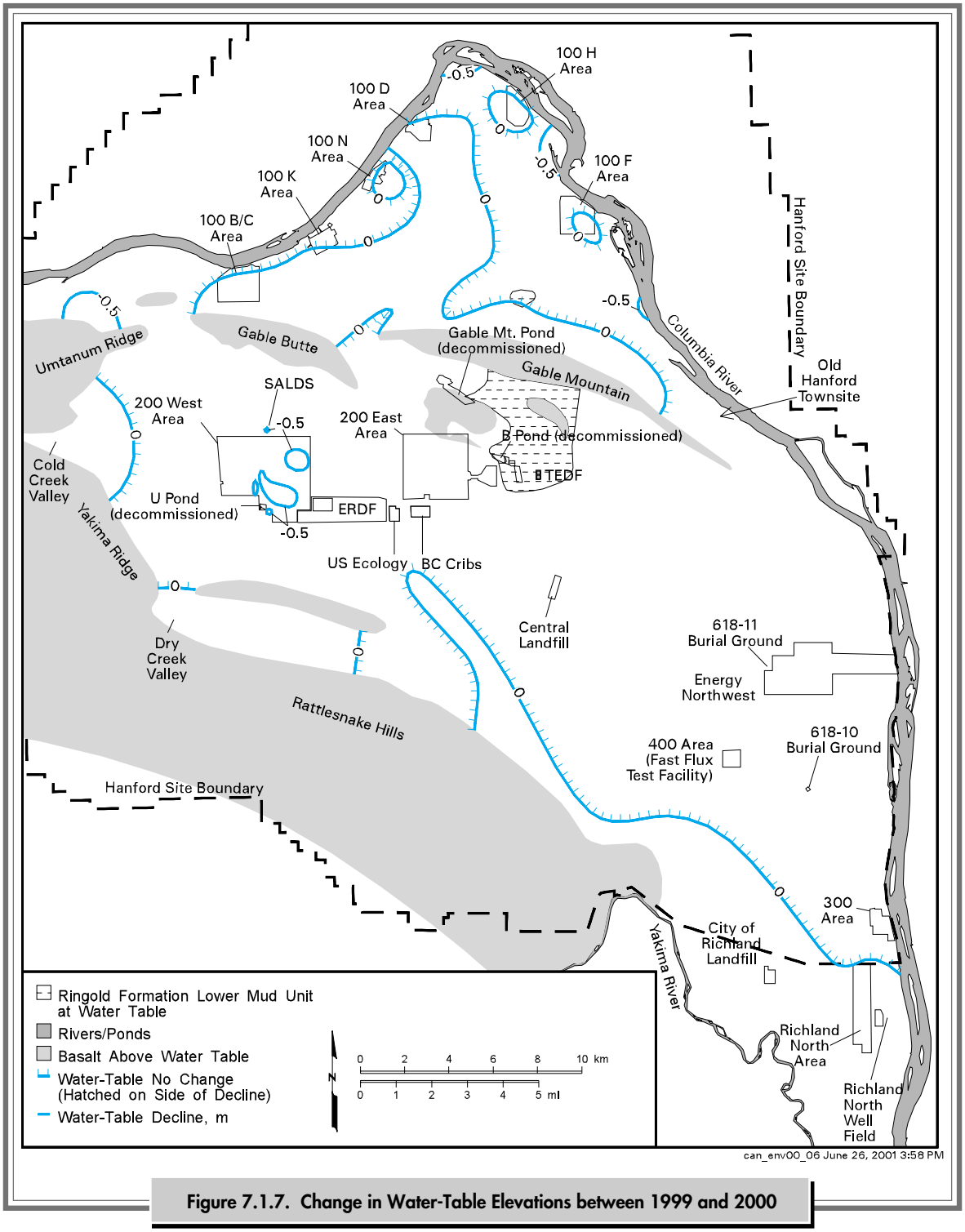

Figure 7.1.7. Change in Water-Table Elevations between 1999 and 2000

was decommissioned in 1984, the mound slowly dissipated. The water table continues to decline in this area (see Figure 7.1.7). The second major mound was created by discharge to the decommissioned, or former, 216-B-3 pond (B Pond), east of the 200-East Area. The water-table elevation near B Pond increased to a maximum before 1990 and decreased because of reduced discharge. After discharge to B Pond ceased in August 1997, the decline in the water-table elevation accelerated. Groundwater mounding related to wastewater discharges also occurred in the 100 and 300 Areas in the past. However, groundwater mounding in these areas was not as great as in the 200 Areas primarily because of lower discharge volumes.

7.1.2.2 Hydrogeologic Studies

In 2000, the hydrogeology of the suprabasalt aquifer system in the 200-East Area and vicinity was re-evaluated (PNNL-12261). The purpose of the study was to refine the conceptual model of groundwater flow in the 200-East Area and vicinity. In this study, the suprabasalt sediment was separated into two aquifer systems, the Hanford unconfined aquifer and the confined Ringold aquifer system. These aquifer systems in this area previously had been referred to as either a basalt-confined aquifer system or a single suprabasalt aquifer.

Hydrostratigraphic mapping indicated that an aquiclude separating the aquifer systems is the most significant basin-wide confining unit within the suprabasalt sediment. This confining unit is composed of silts and clays of the Ringold Formation. The study also concluded that one or more buried ancient channels eroded into the Ringold Formation in a northwest to southeast direction across the 200-East Area. Groundwater and contaminants preferentially flow along this erosional channel.

7.1.3 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 the movement of these contaminants at the Hanford Site are discussed in the following paragraphs.

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 7.1.1 lists the principal contaminants found in each operational 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

Table 7.1.1. Chemical and Radiological Groundwater Contaminants and Their Link to Site Operations

Areas	Facilities Type	Contaminants Generated
100	Reactor operations	Tritium, ^{60}Co, ^{90}Sr, Cr^{6}, SO_4^{-2}
200	Irradiated fuel processing	Tritium, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, Pu, U, CN^{-}, Cr^{6}, F^{-}, NO_3^{-}
200	Plutonium purification	Pu, carbon tetrachloride, chloroform, NO_3^{-}
300	Fuel fabrication	^{99}Tc, U, Cr^{6}, trichloroethlene

to the ground. Other contamination sources in the 200 Areas included 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. This organic liquid, once in contact with groundwater, slowly dissolves and produces contaminant plumes. The presence of non-aqueous liquid has a major impact on the site's groundwater remediation strategy because the organic liquid in the subsurface represents a continuing source of contamination that is very difficult to clean up. Groundwater contamination in the 300 Area resulted mainly from discharge of waste from fuel fabrication.

Liquid effluents discharged to the ground at Hanford Site facilities percolated down through the unsaturated zone toward the water table. Radionuclide and chemical constituents move through the soil column and, in some cases, enter the groundwater. In some locations, sufficient water was discharged to saturate the soil column to the surface. Not all contaminants move at the same rate as the water in the subsurface. Chemical processes such as adsorption onto soil particles, chemical precipitation, and ion exchange slow the movement of some constituents such as strontium-90, cesium-137, and plutonium-239/240. However, these processes may be affected by the chemical characteristics of the waste such as high ionic strength, acidity, or presence of chemical complexants. Other radionuclides, such as technetium-99, iodine-129, and tritium, and chemicals, such as nitrate, are not as readily retained by the soil and move vertically through the soil column at a rate nearly equal to the infiltrating water. When the contaminants reach the water table, their concentrations are reduced by dilution with groundwater. As these dissolved constituents move with the groundwater, many radionuclides and chemicals adhere to sediment particle surfaces (adsorption) or diffuse into the particles (absorption). Radionuclide concentrations are also 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. In the source areas, where large volumes of wastewater were discharged, a large vertical hydraulic gradient developed that moved 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 (see Figure 7.1.5). Contamination that reaches the river is further diluted by river water.

7.1.4 Groundwater Modeling

Researchers use numerical modeling of groundwater flow and contaminant transport to simulate future groundwater flow conditions and predict the migration of contaminants through the groundwater pathway. DOE consolidated multiple versions of sitewide groundwater flow and contaminant transport models into one model to eliminate redundancies and promote consistency in addressing sitewide groundwater problems (DOE/RL-2000-11). During 2000, the technical basis for predicting groundwater flow and contaminant transport was improved by 1) identifying and quantifying uncertainties in the model and 2) performing a transient calibration of the sitewide model. Three applications of the consolidated groundwater model were also performed in 2000. The code used for implementing the consolidated groundwater model is the Coupled Fluid, Energy, and Solute Transport (CFEST-96) code, which was developed by CFEST Co., Irvine, California (Gupta 1997).

In 2000, uncertainties in components of the model were identified. The components of the

model having uncertainties included interaction between the unconfined aquifer and the upper basalt-confined aquifer, variability in recharge from surface runoff, variable flow of the Columbia and Yakima Rivers, irrigation effects on land adjacent to the Hanford Site, definition of boundary conditions, identification of hydrogeologic units, and hydraulic properties. Various conceptual models were developed and run, and the results were compared to quantify the sources of uncertainty.

A transient calibration of the sitewide groundwater model was performed in 2000 to improve the ability of the sitewide model to simulate historical changes in the water table elevation over the entire Hanford Site (PNNL-13447). Information on the rise and fall of the water table since 1943 was used to determine the distribution of aquifer hydraulic properties that produces the best match to the observed changes in the water-table elevation.

The consolidated groundwater model was used for three specific applications in 2000. One of the applications was to simulate the migration of carbon tetrachloride from the Z crib in the 200-West Area to an assumed compliance boundary ~5,000 meters (16,400 feet) from the source. The purpose of the study was to provide upper and lower estimates of the amount of carbon tetrachloride at the source area that will most likely result in carbon tetrachloride concentrations exceeding 5 μg/L at the boundary. The modeling was performed using assumed amounts of 487,500 kilograms (1.1 million pounds), 225,000 kilograms (496,000 pounds), 75,000 kilograms (165,000 pounds), and 7,500 kilograms (16,500 pounds) of carbon tetrachloride that reached groundwater. The modeling study concluded that between 7,500 kilograms (16,500 pounds) and 75,000 kilograms (165,000 pounds) of carbon tetrachloride would result in concentrations of 5 μg/L or more at the compliance boundary. If 75,000 kilograms (165,000 pounds) or more carbon tetrachloride reaches groundwater, then 5 μg/L would be exceeded at the boundary. Carbon tetrachloride concentrations would not likely exceed 5 μg/L at the boundary if 7,500 kilograms (16,500 pounds) or less carbon tetrachloride reached groundwater at the source area.

Groundwater flow and transport modeling was conducted to assess the performance of the Immobilized Low-Activity Waste Disposal Facility in the southern 200-East Area. The sitewide groundwater model simulated the transport of hypothetical contaminants, which are released to groundwater, from the facility to the Columbia River and to a hypothetical well 100 meters (330 feet) downgradient of the facility. The model results indicated that groundwater at the facility moves in a southeasterly direction and then in an easterly direction before reaching the Columbia River. The distance along this groundwater flow path is ~15 kilometers (9.3 miles). Assuming an infiltration rate of 4.2 mm/yr (0.2 inch/yr), an input concentration of 1 Ci/m^3 at the source release area would yield a maximum concentration of 0.0011 Ci/m^3 at a well 100 meters (330 feet) downgradient of the site. Greater levels of infiltration would result in lower concentrations of contaminants in the downgradient well.

The consolidated sitewide groundwater model was used as the groundwater component of the System Assessment Capability to simulate contaminant transport through the groundwater. The System Assessment Capability is a tool being developed to predict the cumulative sitewide effects from all significant contaminants at the Hanford Site. During 2000, historical data were compiled for the initial simulations of the groundwater model.

Groundwater models were used to continue assessing and improving the performance of groundwater pump-and-treat systems in operable units in the 100-K, 100-N, 100-D, 100-H, and 200-West Areas. The operable units and their associated contaminants of concern are presented in Table 7.1.2. In these pump-and-treat systems,

Table 7.1.2. Operable Units and Associated Contaminants of Concern

Area	Operable Unit	Contaminants of Concern
100-K	100-KR-4	Hexavalent chromium
100-N	100-NR-2	Strontium-90
100-H and 100-D	100-HR-3	Hexavalent chromium
200-West	200-UP-1	Technetium-99 and uranium
200-West	200-ZP-1	Carbon tetrachloride

contaminated water is removed by means of extraction wells, treated, and either disposed of to the State-Approved Land Disposal Site or returned upgradient to the aquifer through injection wells. The models were used to predict system performance and progress toward remediation goals. The modeling was used to evaluate different extraction and injection well configurations, predict effects of pumping, assess the extent of hydraulic influence and the capture zone, and evaluate groundwater travel times. Modeling was conducted using the Micro-FEM© finite-element code developed by C. J. Hemker, Amsterdam, The Netherlands.

Computer modeling was used to evaluate hydraulic capture and optimize the pumping rates of the pump-and-treat systems in the operable units in the 100-K, 100-N, 100-D, and 100-H Areas. The modeling results showed that the extraction wells were reducing the net groundwater flow to the Columbia River through the targeted plume area by ~76% in the 100-KR-4 Operable Unit (DOE/RL-2000-01). The modeling results also showed that, by optimizing the pumping rates and adding one extraction well, capture of the targeted plume area can be increased to ~84%. At the 100-NR-2 Operable Unit, the pump-and-treat system continued to reduce the net groundwater flow to the Columbia River by ~96% (DOE/RL-99-79). At the 100-D Area, which is part of the 100-HR-3 Operable unit, the model results indicated that groundwater passing through over 90% of the targeted plume area was being intercepted by the extraction wells. At the 100-H Area, the other part of the 100-HR-3 Operable Unit, the extraction wells were capturing groundwater flowing through ~86% of the targeted plume area (DOE/RL-2000-01). The modeling predicted that the targeted plume area could be increased to ~98% when an additional extraction well is added to the pump-and-treat system. This extraction well began operating in 2000.

For the 200-UP-1 Operable Unit in the 200-West Area, modeling was performed to continue to evaluate the effectiveness in containing the targeted area of the technetium-99 and uranium plumes and track the progress of remediation. The modeling showed that one extraction well (299-W19-39) captured and contained the targeted area of high technetium-99 and uranium concentrations (DOE/RL-99-79). Since pump-and-treat systems started, the extraction well removed at least one pore volume of water from the targeted plume area by the end of September 2000. One pore volume is the total volume of pores considered collectively within the soil of the targeted plume. The ratio of the volume of water removed from the targeted area of the plume to the total volume of water removed from the aquifer, known as plume capture efficiency, was ~55% during 2000.

For the 200-ZP-1 Operable Unit in the 200-West Area, modeling was performed to evaluate the remedial action of the pump-and-treat system.

The modeling results indicated that the pump-and-treat extraction wells continue to contain the high carbon tetrachloride concentration area (greater than 4,000 μg/L) of the plume (DOE/RL-99-79). The modeling predictions showed that since pump-and-treat operations began, pumping had removed one pore volume of water from the upper 15 meters (49 feet) of the aquifer from an area of ~163,400 m^2 (195,400 ft^2) near the northernmost extraction wells. For the southernmost extraction wells, the modeling results showed that since pump-and-treat operations began, pumping had removed one pore volume from an area of ~80,300 m^2 (96,000 ft^2) around those wells. One pore volume is defined as the estimated total volume of pore space within a given area and thickness of aquifer.

7.1.5 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). That plan assures that monitoring at active waste disposal facilities complies with requirements of RCRA 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 and characterize potential and emerging groundwater contamination problems, and to integrate the various groundwater projects to minimize redundancy.

The *Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project* (PNNL-11989) describes how the DOE will implement the groundwater monitoring requirements outlined in DOE (1987) and DOE/RL-89-12. The purpose of the integrated monitoring plan is to 1) describe the monitoring well networks, constituents, sampling frequencies, and criteria used to design the monitoring program; 2) identify federal and state groundwater monitoring requirements and regulations; and 3) provide a list of wells, constituents, and sampling frequencies for groundwater monitoring conducted on the Hanford Site. Federal and state regulations include RCRA, CERCLA, and Washington Administrative Codes (see Section 2.2).

Information on contaminant distribution and transport are integrated into a sitewide evaluation of groundwater quality, which is documented in an annual groundwater monitoring report (e.g., PNNL-13404). Groundwater monitoring is also carried out during CERCLA cleanup investigations. These investigations, managed by Bechtel Hanford, Inc., are documented in annual summary reports (e.g., DOE/RL-2000-01).

7.1.5.1 Groundwater Sampling and Analytes of Interest

Groundwater samples were collected from 694 wells for all monitoring programs during 2000. The locations of sampled wells are shown in Figures 7.1.8 and 7.1.9; well names are indicated only for those wells specifically discussed in the text. Because of the density of unconfined aquifer wells in the operational areas, well names in these areas are also shown on detailed maps in the following sections. Figure 7.1.10 shows the locations of facilities where groundwater monitoring was conducted to comply with RCRA (also see Appendix A in PNNL-13404). Wells at the Hanford Site generally follow a naming system that indicates the approximate location of the well. The prefix of the well name indicates the area of the site, as shown in Table 7.1.3. The names for 600 Area wells follow a local coordinate system in which the numbers

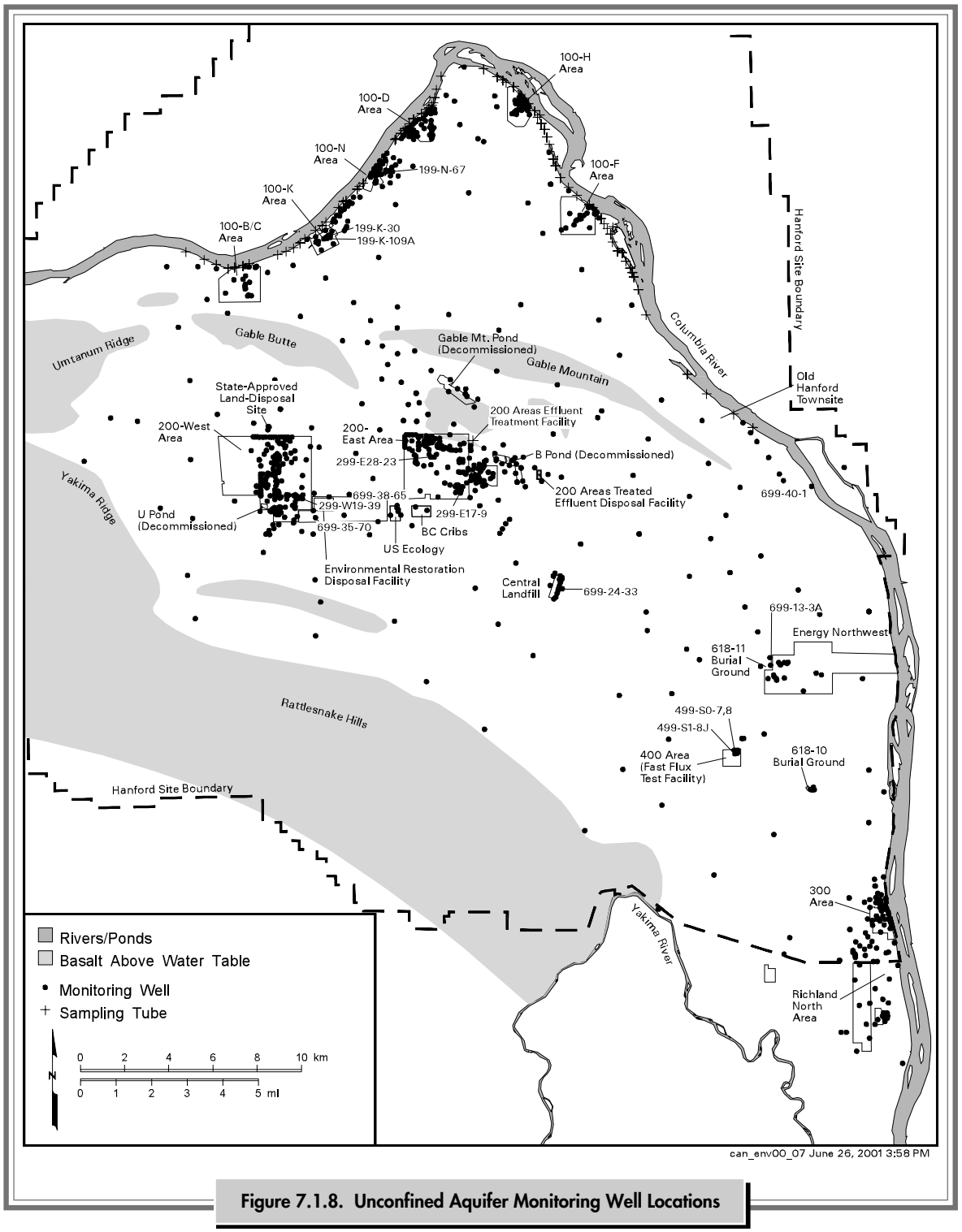

Figure 7.1.8. Unconfined Aquifer Monitoring Well Locations

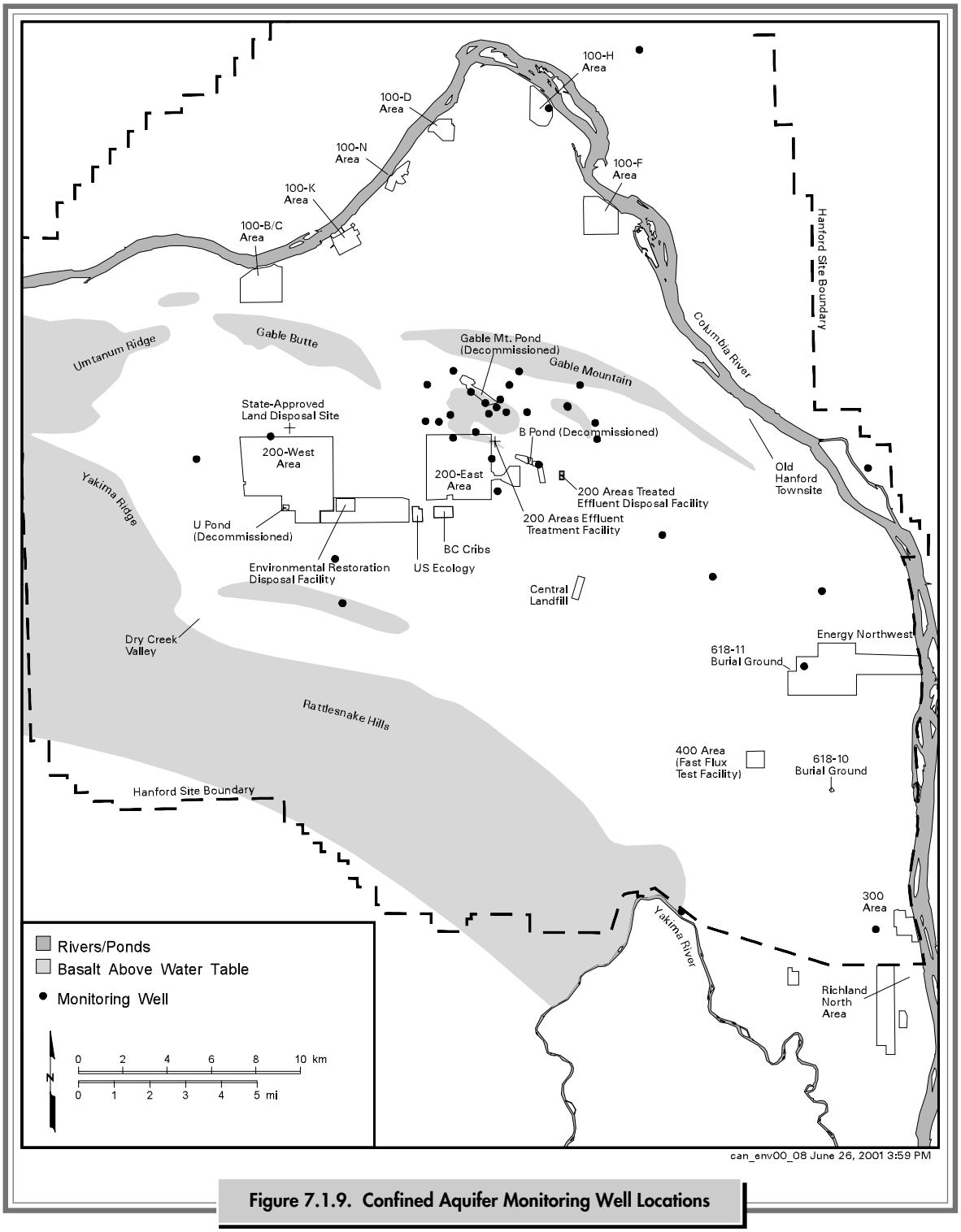

Figure 7.1.9. Confined Aquifer Monitoring Well Locations

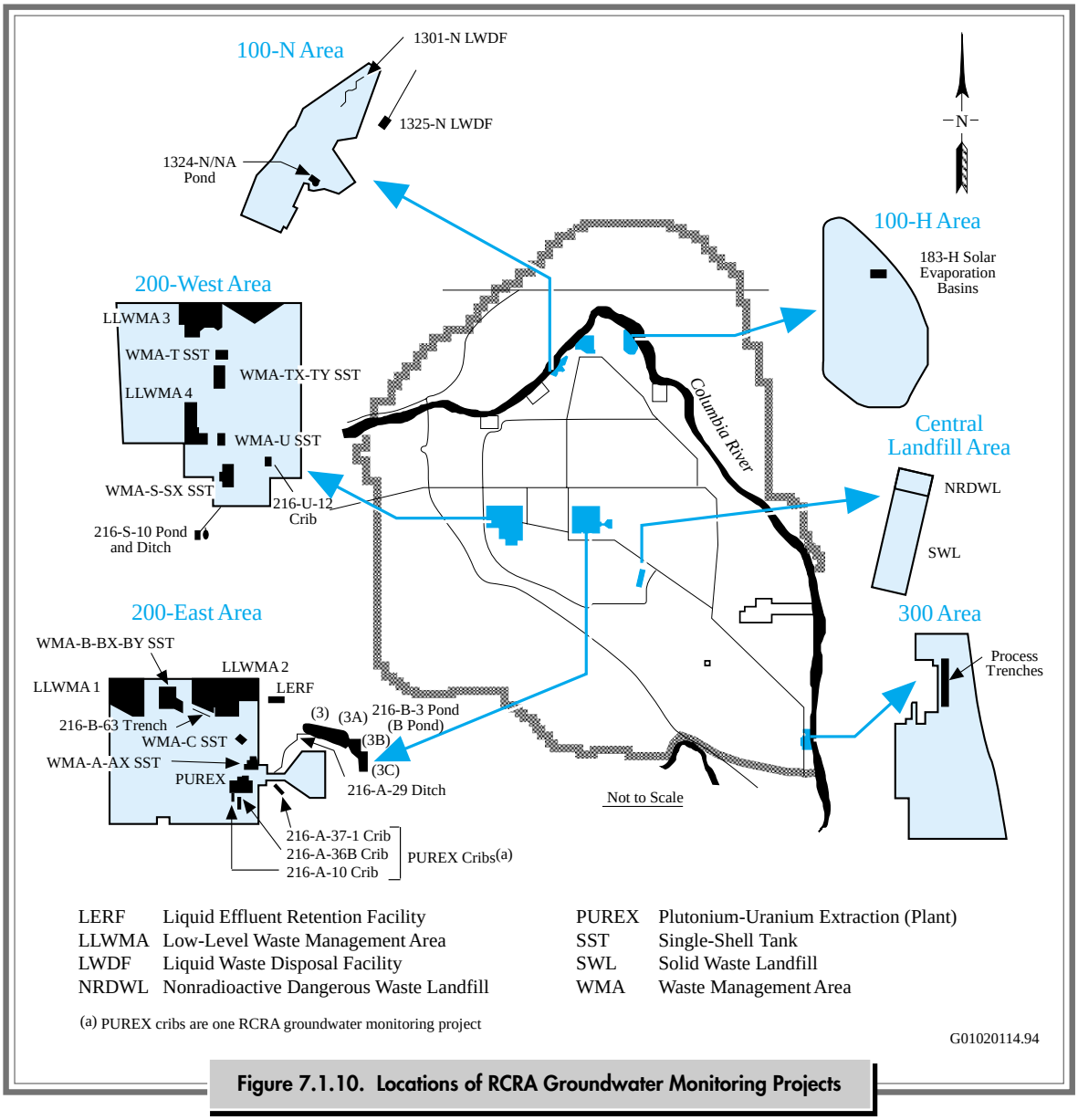

Figure 7.1.10. Locations of RCRA Groundwater Monitoring Projects

indicate the distance relative to an arbitrary datum location in the south-central part of the site.

The monitoring frequency for the wells was selected by Pacific Northwest National Laboratory based on regulatory requirements, variability of historical data, proximity to waste sources (PNL-6456), and characteristics of the groundwater flow system at the sample location. Of the 694 wells sampled, 295 were sampled once, 145 twice, 88 three times, 101 four times, and 65 wells were sampled more than four times during the year. The sampling frequency is every 3 years for several wells that have consistently shown concentrations with steady historical trends. Wells showing larger variability are sampled more frequently (annually or more often). Wells that monitor source areas are sampled more frequently than wells that do not monitor source areas. Contaminants with greater mobility (e.g., tritium) in groundwater may be sampled more frequently than contaminants that are not very mobile (e.g., strontium-90). The sampling

Table 7.1.3. 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 some wells in 2000 was delayed or cancelled due to issues associated with disposal of secondary sampling waste, such as gloves. An acceptable practice for disposing of the waste was implemented during 2000.

Each monitoring program has access to groundwater data collected by other programs through a common database, the Hanford Environmental Information System. This database contains more than 1.6 million groundwater monitoring result records. After the data are verified and/or validated, they are made available to federal and state regulators for retrieval.

Most groundwater monitoring wells on the site are 10 to 20 centimeters (4 to 8 inches) in diameter. Monitoring wells for the unconfined aquifer are constructed with well screens or perforated casing generally in the upper 3 to 6 meters (10 to 20 feet) 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 and maximum concentrations of chemicals 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. Since 1985, RCRA monitoring wells and CERCLA characterization wells have been constructed with stainless steel casing and screens. Most monitoring wells on the site 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; ES-SSPM-001) based on U.S. Environmental Protection Agency (EPA) guidelines (OSWER 9950-1). Analytical techniques used are listed in PNNL-13080 and CERCLA work plans. The samples were analyzed for the radionuclides and chemicals listed in Table 7.1.4.

Most groundwater samples collected on the site in 2000 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.

Nitrate analyses were performed on many samples collected during 2000 because of the extensive areas with elevated nitrate concentrations that

originate from onsite and offsite sources (see Section 7.1.6.2). 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.

Table 7.1.4. Groundwater Analyzed for Radionuclides and Chemicals in 2000

Radiological Parameters	Chemical and Biological Parameters
Tritium	pH (field)
Beryllium-7	Conductance (field and laboratory)
Carbon-14	Total dissolved solids
Potassium-40	Alkalinity
Cobalt-58	Total organic carbon
Iron-59	Total organic halogens
Cobalt-60	Be, Na, Mg, Al, K, Co, Si, As, Se, P
Strontium-90	Ca, V, Cr, Mn, Fe, Ni, Pb, Li, Hg
Technetium-99	Cu, Zn, Sr, Ag, Cd, Sb, Ba, Sn, Tl, Ti
Ruthenium-106	F^-, Cl^-, NO_3^-, PO_4^{-3}, SO_4^{-2}, NO_2^-, Br^-
Antimony-125	CN^-
Iodine-129	NH_4^+
Cesium-134	Hexavalent chromium
Cesium-137	Volatile organic compounds
Neptunium-237	Semivolatile organic compounds
Americium-241	Polychlorinated biphenyls
Gross alpha	Pesticides
Gross beta	Biochemical oxygen demand
Europium isotopes	Chemical oxygen demand
Plutonium isotopes	Coliform bacteria
Radium isotopes	Dissolved oxygen (field)
Uranium isotopes	Total petroleum hydrocarbons
Uranium (total)	Oil and grease
Barium-133	Gasoline
Thorium isotopes	Hardness
Total beta radiostrontium	Oxidation reduction potential
Nickel-63	Temperature
	Turbidity
	Boron
	Molybdenum
	Silica

7.1.5.2 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 of uncertainty are discussed below. Several techniques used to interpret the sample results also are 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 analyses of samples. Gross errors can be introduced in the laboratory or during sampling. Gross errors include transcription errors, calculation errors, mislabeling, 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 to analyze for radioactive constituents count the number of radioactive decay products at a detector, and background counts are subtracted. The nature of radioactive decay and the instrument design result in a random counting error that is reported with the analytical result. Generally, a sample result less than the counting error indicates the constituent was not detected. The background subtraction may result in the reporting of results that are less than zero. Although below-zero results are physically impossible, the negative values are of use for some statistical analyses (see Appendix A for more details).

Systematic errors may result from problems with 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 (see Section 9.0).

In 2000, double-blind samples for specific constituents were analyzed (Section 9.0 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 are limits to the number that can be practicably taken. Comparison of results through time helps interpret this variability.

Overall sample uncertainty may be factored into data evaluation by considering the concentration trend in a given well over time. This often helps identify gross errors, and overall, long-term trends can be distinguished from short-term variability. The interpretation of concentration trends depends on an understanding of chemical properties as well as site hydrogeology. The trend analysis, in turn, aids in refining the conceptual model of the chemical transport.

Plume maps presented in this section 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 levels. 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 powerful tools because knowledge of concentrations in surrounding wells, groundwater flow, site geology, and other available information are factored into their preparation.

7.1.6 Groundwater Monitoring Results

The following sections summarize the distribution of radioactive and chemical contaminants detected in Hanford Site groundwater during 2000. These discussions are followed by a summary of groundwater monitoring results for RCRA sites. Detailed information on groundwater monitoring, including listings of analysis results for each monitoring well in electronic format, is available in PNNL-13404. However, because PNNL-13404 (the annual groundwater report) covers the fiscal year (October 1999 through September 2000), it does not include results from the last 3 months of 2000. This report includes results for January through December 2000.

One way to assess the impact of radionuclides and chemicals in groundwater is to compare them to EPA's drinking water standards and DOE's derived concentration guides (40 CFR 141 and DOE Order 5400.5; see Appendix D, Tables D.2 and D.5). The drinking water standards were established to protect public drinking water supplies. The derived concentration guides were established to protect the public from radionuclides resulting from DOE operations. Specific drinking water standards have been defined for only a few radiological constituents. Drinking water standards have been calculated for other radionuclides, using an annual dose of 4 mrem/yr. Calculations of these standards consider their half-life, the energy and nature of the radioactive decay, and the physiological factors such as its buildup in particular organs. Drinking water standards are more restrictive than derived concentration guides because the standards are based on an annual dose of 4 mrem/yr to the affected organ. The guides are based on an effective dose equivalent of 100 mrem/yr (see Appendix D, Tables D.2 and D.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, which 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.

The total area of contaminant plumes with concentrations exceeding drinking water standards was estimated to be ~231 square kilometers (89 square miles) in 2000. This area, which is a decrease of ~9% compared to 1999, occupies ~15% of the total area of the Hanford Site. Most of the contaminant plume area lies southeast of the 200-East Area extending to the Columbia River (Figure 7.1.11). The most widespread contaminants within these plumes were tritium, iodine-129, technetium-99, uranium, strontium-90, carbon tetrachloride, nitrate, and trichloroethene. Contaminant plumes with concentrations exceeding derived concentration guides occur in isolated areas. The only contaminants at levels above the derived concentration guide in 2000 were tritium, uranium, and strontium-90.

7.1.6.1 Radiological Monitoring Results for the Unconfined Aquifer

Hanford Site groundwater was analyzed for the radionuclides listed in Table 7.1.4. The distribution of tritium, iodine-129, technetium-99, uranium, strontium-90, carbon-14, cesium-137, cobalt-60, and plutonium are discussed in the following sections. Tritium and iodine-129 are the most widespread radiological contaminants associated with past site operations. Technetium-99 and uranium plumes are extensive in the 200 Areas and adjacent 600 Area. Strontium-90 plumes exhibit very high concentrations in the 100 Areas but are of relatively smaller extent. Strontium-90 also occurs in the 200 Areas and near the former Gable Mountain Pond in the 600 Area. Carbon-14 is present in two small plumes in the 100-K Area. Cesium-137, cobalt-60, and plutonium contamination occurs in isolated areas in the 200 Areas. 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-106, antimony-125, and americium-241, are associated with waste from Hanford Site operations. Because of their very low activities in groundwater, they are not discussed in this section. Half-lives of the radionuclides are presented in Appendix A, Table A.5.

Tritium. Tritium, which is present in irradiated nuclear fuel, 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

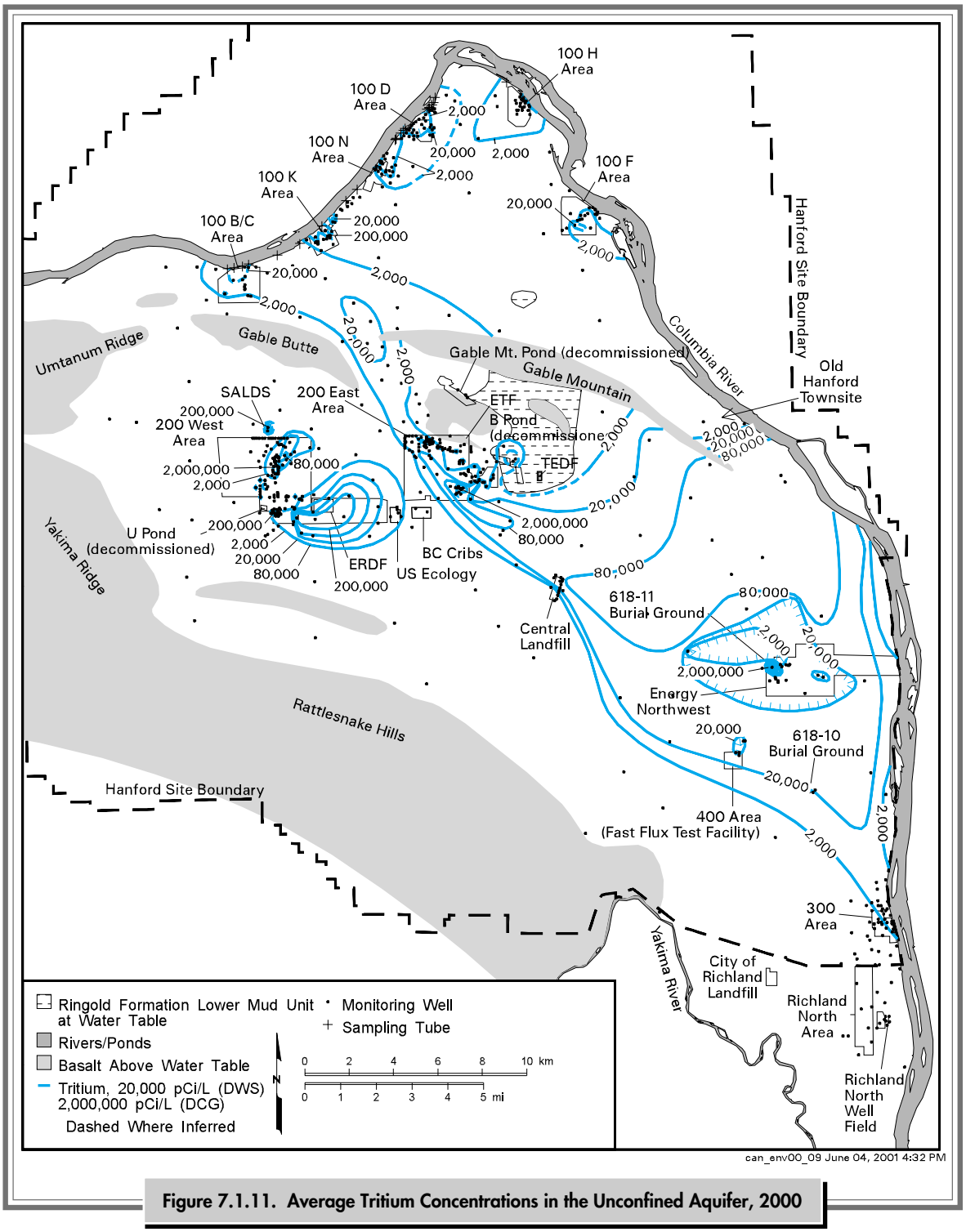

Figure 7.1.11. Average Tritium Concentrations in the Unconfined Aquifer, 2000

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. Consequently, the extent of groundwater contamination from site operations is generally reflected by tritium distribution. For this reason, tritium is the most frequently monitored radionuclide at the Hanford Site. Figure 7.1.11 shows the 2000 distribution of tritium in the unconfined aquifer. Tritium is one of the most widespread contaminants in groundwater across the Hanford Site and exceeded the 20,000-pCi/L drinking water standard in portions of the 100, 200, 400, and 600 Areas. Of these areas, tritium levels exceeded the 2 million-pCi/L derived concentration guide in portions of the 200 and 600 Areas. The highest tritium concentration measured at the Hanford Site in 2000 was 8.38 million pCi/L near the 618-11 burial ground. Tritium levels are expected to decrease because of dispersion and radioactive decay (half-life is 12.35 years).

In 2000, the only liquid effluent containing tritium was discharged to the soil column at the State-Approved Land Disposal Site, which began operating in 1995 and is located just north of the 200-West Area. The total radioactivity received by this facility in 2000 was ~21 curies, which was attributed solely to tritium.

Tritium in the 100 Areas. In 2000, there was no waste containing tritium discharged in the 100 Areas. All the tritium detected here comes from past activities at Hanford. Tritium concentrations greater than the drinking water standard were detected in portions of the 100-B/C, 100-F, 100-K, and 100-N Areas. The largest tritium plume in the 100 Areas with concentrations above the drinking water standard occurs along the Columbia River from the 100-N Area to an area southwest of the 100-D Area.

Tritium concentrations continued to exceed the drinking water standard in several wells in the northern and southwestern parts of the 100-B/C Area in 2000. Most of the tritium contamination is associated with past liquid disposal practices at 100-B/C retention basins and trenches near the Columbia River. The maximum tritium concentration decreased to 39,900 pCi/L in the northern part of the 100-B/C Area.

One well in the 100-F Area contained tritium at concentrations greater than the drinking water standard. A maximum of 24,400 pCi/L occurred near the 118-F-1 burial ground in 2000. This was a decrease from the 1999 maximum. The burial ground received only solid waste, and the source of the tritium contamination is not known.

A tritium plume near the KE Reactor in the 100-K Area continued to contain the highest tritium concentrations within the 100 Areas. The maximum concentration was 1.75 million pCi/L immediately downgradient of the 116-KE-1 crib (Figure 7.1.12). The tritium concentrations at this location (well 199-K-30) are most likely the result of downward migration of tritium in moisture from the vadose zone. This tritium is associated with the 116-KE-1 crib. The tritium trend for well 199-K-30 is shown in Figure 7.1.13. Tritium concentrations in the plume farther downgradient of the 116-KE-1 crib rose to levels above the drinking water standard in 2000. This rise in tritium concentrations may indicate the arrival of a tritium plume originating from leakage of the KE Fuel Storage Basin in 1993. Tritium levels greater than the drinking water standard, but much less than the derived concentration guide, continued to occur during 2000 in a small area near a pump-and-treat extraction well adjacent to the Columbia River.

Soil gas samples were collected from the overlying vadose zone north and east of the KE Reactor and analyzed for helium-3 to determine whether a tritium plume in groundwater could be detected (PNNL-13217). The analysis results indicated that

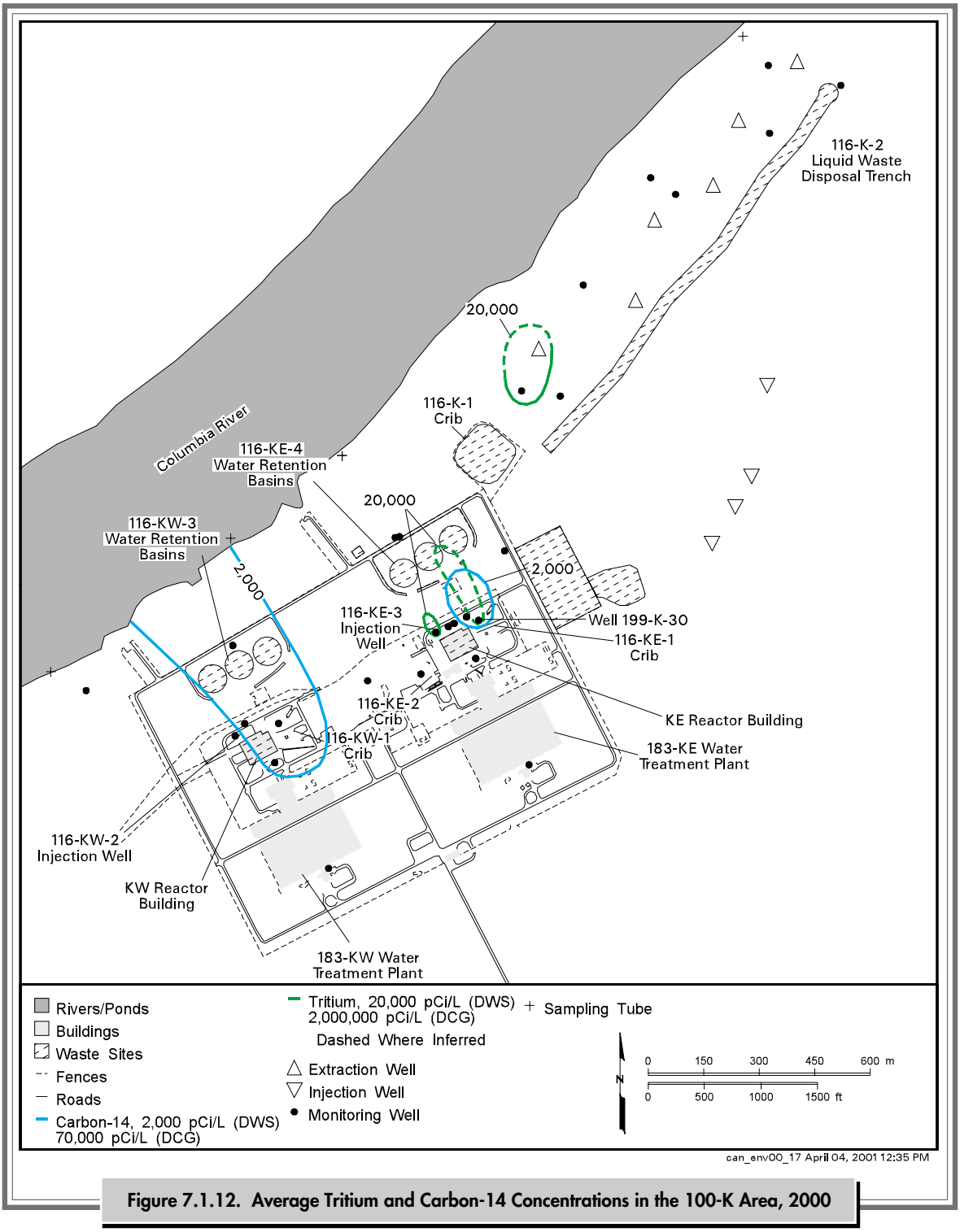

Figure 7.1.12. Average Tritium and Carbon-14 Concentrations in the 100-K Area, 2000

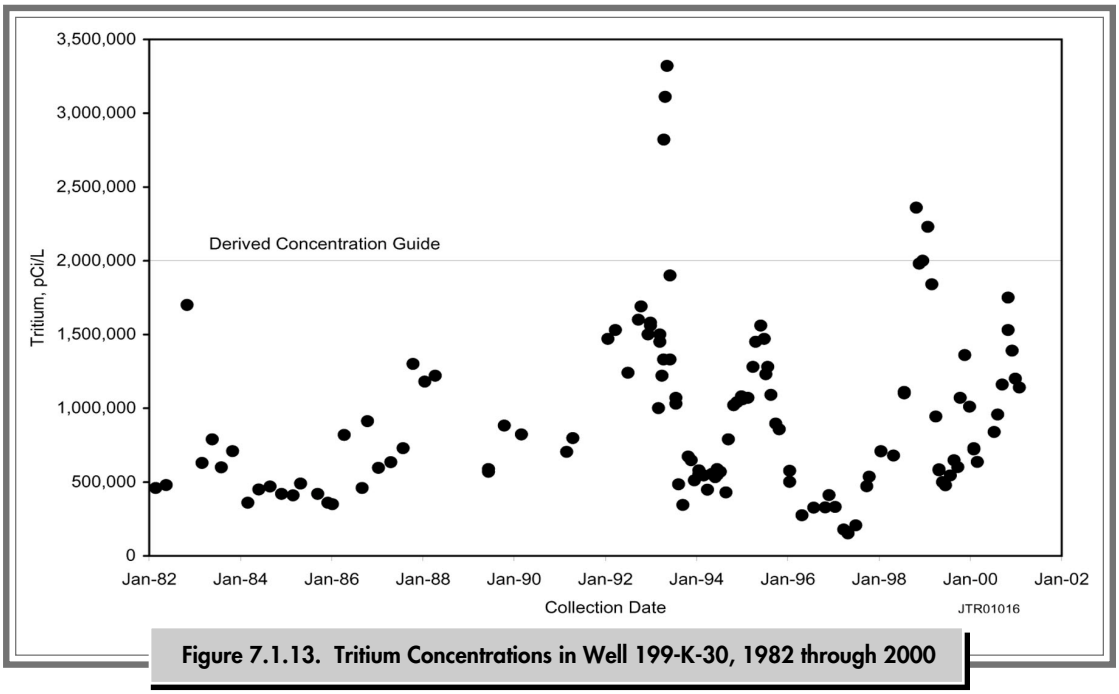

Figure 7.1.13. Tritium Concentrations in Well 199-K-30, 1982 through 2000

a tritium plume could not be detected. Also, tritium was not detected in soil moisture samples collected from the same general area.

A tritium plume at levels exceeding the drinking water standard extends northeast from the northern part of the 100-N Area to the 600 Area along the Columbia River. This plume is associated with past liquid disposal to the 1301-N and 1325-N Liquid Waste Disposal Facilities. The size of the tritium plume continued to decrease in 2000 because of dispersion and radioactive decay. The maximum tritium level reported in the 100-N Area in 2000 was 45,000 pCi/L near the Columbia River.

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. Tritium levels are decreasing slowly in most wells in this area because of dispersion and radioactive decay. However, levels greater than the derived concentration guide detected in one well (299-E17-9) showed an increase in 2000. The maximum tritium level detected in this well was 4.1 million pCi/L in 2000, which is an increase from the maximum of 2.45 million pCi/L in 1999. Well 299-E17-9 monitors the 216-A-36B crib in the southeastern part of the 200-East Area. Tritium concentrations continued to exceed the drinking water standard in many wells monitoring the cribs near the Plutonium-Uranium Extraction Plant.

In the plume that extends from the southeastern portion of the 200-East Area, tritium concentrations above 200,000 pCi/L occurred in a small area downgradient of the Plutonium-Uranium Extraction Plant and did not extend beyond the 200-East Area boundary. The plume area at levels above 200,000 pCi/L has extended at least as far southeast as the Central Landfill in the past (PNL-8073).

A widespread tritium plume extends from the southeastern portion of the 200-East Area to the Columbia River (see Figure 7.1.11). In the western portion of the tritium plume, a control in the movement of the plume to the southeast is the presence of the low permeability Ringold Formation lower mud unit at the water table east of the 200-East Area (PNNL-12261). Flow to the southeast also appears to be controlled by a zone of

highly permeable sediment, stretching from the 200-East Area toward the 400 Area (PNL-7144). Near Energy Northwest, an area of lower tritium concentration is a result of a higher degree of cemented sediment in the unconfined aquifer. The shape of the tritium plume indicates that tritium discharges to the Columbia River between the Old Hanford Townsite and the 300 Area.

Separate tritium pulses associated with the two episodes of Plutonium-Uranium Extraction Plant operations can be distinguished in the plume. A trend plot (Figure 7.1.14) of the tritium concentrations in well 699-40-1 east of the 200-East Area near the shore of the Columbia River clearly shows the arrival of a pulse in the mid-1970s. High tritium concentrations near the Columbia River result from discharges to the ground during the operation of the Plutonium-Uranium Extraction Plant from 1956 to 1972. Following an 11-year shutdown, plant operation began in 1983 and ceased in December 1988. This resulted in elevated tritium levels measured in several wells downgradient from the 200-East Area. Movement of the leading edge of this later pulse shows arrival near the Central Landfill in early 1987 (Figure 7.1.15). Tritium concentrations from the earlier pulse were at least three times the maximum concentrations in the later pulse. The effects of the 1983 to 1988 operational period have not been detected near the Columbia River.

The tritium plume, which has been monitored since the 1960s, provides information on the extent of groundwater contamination over time. Figure 7.1.16 shows the distribution of tritium in selected years from 1964 through 2000. This figure was created from maps in BNWL-90, BNWL-1970, PNL-5041, PNL-6825 (Section 5.0), PNNL-11141, and PNNL-13404. The contours in the original references were recalculated and interpreted to provide uniform contour intervals. Figure 7.1.16 shows that tritium at levels greater than the drinking water standard reached the Columbia River near the Old Hanford Townsite in approximately the mid-1970s. By the late 1980s, tritium at these levels

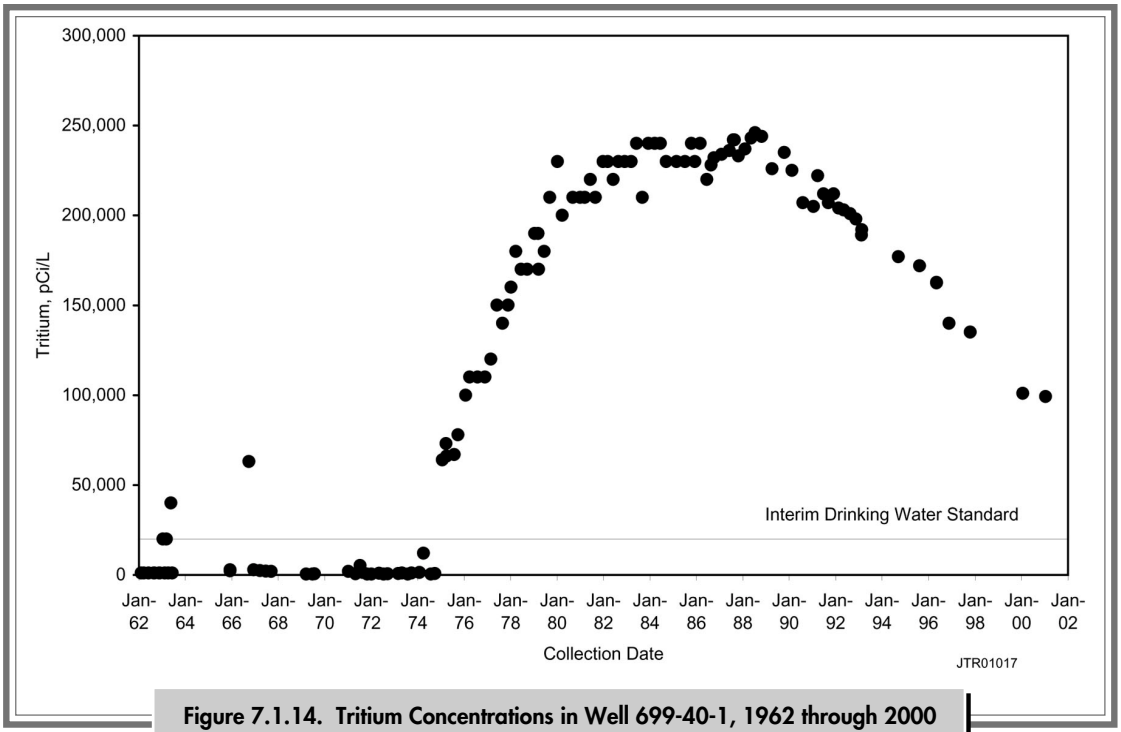

Figure 7.1.14. Tritium Concentrations in Well 699-40-1, 1962 through 2000

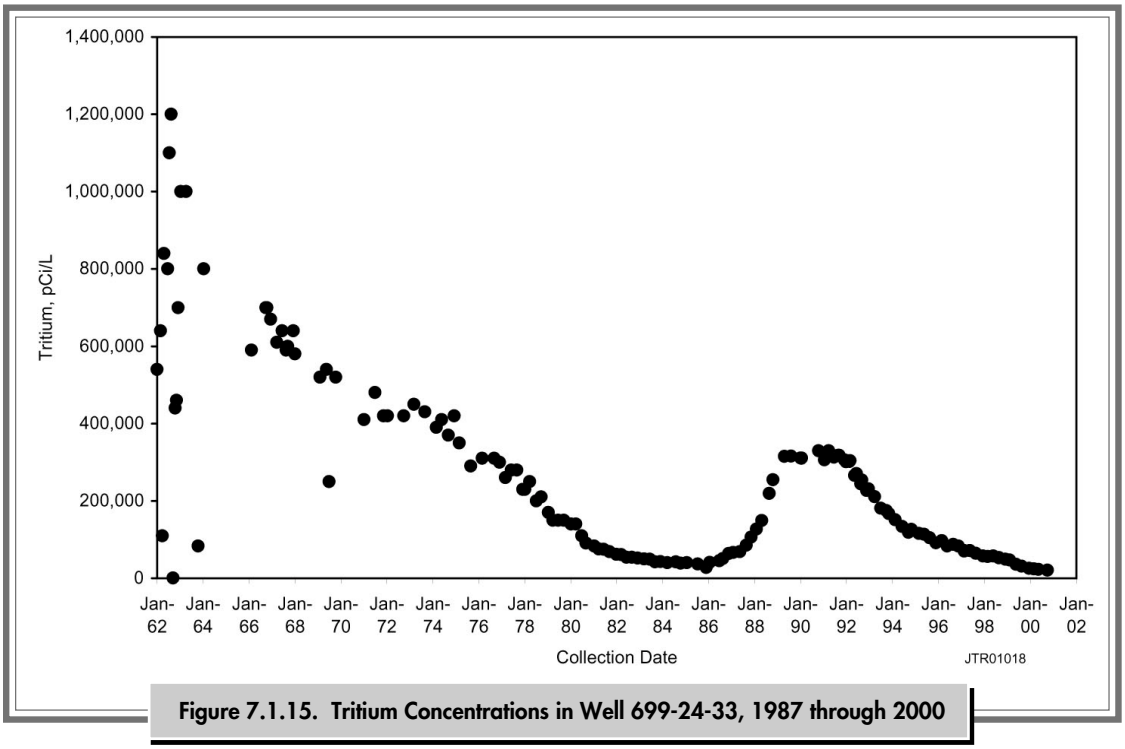

Figure 7.1.15. Tritium Concentrations in Well 699-24-33, 1987 through 2000

was discharging to the Columbia River several kilometers south of the Old Hanford Townsite. The tritium plume continued to expand in the southeastern part of the Hanford Site. By 1995, tritium at concentrations exceeding 20,000 pCi/L was entering the Columbia River along greater portions of the shoreline extending between the Old Hanford Townsite and the 300 Area. Tritium levels did not change significantly between 1995 and 2000.

Tritium is also found at levels above the drinking water standard in the northwestern part of the 200-East Area (see Figure 7.1.11). This plume appears to extend to the northwest through the gap between Gable Mountain and Gable Butte where a pulse of tritium also occurs at levels above the drinking water standard. Sources of tritium in these areas include waste sites in the vicinity of B Plant. The tritium distribution to the northwest and southeast of the 200-East Area indicates a divide in groundwater flow direction across the 200-East Area.

The highest tritium concentrations measured in Hanford Site groundwater in 2000 were in one well (699-13-3A) near the 618-11 burial ground. Tritium levels at this well ranged from 5.69 million pCi/L to 8.38 million pCi/L in 2000. This burial ground is located west of the Energy Northwest reactor complex in the eastern 600 Area (Figure 7.1.17). The burial ground was active from 1962 to 1967 and received a variety of low- and high-level waste from the 300 Area. A special investigation began in 2000 to define the source of the high tritium levels. The Phase I sampling results are reported in PNNL-13228 and are available on the Groundwater Monitoring Project website at http://www.hanford-site.pnl.gov/groundwater.

Phase II of the investigation began in summer 2000 and included a soil gas survey to determine the distribution of tritium in groundwater and the vadose zone. The highest tritium concentration in groundwater estimated from the soil gas results was ~24 million pCi/L at the northeastern corner of the burial ground. The distribution of tritium in the vadose zone is discussed in Section 7.2.

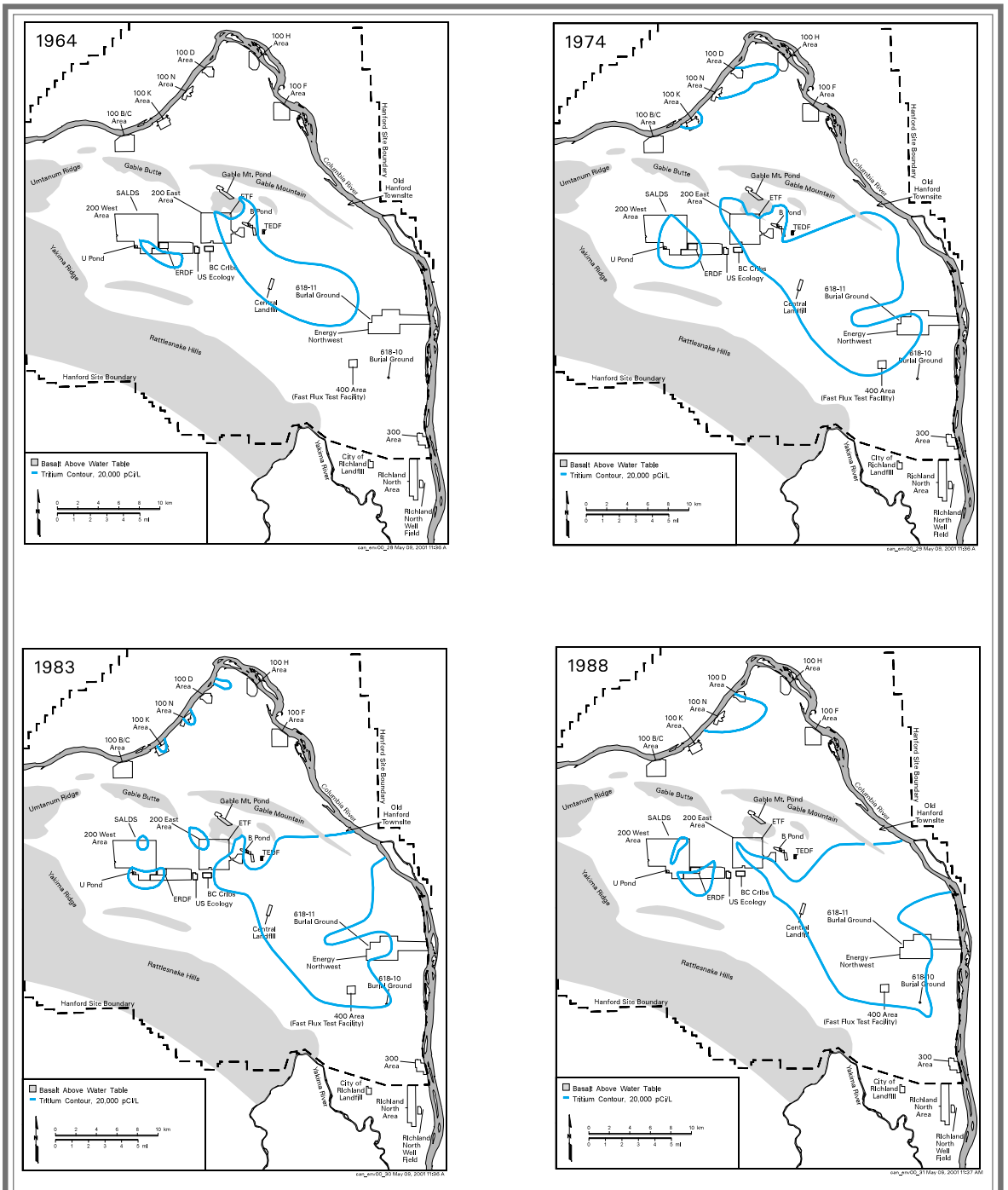

Figure 7.1.16. Historical Tritium Concentrations on the Hanford Site

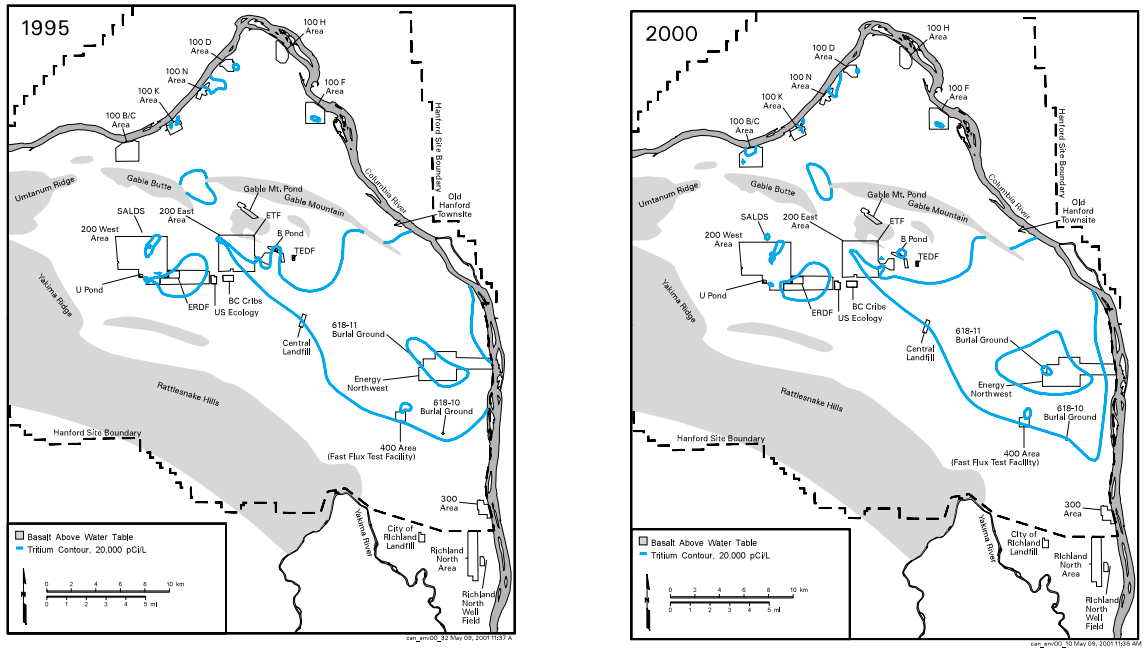

Figure 7.1.16. (contd)

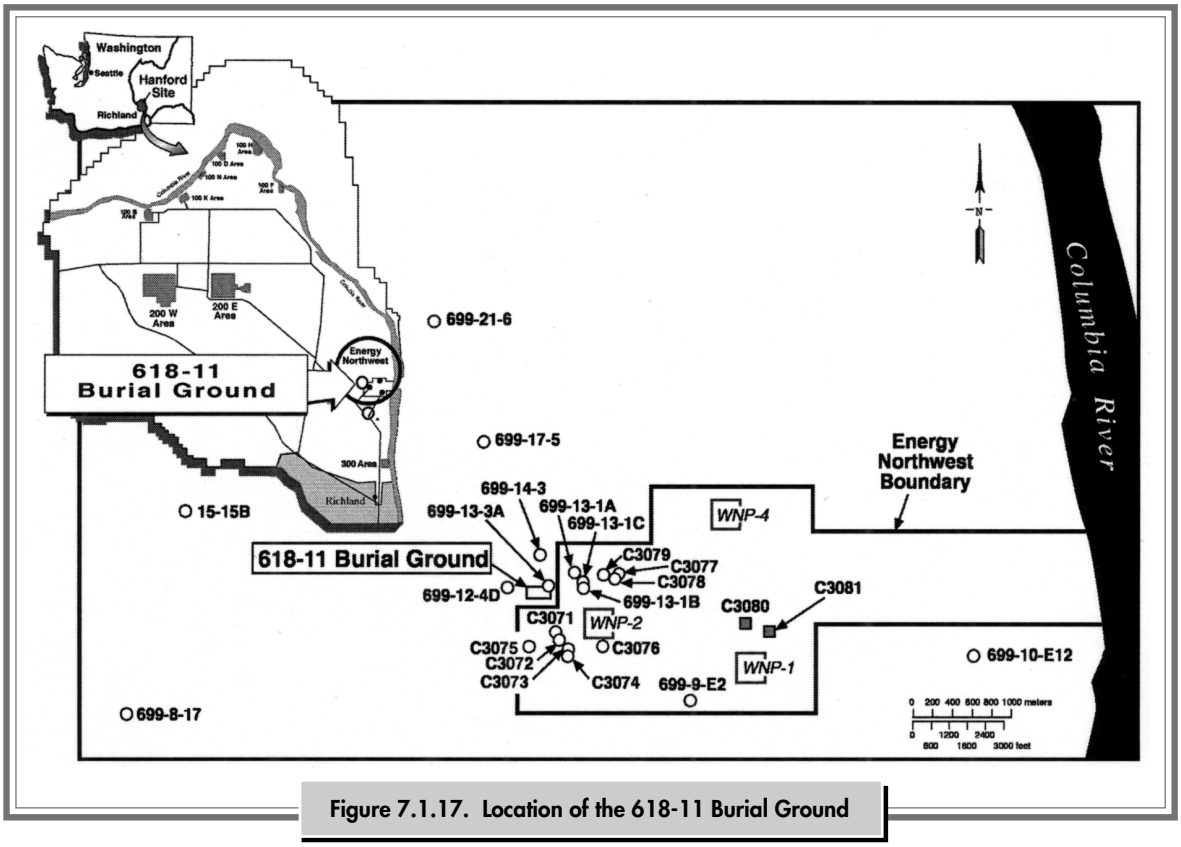

Figure 7.1.17. Location of the 618-11 Burial Ground

Tritium in the 200-West Area. Tritium from sources near the Reduction-Oxidation Plant forms the most extensive plume associated with 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. This plume extends into the 600 Area east of the 200-West Area to US Ecology's facility and the eastern part of the plume curves to the north (see Figure 7.1.11). However, the highest tritium concentrations in the plume are declining, as illustrated in Figure 7.1.18. The maximum concentration in this plume east of the Reduction-Oxidation Plant in 2000 was 338,000 pCi/L. The movement of plumes in the 200-West Area is slow because the Ringold Formation sediment that underlies the area has low permeability and restricts flow. Movement of the plumes in the 200-West Area also is slow because of declining hydraulic gradients. Tritium concentrations exceeded the drinking water standard in much of the plume, including a small area near the former 216-S-25 crib and S-SX tank farm upgradient of the Reduction-Oxidation Plant. The maximum tritium concentration in these areas in 2000 was 502,000 pCi/L adjacent to the former 216-S-25 crib. Concentrations continue to increase slowly in the eastern part of the plume near the US Ecology facility, but at levels less than the drinking water standard.

A smaller tritium plume covers much of the northern part of the 200-West Area and extends to the northeast (see Figure 7.1.11). This plume is associated with former T Plant waste sites, including TY tank farm, the 242-T evaporator, and inactive disposal cribs. The highest tritium concentration detected in the 200-West Area was 2.94 million pCi/L just east of the TX and TY tank farms near the 216-T-26 crib. Tritium concentrations at this location, which exceeded the derived concentration guide in 2000, have increased significantly since 1998. The area where the drinking water standard was exceeded extends northeast past the northern boundary of the 200-West Area.

Tritium concentrations in the top of the unconfined aquifer continued to decline in 2000

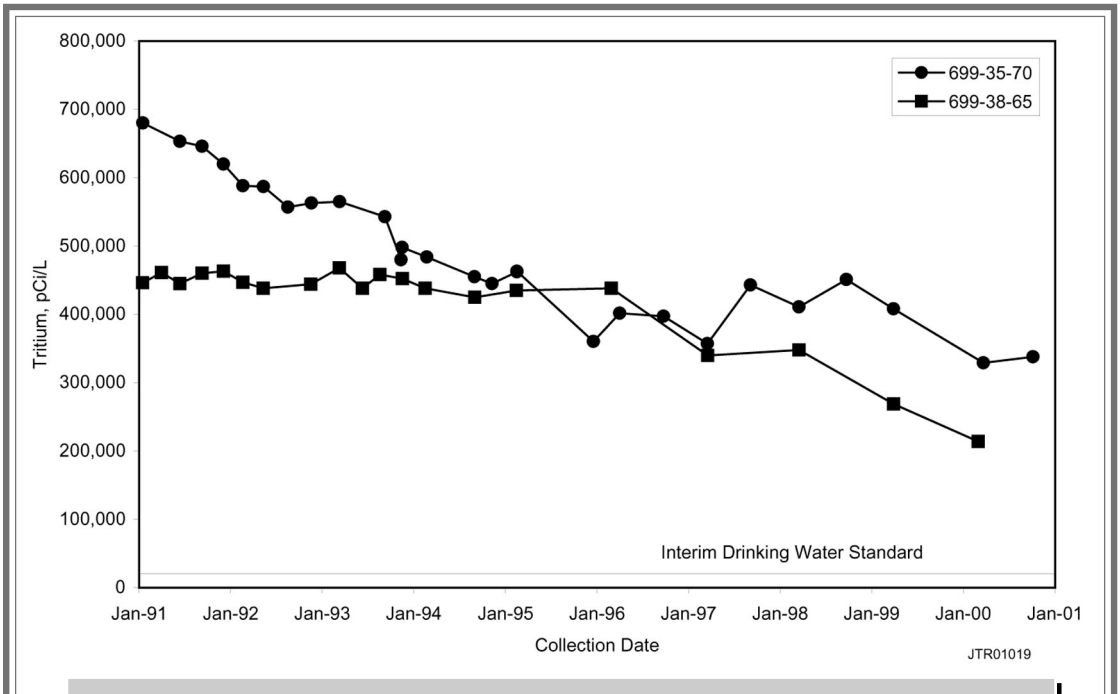

Figure 7.1.18. Tritium Concentrations in Wells 699-35-70 and 699-38-65, 1991 through 2000

at wells monitoring the State-Approved Land Disposal Site just north of the 200-West Area. The maximum concentration decreased from 610,000 pCi/L in 1999 to 340,000 pCi/L in 2000, which exceeded the drinking water standard. However, tritium concentrations continued to rise in the deeper portion of the unconfined aquifer. The maximum tritium concentration in the deeper part of the unconfined aquifer was 850,000 pCi/L in 2000. The lower concentrations in the top of the unconfined aquifer in 2000 reflect the reduced concentration levels in effluent discharged to this facility over the past ~2 years (PNNL-13058). By the end of December 2000, ~325 curies of tritium and over 375 million liters (99 million gallons) of treated effluent containing tritium had been discharged to this facility since operations began in 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 7.1.11). The southern edge of the tritium plume extends into the 300 Area, as shown in Figure 7.1.19. Figure 7.1.19 shows that tritium concentrations decrease from greater than 10,000 pCi/L in the northeastern part of the 300 Area to less than 100 pCi/L in the southwestern part of the 300 Area. This distribution is nearly the same as the 1999 distribution. Although tritium in the 300 Area is below the drinking water standard, a concern has been the potential migration of tritium to a municipal water supply to the south. The municipal water supply consists of the city of Richland's well field and recharge ponds (see Figure 7.1.19). The highest tritium level detected south of the 300 Area was 546 pCi/L near the well field. Monitoring data indicate that the Hanford Site tritium plume has not reached the municipal water supply.

The tritium plume is not expected to impact the well field because of the influence of groundwater flow from the Yakima River, recharge from agricultural irrigation, and recharge from infiltration ponds at the well field (see Figure 7.1.19). The Yakima River is at a higher elevation than the water table and recharges the groundwater in this area. Groundwater flows from west to east (see Figure 7.1.19), minimizing the southward movement of the contaminant plume. Recharge from agricultural irrigation occurs south of the Hanford Site boundary and contributes to eastward flow. The recharge ponds are supplied with Columbia River water, which infiltrates to the groundwater. The amount of recharge water exceeded the amount pumped at the well field by a factor of at least 2:1 in 2000, resulting in groundwater flow away from the well field. Recharge creates a mound that further ensures that tritium-contaminated groundwater will not reach the well field.

Tritium in the 400 Area. The tritium plume that originated in the 200-East Area extends under the 400 Area. The maximum concentration detected in this area during 2000 was 30,300 pCi/L in the northern part of the 400 Area. Tritium levels in the primary (499-S1-8J) and backup (499-S0-7 and 499-S0-8) water supply wells did not exceed the annual average drinking water standard of 20,000 pCi/L in 2000. Tritium levels in these wells did not exceed the drinking water standard in any month. The water supply wells are also located in the northern part of the 400 Area. Additional information on the 400 Area water supply is provided in Section 4.3.

Iodine-129. Iodine-129 has a relatively low drinking water standard (1 pCi/L), has the potential to accumulate in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and has a long half-life (16 million years). The iodine-129 plume at levels exceeding the drinking water standard is extensive in the 200 and 600 Areas. No groundwater samples showed iodine-129 concentrations above the 500-pCi/L derived concentration guide in 2000. Iodine-129 may be released as a vapor during fuel dissolution and during other elevated temperature processes and, thus, may be associated

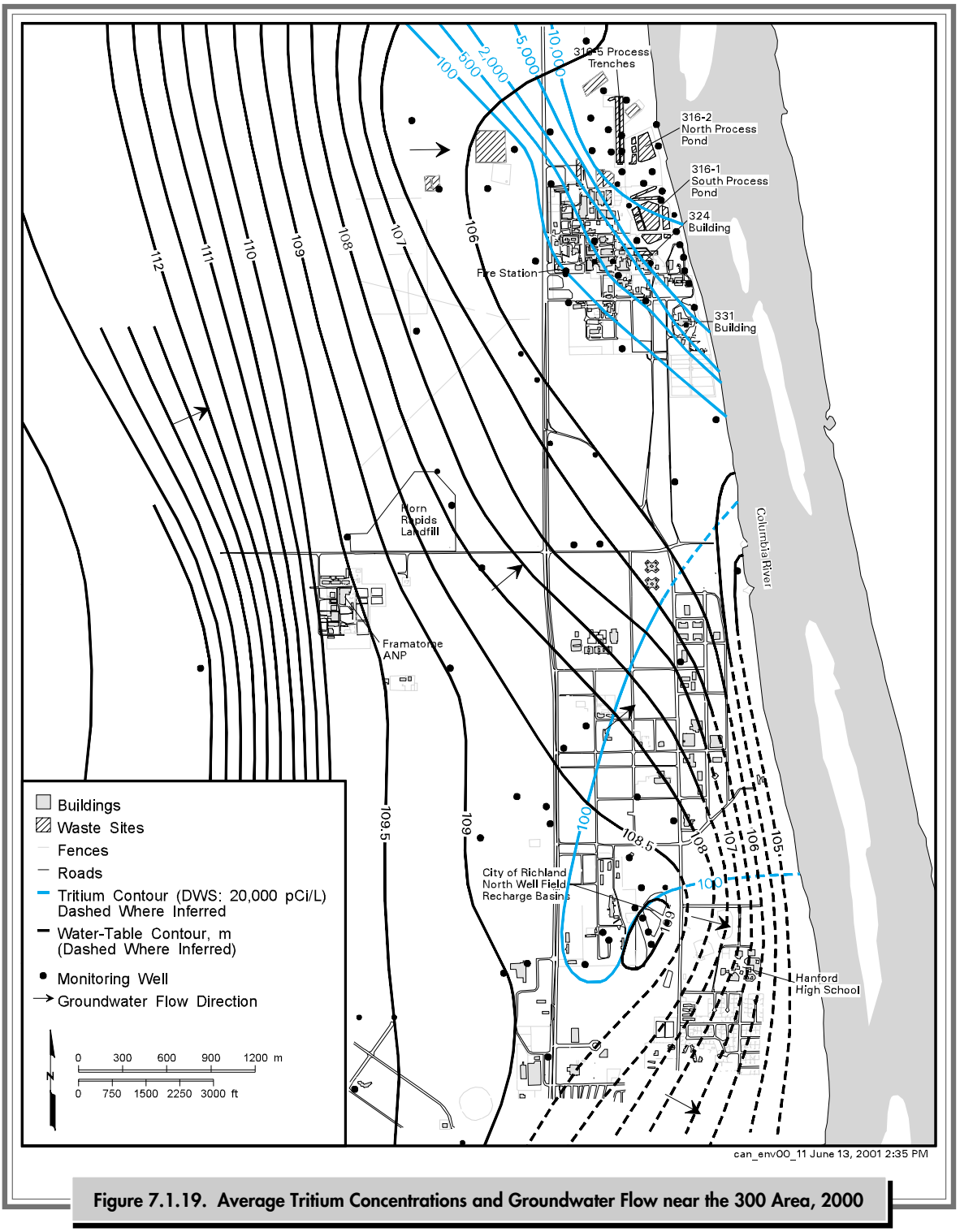

Figure 7.1.19. Average Tritium Concentrations and Groundwater Flow near the 300 Area, 2000

with process condensate waste. At the Hanford Site, the main contributor of iodine-129 to groundwater is past-practice liquid discharges to cribs in the 200 Areas. Iodine-129 has essentially the same high mobility in groundwater as tritium. The highest level of iodine-129 detected in 2000 on the Hanford Site was 63.9 pCi/L near the T, TX, TY tank farms.

Iodine-129 in the 200-East Area. The highest iodine-129 concentrations in the 200-East Area are in the southeast near the Plutonium-Uranium Extraction Plant and in the northwest in the vicinity of B Plant (Figure 7.1.20). The maximum level of iodine-129 detected in 2000 in the 200-East Area was 10.8 pCi/L south of the Plutonium-Uranium Extraction Plant near the 216-A-36B crib. Iodine-129 concentrations near this area are declining slowly or are stable. The iodine-129 plume extends from the Plutonium-Uranium Extraction Plant area southeast into the 600 Area and appears coincident with the tritium plumes (see Figure 7.1.11). 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 to the east as the Columbia River but at levels below the drinking water standard. Data indicate that the portion of the iodine-129 plume at levels above the drinking water standard moved 2.5 kilometers (1.6 miles) toward the Columbia River between 1990 and 2000. The plume likely had the same sources as the tritium plume. Iodine-129 also is 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. The maximum level detected in this area in 2000 was 7.3 pCi/L. This plume extends northwest into the gap between Gable Mountain and Gable Butte.

Iodine-129 in the 200-West Area. The distribution of iodine-129 in Hanford Site groundwater is shown in Figure 7.1.20. The highest level detected on the site in 2000 was 63.9 pCi/L near the T, TX, and TY tank farms in the northern part of the 200-West Area. This level occurs in a plume that extends northeast toward T Plant. The iodine-129 plume, which is generally coincident with the technetium-99 and tritium plumes in this area, most likely originates from the 242-T evaporator located between the TX and TY tank farms. A much larger iodine-129 plume occurs in the southeastern part of the 200-West Area, which originates near the Reduction-Oxidation Plant, and extends east into the 600 Area. This plume is essentially coincident with the tritium plume, though there appears to be a contribution from cribs to the north near U Plant. In 2000, the maximum concentration detected in this plume was 35.1 pCi/L in the 600 Area east of the Reduction-Oxidation Plant. Iodine-129 levels in this plume did not change significantly between 1999 and 2000.

Technetium-99. Technetium-99, which has a half-life of 210,000 years, was produced as a high-yield fission byproduct and was present in waste streams associated with fuel reprocessing. Past reactor operations may also have resulted in the release of some technetium-99 associated with fuel element breaches. Technetium-99 is typically associated with uranium through the fuel processing cycle, but uranium is less mobile in groundwater. 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 site groundwater.

The derived concentration guide is 100,000 pCi/L and the interim drinking water standard is 900 pCi/L for technetium-99. Technetium-99 was found at concentrations greater than the 900-pCi/L interim drinking water standard in the 200-East and 200-West Areas. The highest level measured on the Hanford Site in 2000 was 72,300 pCi/L near the SX tank farm.

Technetium-99 in the 200-East Area. Groundwater in the northwestern part of the

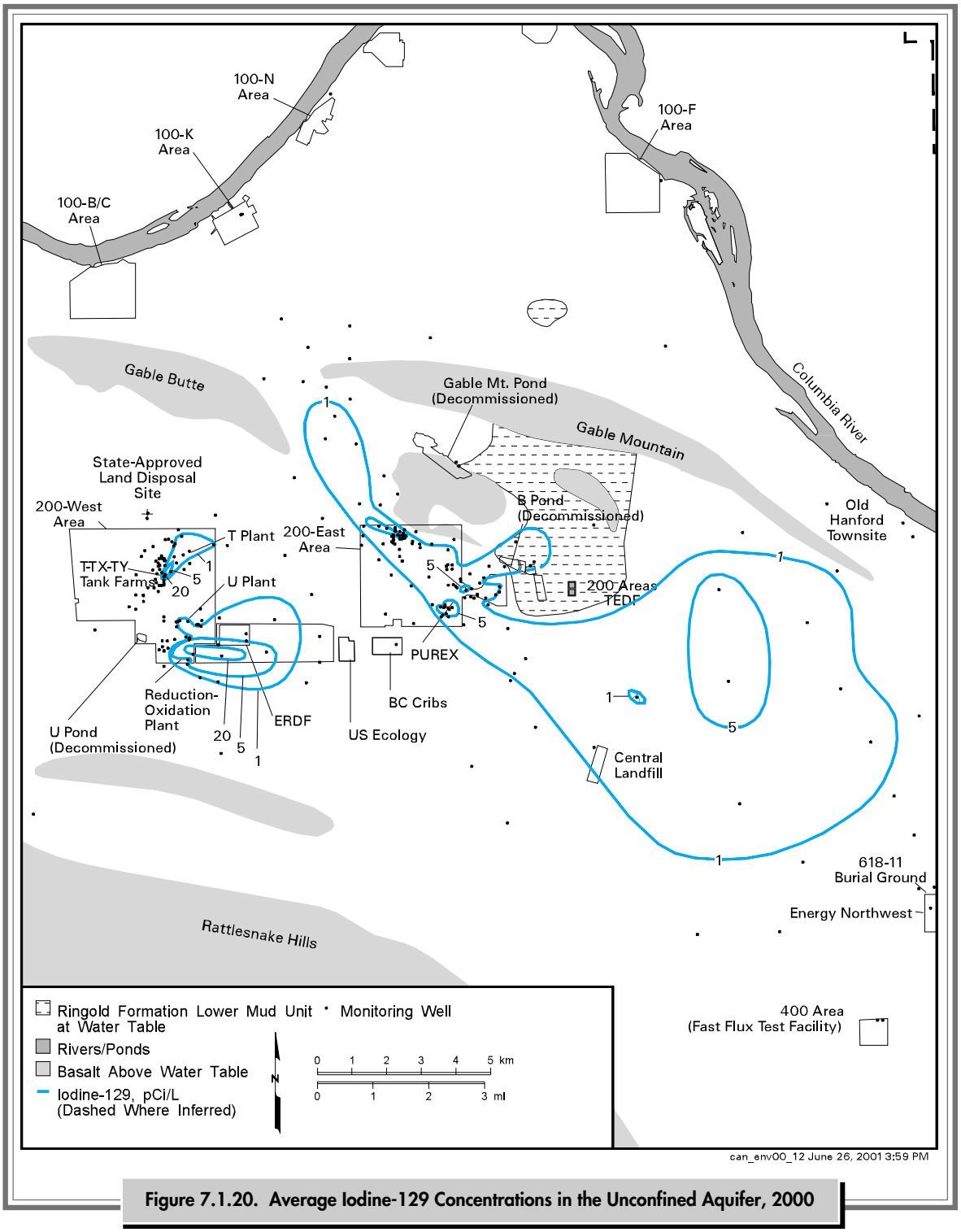

Figure 7.1.20. Average Iodine-129 Concentrations in the Unconfined Aquifer, 2000

200-East Area and a part of the 600 Area north of the 200-East Area contains technetium-99 at concentrations above the interim drinking water standard (Figure 7.1.21). The source of the technetium contamination was apparently the BY cribs (Section 2.9.1 in PNNL-13116). However, some of this contamination is believed to originate from tank farms B, BX, and BY (PNNL-11826). Technetium-99 concentrations continued to increase in several wells monitoring tank farms B, BX, and BY in 2000. The maximum concentration in the 200-East Area in 2000 occurred at the BY cribs at a level of 13,300 pCi/L. The maximum technetium-99 concentration in the plume north of the 200-East Area in 1999 was 3,200 pCi/L. This plume appears to be moving north through the gap between Gable Mountain and Gable Butte.

Technetium-99 in the 200-West Area. The largest technetium-99 plume in the 200-West Area originates from cribs that received effluent from U Plant and extends into the 600 Area to the east (Figure 7.1.22). The technetium plume is approximately in the same location as the uranium plume because technetium-99 and uranium, which are typically associated with the same fuel reprocessing cycle, were disposed to the same 216-U-1, 216-U-2, and 216-U-17 cribs. Although a pump-and-treat system reduced technetium-99 concentrations in most of the plume near the 216-U-17 crib to levels below the 9,000-pCi/L cleanup level between 1999 and 2000, an area of increasing concentrations occurs in the northwestern part of the plume near the former injection well. This well is located approximately midway between the 216-U-1, 216-U-2, and the 216-U-17 cribs. The maximum level in this plume was detected at a concentration of 27,700 pCi/L. The pump-and-treat system removed 7.3 kilograms (0.0161 pound) of technetium-99 in 2000.

Several wells that monitor tank farms T, TX, and TY consistently showed technetium-99 concentrations above the interim drinking water standard in 2000 (see Figure 7.1.22). The highest was 7,450 pCi/L east of the TX and TY tank farms, where technetium-99 levels have been increasing in recent years. The 200-ZP-1 pump-and-treat operation immediately to the south is having a significant influence on the distribution of contaminants beneath the TX and TY tank farms. A large cone of depression in the water table is resulting in contaminants from beneath the tank farms to be drawn toward the pump-and-treat system.

In the northeastern corner of T tank farm, technetium-99 levels were above the interim drinking water standard in two wells. The maximum in this area was 4,470 pCi/L in 2000. This was a decrease from the maximum of 7,110 pCi/L in 1999. The sources of the technetium-99 contamination include tank farms T, TX, and TY (PNNL-11809).

Technetium-99 contamination in small areas in the southern part of the 200-West Area originates near tank farms S and SX and the 216-S-13 crib. Multiple sources of technetium-99 contribute to groundwater contamination in this area (PNNL-11810; PNNL-13441). The maximum level detected was 72,300 pCi/L in the southwestern corner of tank farm SX, where a gradual upward trend in technetium-99 occurs. This was the highest technetium-99 concentration detected on the Hanford Site in 2000.

Total Uranium. There were numerous possible sources of uranium released to the groundwater at the Hanford Site in the past, 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 oxidation state, pH, and the presence of carbonate. Uranium is observed to migrate in site groundwater but is retarded relative to more mobile species such as technetium-99 and tritium. The

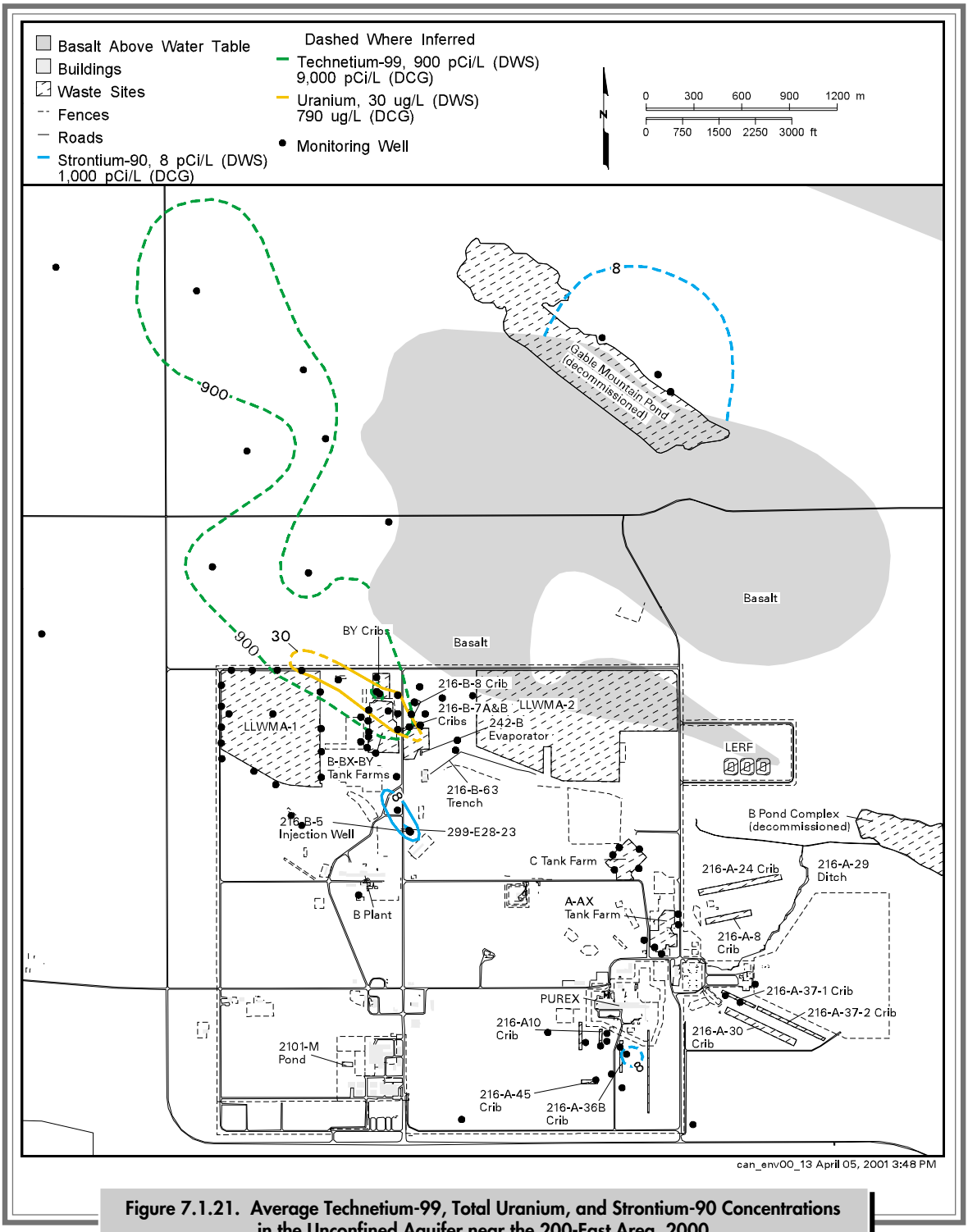

Figure 7.1.21. Average Technetium-99, Total Uranium, and Strontium-90 Concentrations in the Unconfined Aquifer near the 200-East Area, 2000

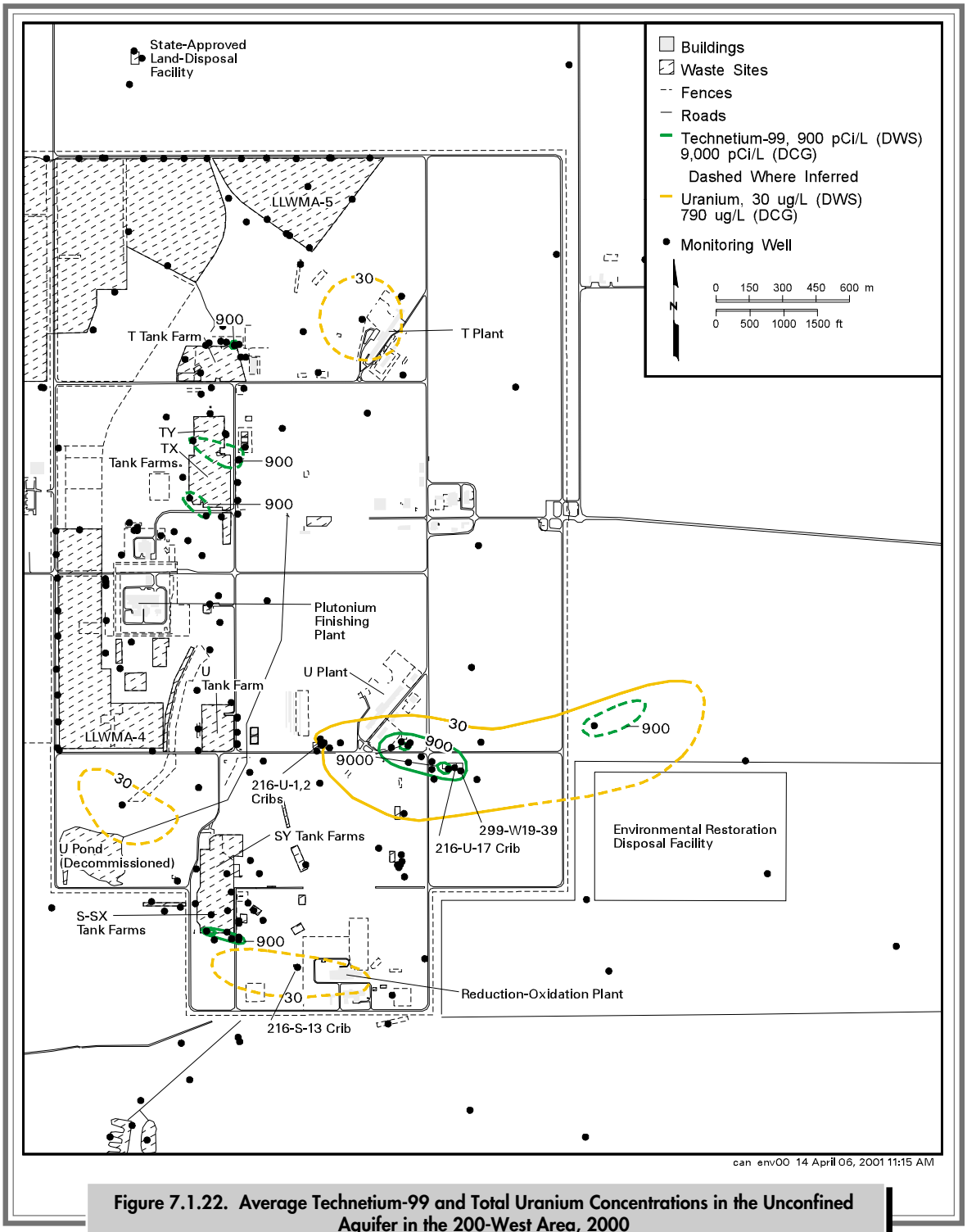

Figure 7.1.22. Average Technetium-99 and Total Uranium Concentrations in the Unconfined Aquifer in the 200-West Area, 2000

EPA's drinking water standard for uranium is 30 μg/L[a], which is protective of both chemical toxicity and cancer risk. The derived concentration guide that represents an annual effective dose equivalent of 100 mrem/yr is 790 μg/L for uranium.

Total uranium has been detected at concentrations greater than the drinking water standard in portions of the 100, 200, 300, and 600 Areas. The highest levels detected at the Hanford Site in 2000 were in the 200-West Area near U Plant, where uranium levels were 1,900 μg/L and exceeded the derived concentration guide.

Total Uranium in the 100 Areas. Uranium was detected at levels exceeding the 30-μg/L drinking water standard in a small area in the 100-H Area. The maximum detected in 2000 was 49.3 μg/L between the 183-H solar evaporation basins and the Columbia River. Concentrations of uranium (and associated technetium-99) in the 100-H Area usually fluctuate in response to changes in groundwater levels. Near the river, low groundwater levels are usually associated with higher concentrations. Past leakage from the basins is the source of the 100-H Area uranium contamination.

Total Uranium in the 200-East Area. In the 200-East Area, uranium contamination at levels greater than the drinking water standard is limited to isolated areas associated with B Plant. The uranium distribution in 2000 indicates the highest concentrations were in the vicinity of the B, BX, and BY tank farms; BY cribs; and 216-B-5 injection well that has been inactive since 1947. The highest concentration detected was 515 μg/L west of the BY tank farm (southwest of the BY cribs). The uranium plume has a narrow northwest-southeast shape. Though unclear, a likely source of the uranium contamination is from the tank farm area.

Total Uranium in the 200-West Area. The highest uranium concentrations in Hanford Site groundwater occurred near U Plant, at wells downgradient from the inactive 216-U-1 and 216-U-2 cribs and adjacent to the 216-U-17 crib (see Figure 7.1.22). The maximum detected in this area and on the Hanford Site in 2000 was 1,900 μg/L adjacent to the 216-U-17 crib. The uranium plume, which extends into the 600 Area to the east, is approximately in the same location as the technetium-99 plume discussed above. Uranium and technetium-99 were typically associated with the same fuel reprocessing cycle and were disposed to the same cribs. However, uranium is less mobile than technetium-99 because of its stronger sorption to the sediment. A greater proportion of the uranium contamination remains at or near the source area. The high concentrations exceeded the derived concentration guide for uranium. A pump-and-treat system continued to operate in 2000 to remove uranium from groundwater. The pump-and-treat system removed 17.0 kilograms (37.6 pounds) of uranium in 2000.

Other areas with uranium contamination at levels above the drinking water standard are also shown in Figure 7.1.22, including 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 in these areas was 30.9 μg/L immediately southeast of tank farms S and SX (northwest of the Reduction-Oxidation Plant). In the northern part of the 200-West Area, a localized area of uranium contamination occurs near T Plant, where concentrations were above the drinking water standard at a maximum level of 454 μg/L.

Total Uranium in the 300 Area. A plume of uranium contamination exists near uranium fuel fabrication facilities and inactive sites known to have received uranium waste. The plume extends downgradient from inactive liquid waste disposal

(a) The final rule for the uranium drinking water standard was promulgated on December 7, 2000, and becomes effective on December 8, 2003 (40 CFR Parts 9, 141, and 142).

facilities to the Columbia River (Figure 7.1.23). 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. The maximum concentration detected at this area in 2000 was 234 μg/L near the Columbia River. Because wastewater is no longer discharged to the 316-5 process trenches, elevated concentrations at the south end of the process trenches indicate that the soil column contributes uranium contamination to the groundwater. Uranium levels in the 300 Area fluctuate annually but show an overall decline. The annual fluctuation in uranium levels is caused by river stage changes, which results in mobilization of more uranium during high river stages in spring and less uranium during low river stages in fall or early winter.

A localized area of elevated levels of uranium between the 324 Building and the Columbia River showed a maximum concentration of 152 μg/L in 2000 (see Figure 7.1.23). In recent years, the elevated area of uranium near this building has moved downgradient with groundwater flow to a position adjacent to the Columbia River.

Total Uranium in the 600 Area. A well southeast of the 400 Area (adjacent to Route 4S) had a maximum uranium concentration of 46.7 μg/L in 2000. Uranium levels have declined slightly in this well in recent years. The contamination at this well is attributed primarily to the nearby inactive 316-4 crib. The retired 618-10 burial ground is also located near this well. A single uranium result from a well near the 618-11 burial ground in the 600 Area was 30.8 μg/L in 2000.

Strontium-90. Strontium-90 was produced as a high-yield fission product and was present in waste streams associated with past 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 radionuclides such as cesium-137 and plutonium. Because of sorption, a large proportion of the strontium-90 in the subsurface is not present in solution. The half-life of strontium-90 is 29.1 years.

In 2000, strontium-90 concentrations greater than the 8-pCi/L drinking water standard were found in one or more wells in each of the 100, 200, and 600 Areas. Levels of strontium-90 were greater than the 1,000-pCi/L derived concentration guide in the 100-K and 100-N Areas. The 100-N Area had the widest distribution with the highest concentrations detected at the Hanford Site during 2000. The maximum concentration was 17,700 pCi/L.

Strontium-90 in the 100 Areas. Strontium-90 concentrations greater than the drinking water standard extend from the B Reactor to the Columbia River in the northeastern part of the 100-B/C Area. The highest concentrations continued to be found in wells near the inactive 116-B-1 and 116-C-1 trenches and trends indicate concentration levels did not change significantly in 2000. The maximum concentration detected was 65.6 pCi/L near the inactive 116-C-1 trench. 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).

Strontium-90 is not widely distributed in the 100-D Area. Strontium-90 levels were consistently greater than the drinking water standard in one well near the inactive D Reactor fuel storage basin. However, this well was decommissioned in late 1999, and there were no strontium-90 data from nearby wells in 2000. Strontium-90 was detected at levels just above the drinking water standard near the former 116-D-7 retention basin in the northern part of the 100-D Area. The maximum concentration in this area was 12.3 pCi/L in 2000.

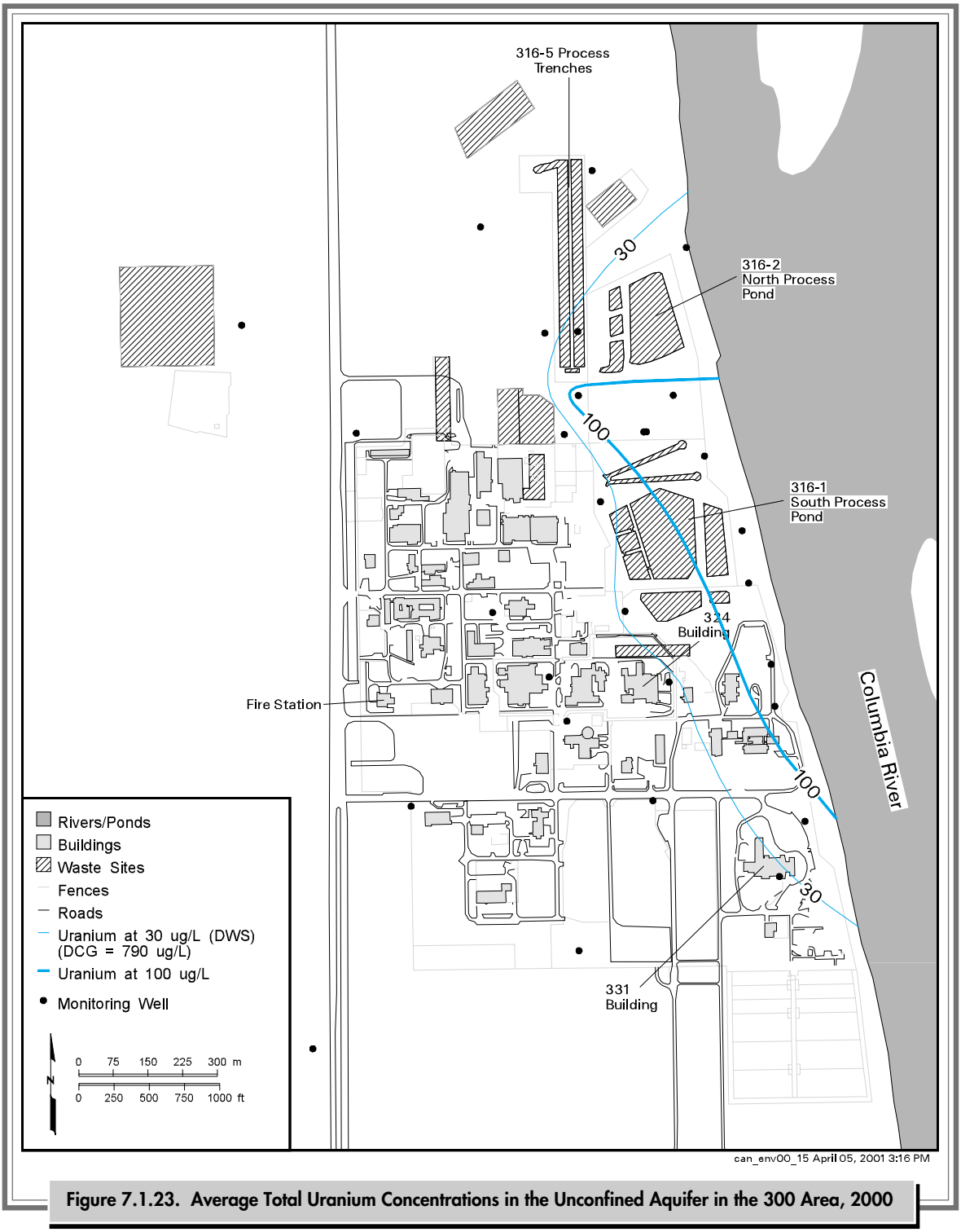

Figure 7.1.23. Average Total Uranium Concentrations in the Unconfined Aquifer in the 300 Area, 2000

Strontium-90 levels in the 100-D Area have not changed significantly in recent years.

Strontium-90 exceeded the drinking water standard near the 116-F-14 retention basins and 116-F-2 and 116-F-9 trenches in the eastern part of the 100-F Area. The maximum concentration detected in 2000 was 265 pCi/L. Strontium-90 levels fluctuate in the 100-F Area.

In the 100-H Area, strontium-90 contamination levels greater than the drinking water standard were present in an area adjacent to the Columbia River near the 107-H retention basin. The maximum detected in the 100-H Area in 2000 was 38 pCi/L between the retention basin and the Columbia River. The source of the contamination is past disposal of reactor coolant containing strontium-90 to the 107-H retention basin and the 107-H liquid waste disposal trench in the 100-H Area. Contaminated soil was excavated from the upper portion of the vadose zone at these facilities and disposed of to the Environmental Restoration Disposal Facility during 1999 and 2000.

Strontium-90 at levels greater than the drinking water standard continues to occur in isolated areas in the 100-K Area. These areas include fuel storage basin drain fields/injection wells associated with the KE and KW Reactors and the area between the 116-K-2 liquid waste disposal trench and the Columbia River. The maximum concentration detected in 2000 was 5,650 pCi/L at well 199-K-109A, the only well in the 100-K Area where levels were above the derived concentration guide. The original source of the strontium-90 in this well was identified as past-practice disposal to the 116-KE-3 drain field/injection well near KE Reactor (PNNL-12023). The maximum strontium-90 concentration near the disposal trench in 2000 was 38.9 pCi/L. Near the KW Reactor, strontium-90 is elevated above the drinking water standard. The concentration of strontium-90, which is sampled less than an annual frequency, has historically been approximately one half the gross beta concentration at this location. Gross beta concentrations, which are caused primarily by decay of strontium-90, reached a maximum of 106 pCi/L near the KW Reactor in 2000.

The distribution of strontium-90 in the 100-N Area is shown in Figure 7.1.24. Strontium-90 was detected at concentrations greater than the derived concentration guide in several wells 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 maximum level detected on the Hanford Site in 2000 was 17,700 pCi/L near the head end of the 1301-N facility (well 199-N-67). The distribution of strontium-90 near this facility has not changed significantly in the past 20 years.

In the 100-N Area, strontium-90 discharges to the Columbia River through springs along the shoreline. Sections 4.2 and 3.2 give the results of spring water sampling. Because of high concentrations in wells near the river, it was expected that strontium-90 exceeded the drinking water standard at the interface between the groundwater and the river (DOE/RL-96-102). The highest strontium-90 concentration in a near-river well in 2000 was 14,700 pCi/L. Strong, positive correlations between high groundwater-level elevations and high strontium-90 concentrations in wells indicate that strontium-90 is remobilized during periods of high water levels. A pump-and-treat system continued to operate in 2000 to reduce the discharge of strontium-90 to the Columbia River.

Strontium-90 in the 200 and 600 Areas. Strontium-90 distribution in the 200-East Area is shown in Figure 7.1.21. Strontium-90 concentrations in the 200-East Area have been above the derived concentration guide in two wells near the inactive 216-B-5 injection well. However, these wells were not sampled in 2000 because of waste management issues associated with sample disposal. One of these wells, 299-E28-23, has shown a steady

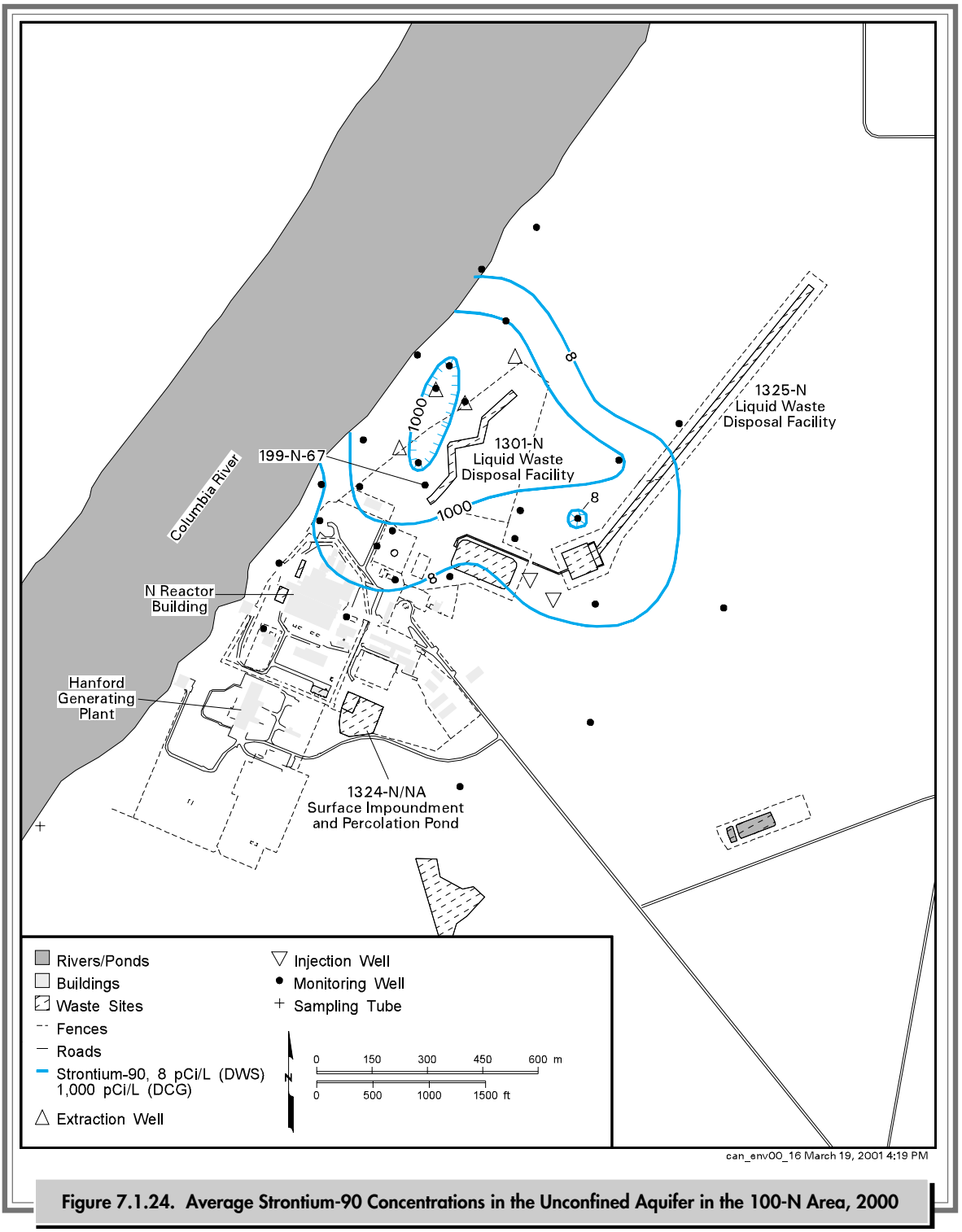

Figure 7.1.24. Average Strontium-90 Concentrations in the Unconfined Aquifer in the 100-N Area, 2000

increase in strontium-90 levels since 1990 and had a maximum concentration of 10,800 pCi/L in 1998. The maximum strontium-90 concentration detected near the injection well in 2000 was 50.4 pCi/L, which is above the 8-pCi/L drinking water standard. The former injection well received an estimated 27.9 curies of strontium-90 during 1945 and 1946 (PNL-6456). In the 200-East Area, strontium-90 was detected above the drinking water standard in one well near the Plutonium-Uranium Extraction Plant cribs. Strontium-90 levels have been stable in this well.

In the 200-West Area, strontium-90 was detected above the 8-pCi/L drinking water standard in one well near the Reduction-Oxidation Plant cribs. The maximum concentration near the cribs was 74.3 pCi/L in 2000. Strontium-90 levels have been increasing in this well in recent years.

In the 600 Area, the highest strontium-90 concentrations were detected in wells in the former Gable Mountain Pond area (see Figure 7.1.21). In one well, the level of strontium-90 rose above the derived concentration guide in 2000 to a maximum concentration of 1,210 pCi/L. Strontium-90 contamination in this area resulted from the discharge of radioactive liquid waste to the former Gable Mountain Pond during its early use.

Carbon-14. Carbon-14 concentrations occur in the 100-K Area and exceed the 2,000-pCi/L interim drinking water standard in two small plumes near the KE and KW Reactors (see Figure 7.1.12). The sources of the carbon-14 were the 116-KE-1 and 116-KW-1 condensate cribs, respectively. However, waste disposal to these cribs ended in 1971. Carbon-14 was included with tritium in the condensate wastewater disposed to the cribs. However, the distribution of carbon-14 in groundwater is not the same as for tritium because carbon-14 interacts with carbonate minerals and, thus, disperses more slowly than does tritium (PNNL-12023). The maximum concentration in 2000 was 16,300 pCi/L near the 116-KE-1 crib. Carbon-14 levels have remained stable in most of the 100-K Area wells. The derived concentration guide for carbon-14 is 70,000 pCi/L. Carbon-14 has a long half-life of 5,730 years, which suggests that some of the carbon-14 will reach the Columbia River before it decays. A portion of the carbon-14 will likely remain fixed in carbonate minerals.

Cesium-137. Cesium-137, which has a half-life of 30 years, is produced as a high-yield fission product and is present in historic waste streams associated with fuel processing. Former reactor operations also may have resulted in the release of some cesium-137 associated with fuel element breaches. Normally, cesium-137 is strongly sorbed on soil and, thus, is not very mobile 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 waste containing cesium-137 from 1945 to 1947. Annual measurements of cesium-137 in one of these wells have consistently shown levels greater than the interim drinking water standard. However, this well was not sampled in 2000 because of waste management issues associated with sample waste. Cesium-137 levels did not change significantly in the other two wells. Cesium-137 appears to be restricted to the immediate vicinity of the former injection well.

Cobalt-60. Cobalt-60 in groundwater is typically associated with waste generated by reactor effluent disposed to the ground in the past. Cobalt-60 is normally present as a divalent transition metal cation and, as such, tends to be immobile in groundwater. However, complexing agents may mobilize it. All cobalt-60 levels in groundwater samples analyzed in 2000 were below the 100-pCi/L interim drinking water standard. The derived concentration guide for cobalt-60 is 5,000 pCi/L.

Cobalt-60 was detected in the northwestern part of the 200-East Area and the adjacent 600 Area north of the 200-East Area. These 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 2000 was 78.4 pCi/L at the BY cribs. Cobalt-60 levels are increasing with associated cyanide and technetium-99 in wells near the BY cribs. Because of its relatively short half-life (5.3 years), much of the cobalt-60 in groundwater in this area has decayed to low concentrations.

Plutonium. Plutonium was released to the soil column in the past at several locations in both the 200-West and 200-East Areas. Plutonium is generally considered to sorb strongly to sediment, which limits its mobility in the aquifer. The derived concentration guide for both plutonium-239 and plutonium-240 is 30 pCi/L. Radiological analysis is incapable of distinguishing between plutonium-239 and plutonium-240; therefore, 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. However, if the derived concentration guide that is based on a 100-millirem dose standard is converted to the 4-millirem dose equivalent used for the drinking water standard, 1.2 pCi/L would be the relevant guideline. The half-lives of plutonium-239 and plutonium-240 are 24,000 and 6,500 years, respectively.

The only well where plutonium isotopes have been detected in groundwater above the 30-pCi/L derived concentration guide was near the inactive 216-B-5 injection well in the 200-East Area. However, this well was not sampled in 2000 because of waste management issues associated with sample waste. One other well near the inactive injection well showed a level above the 1.2-pCi/L relevant drinking water guideline. The maximum concentration detected on the Hanford Site in 2000 was 9.4 pCi/L of plutonium-239/240. Plutonium levels did not change significantly in this well between 1999 and 2000. Because plutonium is strongly adsorbed to sediments and may have been injected into the aquifer as suspended particles, it is likely that the values measured result in part from solid rather than dissolved material. The injection well received an estimated 244 curies of plutonium-239/240 during its operation from 1945 to 1947 (PNL-6456).

Some of the results of a plutonium speciation study conducted in the 100-K Area in 1999 were available in 2000. The purpose of the research was to study the association of actinides with dissolved organic complexes in subsurface water. Plutonium in the 100-K Area was detected at extremely low concentrations. The maximum concentration of plutonium detected was ~0.0002 pCi/L.

7.1.6.2 Chemical Monitoring Results for the Unconfined Aquifer

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. Hazardous chemicals that are less widely distributed and have lower concentrations in groundwater include chloroform, trichloroethene, tetrachloroethene, cis-1,2-dichloroethene, cyanide, and fluoride.

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 7.1.7. Other chemical parameters listed in

Table 7.1.4 are indicators of the natural chemical composition of groundwater and are usually not considered 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. These trace metal constituents, rarely observed at greater than background concentrations, include antimony, barium, beryllium, boron, cadmium, copper, nickel, silver, vanadium, and zinc.

The following presents a summary of the chemical constituents in groundwater at concentrations greater than existing or proposed drinking water standards (40 CFR 141 and EPA 822-R-96-001; see Appendix D).

Nitrate. Many groundwater samples collected in 2000 were analyzed for nitrate. The distribution of nitrate on the Hanford Site is shown in Figure 7.1.25; this distribution is similar to previous evaluations. Nitrate is the most widespread chemical contaminant in Hanford Site groundwater because of its mobility in groundwater and the large volumes of liquid waste containing nitrate discharged to the ground. However, the areas effected by levels greater than the drinking water standard are small. Nitrate was measured at concentrations greater than the drinking water standard (45 mg/L as nitrate ion) in portions of the 100, 200, and 600 Areas. The maximum nitrate concentration measured on the Hanford Site was 1,213 mg/L in the 200-West Area. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical reprocessing operations. Nitrate is associated primarily with process condensate liquid waste, though other liquids discharged to the ground also contained nitrate. However, additional sources of nitrate, primarily associated with agriculture, occur off the site to the south, west, and southwest.

Nitrate in the 100 Areas. Nitrate was measured at concentrations exceeding the drinking water standard in all 100 Areas except the 100-B/C Area. Nitrate concentrations have generally been rising in many 100 Area wells.

Nitrate is found at levels greater than the drinking water standard in much of the 100-D Area. The highest nitrate level found in the 100-D Area in 2000 was 100 mg/L near the 120-D-1 ponds. Nitrate concentrations near the 120-D-1 ponds have shown increased trends in recent years.

Nitrate continues to be widely distributed in 100-F Area groundwater. The central and southern portions of the 100-F Area contain nitrate at levels greater than the drinking water standard. Trends continue to show increasing nitrate levels in many of the 100-F wells in 2000. The nitrate plume extends to the south and southeast into the 600 Area from upgradient sources near F Reactor. In the southern part of the 100-F Area, groundwater flow was to the southeast. The maximum nitrate detected in the 100-F Area in 2000 was 158 mg/L in the southwestern part of the 100-F Area.

A nitrate plume with concentrations above the drinking water standard lies in the eastern portion of the 100-H Area adjacent to the Columbia River. The highest concentrations are restricted to a small area downgradient of the former 183-H solar evaporation basins. The maximum nitrate detected in 2000 was 150 mg/L between the basins and the river.

Nitrate is widely distributed in the 100-K Area and has multiple sources, including septic system drain fields and past-practice disposal to the soil column. In the 100-K Area, nitrate levels decreased in a number of wells between 1999 and 2000. Only one well sample in the 100-K Area indicated a

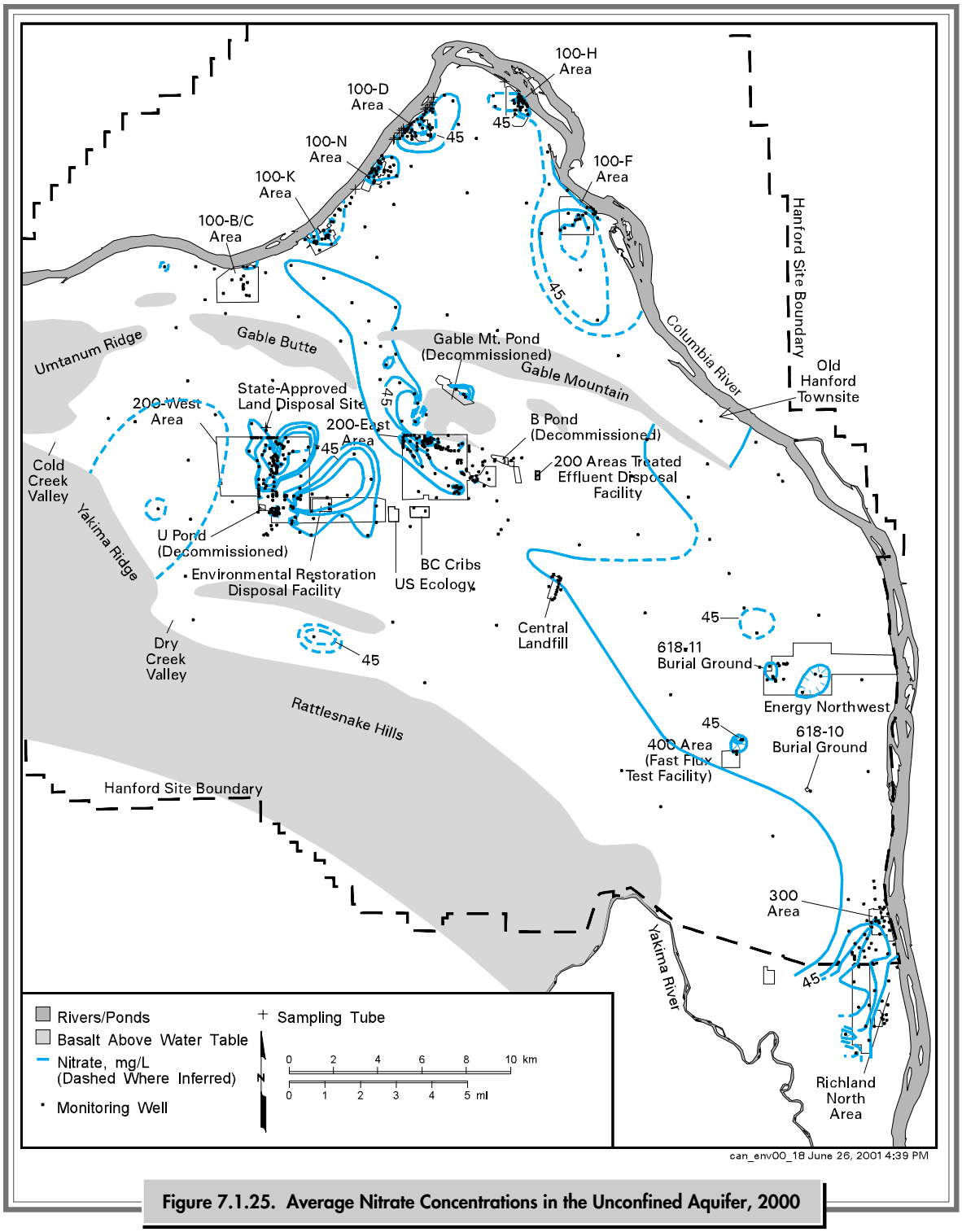

Figure 7.1.25. Average Nitrate Concentrations in the Unconfined Aquifer, 2000

nitrate concentration that exceeded the drinking water standard in 2000. The maximum concentration detected in the 100 Areas in 2000 was 160 mg/L in a well adjacent to the KE Reactor.

Although detected over most of the 100-N Area, nitrate contamination above the drinking water standard occurs at isolated locations in the 100-N Area. The maximum in the 100-N Area was 140 mg/L in a well located between the 1301-N Liquid Waste Disposal Facility and the Columbia River.

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 drinking water standard is smaller than the area with tritium exceeding its drinking water standard. Nitrate exceeds the drinking water standard in the northern part of the 200-East Area and adjacent 600 Area to the northwest and near the Plutonium-Uranium Extraction Plant in the southeastern part of the 200-East Area. In the northern part of the 200-East Area, the plume has two parts, a western plume that extends from B Plant to the northwest and an eastern portion that extends from the BY cribs to the north and northwest. The two portions of the plume join northwest of the 200-East Area. A 2000 nitrate plume map of the northern part of the 200-East Area and the adjacent 600 Area is presented in Figure 2.9-10 of PNNL-13404.

Past disposal practices related to the BY cribs is a major contributor to the high nitrate concentrations in the northern part of the 200-East Area and adjacent 600 Area. In 2000, the highest 200-East Area concentrations were reported in several wells near the 216-B-8 crib. The maximum concentration was 695 mg/L in a well adjacent to the inactive 216-B-8 crib. Nitrate levels continue to increase near the 216-B-8 and 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 inactive 216-A-10 and 216-A-36B cribs have tended to decrease in the past few years but remained greater than the drinking water standard, though these cribs were removed from service in 1987. The maximum nitrate concentration detected in this vicinity was 150 mg/L adjacent to the 216-A-36B crib.

Nitrate is also elevated in a few wells near the former Gable Mountain Pond north of the 200-East Area. In 2000, the highest measured concentration in this area was 106 mg/L.

Nitrate in the 200-West Area. Nitrate concentrations greater than the drinking water standard were widespread in groundwater beneath the 200-West Area and adjacent parts of the 600 Area. The major nitrate plumes were found in wells east of U Plant and wells in the north-central part of the 200-West Area. The widespread distribution of nitrate reflects the multiple sources in the 200-West Area. Nitrate plume maps of the 200-West and adjacent 600 Areas are presented in Figures 2.8-8 and 2.8-30 of PNNL-13404.

Near U Plant, widespread nitrate contamination is associated with the tritium and iodine-129 plumes. The nitrate contamination in this area is attributed to multiple sources, including the 216-U-1 and 216-U-2 cribs southwest of U Plant and the 216-U-17 crib southeast of U Plant. The 216-U-1 and 216-U-2 cribs received more than 1 million kilograms (2.2 million pounds) of chemicals containing nitrate during their operation from 1951 to 1967 (PNL-6456). The highest nitrate concentration measured in the plume in 2000 was 859 mg/L near the inactive 216-U-17 crib. A pump-and-treat system continued to operate in this area and 3,506 kilograms (7,729 pounds) were removed in 2000. However, nitrate is not the primary target of the pump-and-treat system.

Nitrate concentrations continued to be elevated above the drinking water standard near other inactive cribs to the south that are associated with the

U Plant and Reduction-Oxidation Plant. These elevated levels represent nitrate plumes that merge with the plume from the U Plant area. The maximum nitrate concentration reported in these areas in 2000 was 60.6 mg/L at a crib near the Reduction-Oxidation Plant.

A small, isolated plume of elevated nitrate occurs west of the Reduction-Oxidation Plant near the inactive 216-S-25 crib and S and SX tank farms, where the maximum concentration was 677 mg/L. Nitrate concentrations in this small plume appear to be associated with technetium-99.

A large area, encompassing the northern half of the 200-West Area, contains nitrate in groundwater at concentrations much greater than the 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., ~2.3 million kilograms [5.1 million pounds] of nitrate to the 216-T-7 crib). Maximum concentrations in these wells in 2000 ranged up to 1,213 mg/L adjacent to the 216-T-7 crib and tile field in the western portion of the T tank farm. Nitrate concentrations have increased or remained stable near these tank farms.

A smaller area of elevated nitrate concentrations above the drinking water standard is located in vicinity of the Plutonium Finishing Plant, which is in the central part of the 200-West Area. One source of the elevated nitrate is the 216-Z-9 trench, which received ~1.3 million kilograms (2.9 million pounds) of chemicals containing nitrate from 1955 to 1962. The highest reported concentration in 2000 at the Plutonium Finishing Plant was 392 mg/L adjacent to the trench, which is located east of the Plutonium Finishing Plant.

Nitrate in Other Areas. Nitrate contamination occurs near the city of Richland in the former 1100 Area, Richland North Area, and adjacent parts of the 600 Area along the southern boundary of the Hanford Site. This contamination is apparently affected by nitrate sources off the Hanford Site. These sources may include agriculture, food processing, and nuclear fuel manufacturing at offsite commercial facilities. The part of this plume with nitrate concentrations greater than the drinking water standard extends from off the site, south of the Hanford Site, to the 300 Area to the northeast. Nitrate concentrations generally continued to increase in the southern part of the Hanford Site and the adjacent area south of the Hanford Site in 2000. The maximum nitrate concentration in 2000 was 224 mg/L off the Hanford Site just south of the Hanford Site boundary (EMF-1865, Addendum 23). This nitrate is likely the result of agriculture to the west and southwest. A 2000 plume map showing detail of the nitrate distribution is presented in Figure 2.12-9 in PNNL-13404.

Although most nitrate detected on the site is the result of Hanford Site operations, elevated nitrate concentrations 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 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 drinking water standard in one well since 1985. A maximum nitrate concentration of 53.1 mg/L was found in a well located just north of the Rattlesnake Hills.

Nitrate was detected at levels exceeding the drinking water standard in a well downgradient of the 400 Area process ponds. These levels, which have remained steady, were attributed to a former sanitary sewage lagoon west of the process ponds. The maximum concentration observed was 87.7 mg/L in 2000.

Chromium. Use of chromium 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 in soil and groundwater remains from that use. Chromium was used for decontamination in the 100, 200, and 300 Areas and for oxidation state control in the Reduction-Oxidation Plant process. In the hexavalent form, chromium is present in a soluble 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 from several of the wells onsite for analyses of chromium and other metals. Unfiltered samples may contain metals present as particulate matter, whereas filtered samples are representative of the more mobile, dissolved metals. Filtered samples also may 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 representative of dissolved hexavalent chromium, will be used to describe the level of contamination in the discussion below.

Chromium in the 100 Areas. Chromium was detected above the drinking water standard in 2000 in the 100-D, 100-F, 100-H, 100-K, and 100-N Areas. The maximum detected concentration was 2,260 μg/L in the 100-D Area. Groundwater pump-and-treat systems continued to operate in 2000 to reduce the amount of hexavalent chromium entering the Columbia River at the 100-D, 100-H, and 100-K Areas. The purpose of the pump-and-treat systems is to prevent discharge of hexavalent chromium into the Columbia River at concentrations exceeding 11 μg/L, which is the EPA's standard for protection of freshwater aquatic life.

The chromium distribution in the 100-D Area is shown in Figure 7.1.26. Chromium contamination at levels greater than the drinking water standard is defined by two plumes. The source of the chromium plume in the southwestern part of the 100-D Area is suspected to be sodium dichromate used in the 190-DR building or disposed of in nearby waste sites. In 2000, the maximum chromium concentration from filtered samples was 2,260 μg/L in the southwestern plume near the Columbia River. The southwestern plume contains the highest concentrations of hexavalent chromium on the Hanford Site. The source of the chromium plume in the northern part of the 100-D Area is sodium dichromate released to the ground at former facilities near D Reactor. Leakage from inactive retention basins and liquid waste disposal trenches north of D Reactor may also have contributed to this chromium plume. The maximum chromium concentration in the northern plume was 393 μg/L in 2000.

In situ redox manipulation technology continues to be demonstrated in the southwestern 100-D Area to address hexavalent chromium contamination in groundwater. This technology immobilizes hexavalent chromium by reducing the soluble, more toxic, chromate ion to highly insoluble, less toxic, chromium hydroxide or iron chromium hydroxide. This is accomplished by injecting a chemical-reducing agent into closely spaced wells. Following reduction, the reagent and reaction products are pumped out of the wells. In 2000, the treatment zone was expanded by injecting the chemical-reducing agent into 10 new wells. Chromium concentrations continue to remain low in a small area of the plume. In two monitoring wells

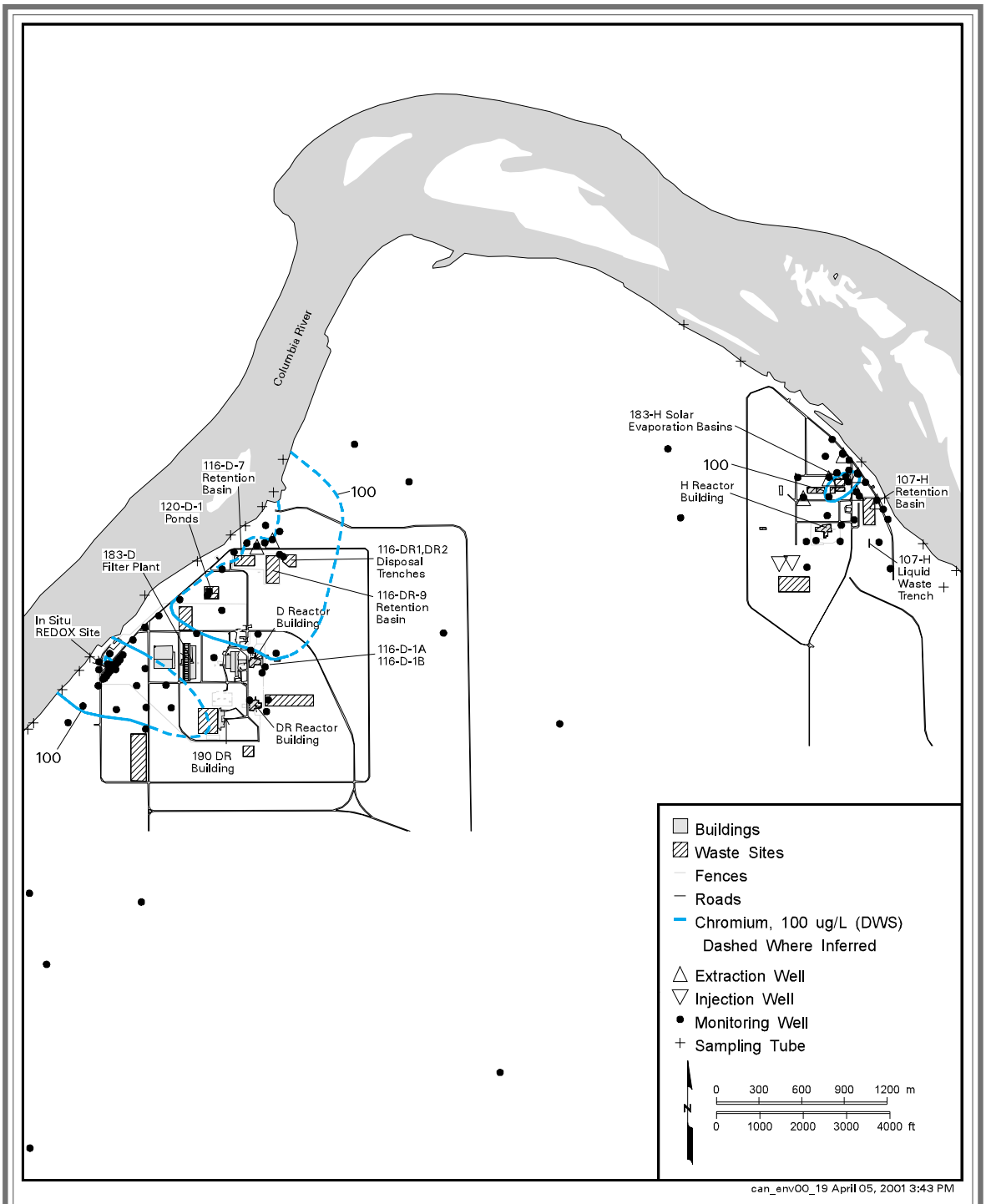

Figure 7.1.26. Average Filtered Chromium Concentrations in the 100-D and 100-H Areas, 2000

downgradient of the redox system, chromium concentrations declined from 769 to <5 μg/L and from 912 to 370 μg/L in 2000 in response to previous injections in 1998 and 1999.

A small chromium plume in the 100-H Area contains chromium levels greater than the drinking water standard (see Figure 7.1.26). In 2000, the maximum chromium concentration from filtered samples collected from the shallow parts of the unconfined aquifer was 152 μg/L near the former 183-H solar evaporation basins. Chromium levels have fluctuated in response to changing water-table conditions. Potential sources include past disposal of sodium dichromate near H Reactor, disposal to the inactive 107-H liquid waste disposal trench, and chromium in acid waste stored in the former 183-H basins (Peterson and Connelly 1992). Upgradient sources include waste sites in the 100-D Area. Chromium was also found at levels above the drinking water standard in one well monitoring the deeper part of the unconfined aquifer. Filtered samples from this well, located near the former 183-H basins, contained 160 μg/L of chromium in 2000. Chromium levels in this well have been decreasing in recent years.

Chromium in the 100-K Area occurs in groundwater at levels greater than the drinking water standard in three areas (Figure 7.1.27). Two localized areas of chromium contamination occur near the KW Reactor and the water treatment basins southeast of the KE Reactor. The maximum concentration near the KW Reactor in 2000 was 463 μg/L. Trends show that chromium concentrations decreased in 2000 near the KW Reactor after showing increases the previous two years. This decline is suspected to be the result of dilution caused by infiltration of surface water sources, such as precipitation and leaking utility lines. One potential source of the chromium plume near the KW Reactor is the railcar transfer station and storage tanks southeast of the 183-KW water treatment plant. The other small chromium plume occurs near the 183-KE water treatment basins. The most likely sources of this chromium are sodium dichromate storage tanks or the railcar transfer station near the area. The maximum chromium concentration in this plume in 2000 was 543 μg/L adjacent to the treatment basins.

A much wider area of chromium contamination is found in vicinity of the former 116-K-2 liquid waste disposal trench to the northeast. The maximum concentration in this area was 164 μg/L in 2000.

In the 100-N Area, chromium contamination is not widespread in groundwater. However, filtered samples in one well that monitors a locally confined unit within the Ringold Formation have consistently shown concentrations at steady levels greater than the drinking water standard. This well is northwest of the 1301-N Liquid Waste Disposal Facility. The maximum chromium concentration in 2000 was 172 μg/L. Chromium was disposed to the 1301-N Liquid Waste Disposal Facility until the early 1970s (DOE/RL-96-39).

Chromium in the 200 Areas. Chromium at concentrations greater than the drinking water standard in the 200-East Area was found in one well on the southern boundary of A and AX tank farms. The maximum concentration detected in samples collected from this well was 3,250 μg/L. A special study was conducted in 2000 to investigate the high metal (chromium, nickel, and manganese) concentrations at this well. The study indicated that the elevated metal concentrations historically found at this well are related to corrosion of the well screen.

Chromium contamination has been found in small areas in the 200-West Area. Areas where concentrations exceeded the drinking water standard in 2000 include the T, TX, and TY tank farms. Filtered samples from a well east of TX and TY tank farms showed a maximum concentration of 542 μg/L, the highest filtered chromium concentration in the 200-West Area. The highest concentration found at the T tank farm was 257 μg/L. Chromium concentrations have generally been

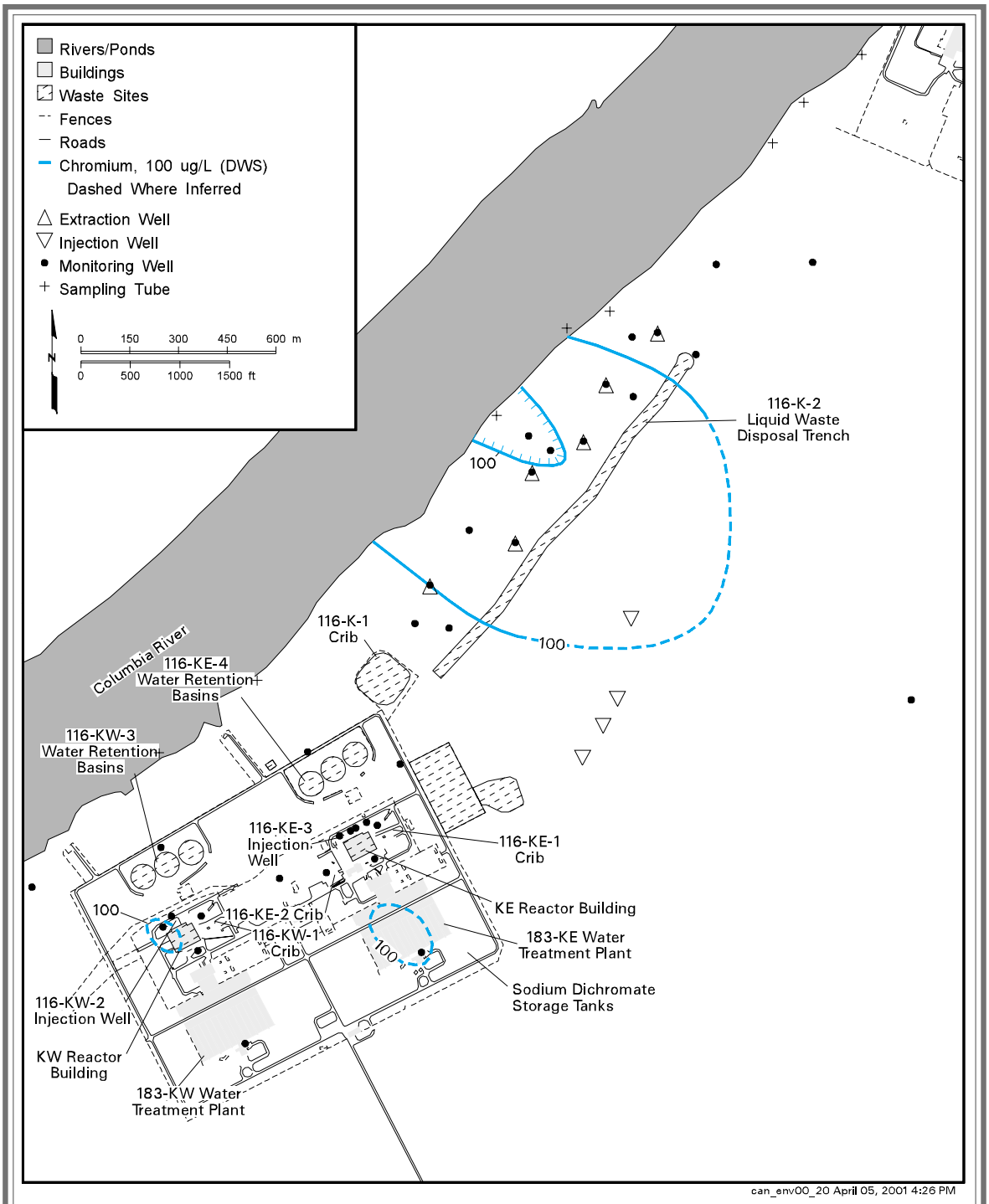

Figure 7.1.27. Average Filtered Chromium Concentrations in the 100-K Area, 2000

increasing in these areas. Chromium concentrations previously elevated above the drinking water standard near the former 216-S-10 pond declined to levels below the drinking water standard in 2000.

Chromium in Other Areas. Filtered chromium concentrations above the drinking water standard frequently occur south of the 200-East Area. The maximum concentration detected in filtered samples in this area in 2000 was 201 μg/L. The extent of chromium contamination in this area is poorly defined, and the source has not been determined.

Carbon Tetrachloride. Carbon tetrachloride contamination occurs above the 5-μg/L drinking water standard in much of the 200-West Area and represents one of the most significant contaminant plumes at the Hanford Site (Figure 7.1.28). The maximum detected concentration was 7,100 μg/L near the Plutonium Finishing Plant in the 200-West Area. The plume, which covers an area that is more than 11 square kilometers (4 square miles), extends past the 200-West Area boundary into the 600 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. Major sources identified in this area include the 216-Z-9 trench, the 216-Z-1A drain/tile field, and the 216-Z-18 crib. 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 non-flammable thinning agent while machining plutonium. A minor source of carbon tetrachloride is a former 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.

Wells in vicinity of the Plutonium Finishing Plant showed the highest concentrations in the plume, with levels exceeding the drinking water standard by more than two orders of magnitude. The maximum concentration was 7,100 μg/L near one pump-and-treat extraction well just north of the plant. Pump-and-treat operations, which began in 1994, have influenced the distribution of carbon tetrachloride. In the center of the plume, the area within the 4,000-μg/L contour has increased in size because of the effects of pumping from the extraction wells downgradient of this area. The plume center moved to the north and east toward the extraction wells in recent years, as evidenced by increased concentrations in several extraction and monitoring wells (BHI-01311). Concentrations increased in the two northern extraction wells during 2000. The extraction wells are located north and east of the Plutonium Finishing Plant. Carbon tetrachloride concentrations were below the minimum detection limit in vicinity of the injection wells southwest of the plant during 2000. Concentrations have declined because of injection of the treated water. The pump-and-treat system removed 1,318 kilograms (2,906 pounds) of carbon tetrachloride in 2000.

The carbon tetrachloride plume is divided into two major lobes, one in the northern half and one in the southern half of the 200-West Area. In the northern lobe, an area of increasing carbon tetrachloride concentrations has moved slowly beyond the northeastern 200-West Area boundary since 1997. In the southern lobe, carbon tetrachloride concentrations continue to increase near the S-SX tank farm to levels averaging 130 μg/L during 2000.

The extent of carbon tetrachloride contamination in deeper parts of the aquifer is uncertain because of the limited concentration data from depths below the water table. The limited amount of data indicates that the concentrations are highest at the top of the aquifer and decline with depth at most locations within the plume. Carbon tetrachloride contamination has been detected to depths greater than 60 meters (197 feet) below the water

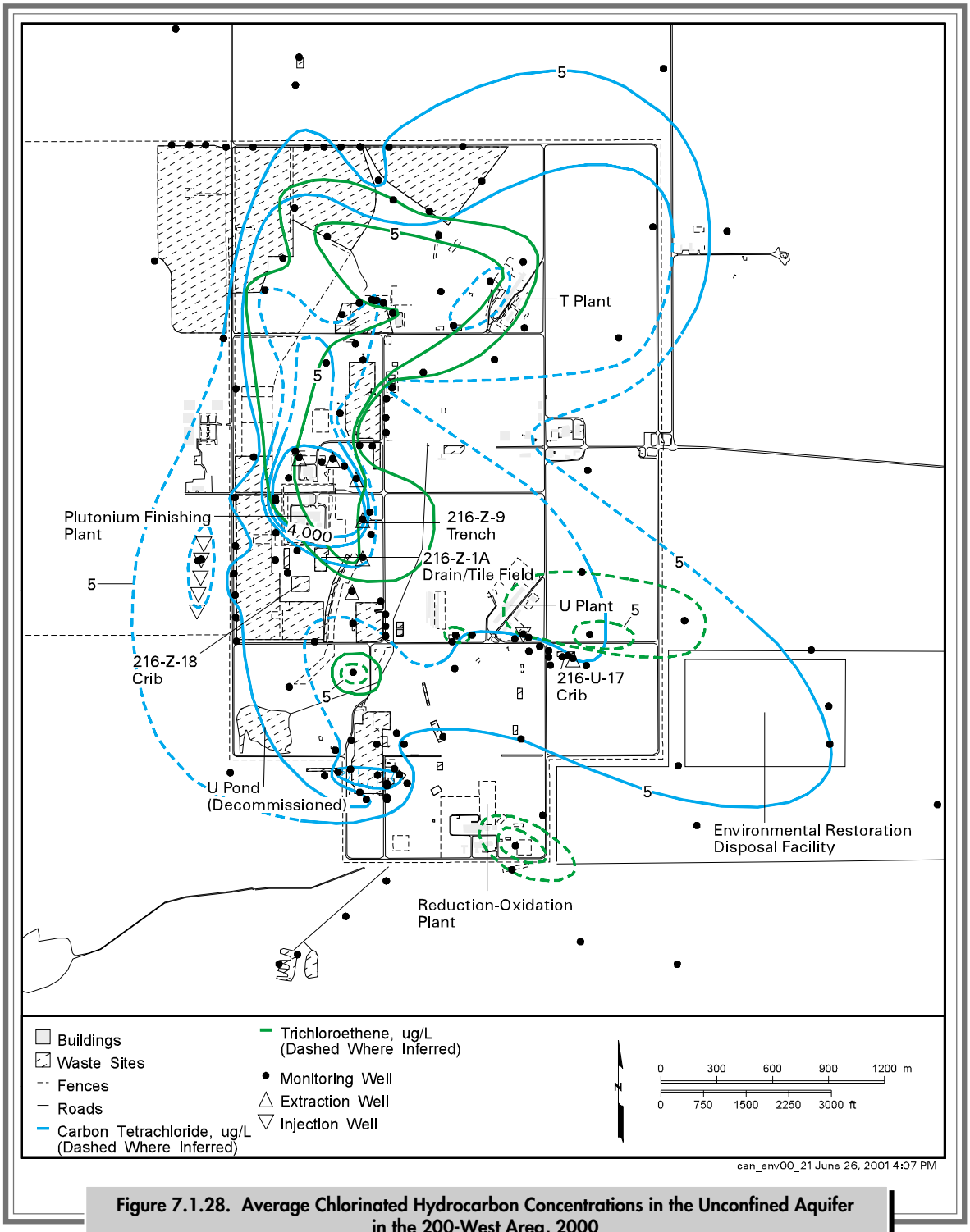

Figure 7.1.28. Average Chlorinated Hydrocarbon Concentrations in the Unconfined Aquifer in the 200-West Area, 2000

table. A detailed summary of available data indicates that carbon tetrachloride concentrations range up to 3,789 μg/L in the middle part of the unconfined aquifer (BHI-01311). In the lower part of the unconfined aquifer, carbon tetrachloride concentrations range up to 2,651 μg/L. These data represent samples collected between 1991 and 1999.

Changes in groundwater flow since decommissioning U Pond may influence the plume configuration and the concentrations at particular locations. Another potential influence is the continued spreading of carbon tetrachloride above the water table, in either the liquid or the vapor phase. Free-phase, liquid, carbon tetrachloride above and possibly below the water table provides a continuing source of contamination. Therefore, lateral expansion of the carbon tetrachloride plume is expected to continue.

Chloroform. A chloroform plume appears to be associated with, but not exactly coincident with, the carbon tetrachloride plume in the 200-West Area. The highest chloroform concentrations were measured in vicinity of the Plutonium Finishing Plant, where the maximum level was 130 μg/L. The drinking water standard for chloroform is 100 μg/L (total trihalomethanes). The origin of chloroform is suspected to be a degradation product of carbon tetrachloride or an anaerobic degradation product associated with septic drain fields.

Trichloroethene. A commonly used organic solvent, trichloroethene has a drinking water standard of 5 μg/L. In 2000, trichloroethene was detected at levels greater than the drinking water standard in several wells in the 100, 200, 300, and 600 Areas. The most widespread area of contamination occurred in the 200-West Area.

Trichloroethene in the 100 Areas. Trichloroethene was detected at levels greater than the drinking water standard in the southwestern corner of the 100-F Area and in the adjacent 600 Area. Trichloroethene concentrations in this area show slowly declining trends. The maximum concentration detected in this area was 16 μg/L in both the 100-F and adjacent 600 Areas. No specific sources of this contamination have been identified.

In the 100-K Area, a localized area of trichloroethene contamination occurs near the KW Reactor complex. This area of contamination resulted from the past disposal/spillage of organic solvents. One well downgradient of the KW Reactor showed a maximum trichloroethene concentration above the drinking water standard at a level of 11 μg/L. Trichloroethene concentrations appear to be decreasing with time.

Trichloroethene in the 200 Areas. Trichloroethene was detected at levels greater than the drinking water standard in several parts of the 200-West Area (see Figure 7.1.28). The most significant area extends from the Plutonium Finishing Plant northeast to an area west of T Plant. The source of the contamination is presumably past disposal in these plant areas. The highest concentration was 31 μg/L northeast of the Plutonium Finishing Plant near the northern extraction wells for the carbon tetrachloride 200-ZP-1 pump-and-treat system. A smaller, isolated area of contamination occurs downgradient of the U Plant cribs, where the maximum concentration was 15 μg/L. Another localized area of trichloroethene contamination occurs east of the Reduction-Oxidation Plant in the southern part of the 200-West Area. The maximum concentration in this area in 2000 was 9 μg/L.

Trichloroethene in the 300 and 600 Areas. A localized plume of trichloroethene occurs in the 300 Area near the 316-5 process trenches. Trichloroethene was detected at a concentration above the drinking water standard in one well downgradient of the process trenches. The maximum concentration in 2000 was 5.3 μg/L.

Trichloroethene was found at a level above the drinking water standard in one well in vicinity of the inactive Horn Rapids landfill in the southern

part of the site (Richland North Area). This contamination, which is degrading naturally, forms an elongated plume that extends from an area just south of the landfill to near the southwestern corner of the 300 Area and has an origin off the Hanford Site. The maximum contamination detected in this plume in 2000 was 5.1 μg/L on the northeastern side of the landfill.

cis-1,2-Dichloroethene. Concentrations of cis-1,2-dichloroethene remain elevated in one well near the former process trenches and ponds in the 300 Area. This well is completed in the deeper part of the unconfined aquifer and is the only well on the site where this constituent is found at levels above the 70-μg/L drinking water standard. In 2000, a maximum of 170 μg/L was detected in this well. The source of the cis-1,2-dichloroethene is the 316-5 process trenches.

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 northern and southern portions of the 200-East Area. Smaller quantities were also disposed to former 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. Samples collected from two wells near the inactive BY cribs showed concentrations above the drinking water standard in 2000. The maximum concentration near the cribs was 411 μg/L. Cyanide levels near the cribs have generally increased along with associated technetium-99 and 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.

Fluoride. At this time, fluoride has a primary drinking water standard of 4 mg/L and a secondary standard of 2 mg/L. Secondary standards are based primarily on aesthetic rather than health considerations. Fluoride was detected above the primary drinking water standard in three wells monitoring T tank farm in the 200-West Area in 2000. The maximum fluoride concentration was 9.8 mg/L near the 216-T-7 crib. A few other wells near the T tank farm showed concentrations above the secondary standard. Aluminum fluoride nitrate used in past 200-West Area processes is the probable source of the fluoride contamination.

7.1.6.3 Radiological and Chemical Monitoring Results for the Upper Basalt-Confined Aquifer

The purpose in monitoring groundwater in the upper basalt-confined aquifer is to determine the potential for hazardous or radiological contamination within this aquifer. Monitoring the upper basalt-confined aquifer is important because of the potential for downward migration of contaminants from the overlying unconfined aquifer. Contaminants that reach the upper basalt-confined aquifer have the potential to migrate off the Hanford Site. The upper basalt-confined aquifer is also monitored to assess the potential migration of contaminants onto the Hanford Site from offsite sources.

The upper basalt-confined aquifer is monitored by ~40 wells that are sampled annually to triennially. Most of these wells are located near the 200 Areas in the central part of the Hanford Site (see Figure 7.1.9). During 2000, nine upper basalt-confined aquifer wells were sampled for chemical and radiological constituents.

During 2000, most of the wells that represent the upper basalt-confined aquifer were sampled for tritium, iodine-129, and nitrate. These constituents are the most widespread in the overlying unconfined aquifer, are most mobile in groundwater, and provide an early warning of potential contamination in the upper basalt-confined aquifer. The distribution of sample results for these and other selected constituents are shown in Figure 7.1.29. Constituent concentrations for all samples collected from the upper basalt-confined aquifer were less than their respective drinking water standard during 2000. The highest tritium concentration found in the upper basalt-confined aquifer in 2000 was 5,770 pCi/L beneath B Pond. Since 1996, tritium concentrations have declined steadily at this location. Tritium at this location is believed to have originated from downward migration from the overlying, unconfined aquifer. Iodine-129 was not detected in samples collected from wells that represent the upper basalt-confined aquifer. In most of the wells sampled for nitrate, concentrations in the upper basalt-confined aquifer increased during 2000. The highest nitrate concentration detected, 11 mg/L, was found just north of the 200-East Area. The distribution of contaminants in the upper basalt-confined aquifer is discussed more thoroughly in the fiscal year 2000 annual groundwater report (PNNL-13404).

Aquifers confined below the uppermost basalt layers are affected much less from Hanford Site contamination than the unconfined aquifer system within the overlying sediment. 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 past 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.

Intercommunication between the unconfined and basalt-confined aquifers in vicinity of the northern part of the 200-East Area has been identified previously in RHO-BWI-ST-5 and RHO-RE-ST-12 P. 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 this area has been attributed to erosion of the upper Saddle Mountains Basalt and a downward vertical gradient that resulted from groundwater mounding associated with past waste disposal. Since the groundwater mound diminished, the downward vertical gradient has decreased in recent years and was negligible in 2000.

Groundwater data indicate that a downward hydraulic gradient from the unconfined to the confined aquifers also occurs in the western portion of the Hanford Site and in regions north and east of the Columbia River. However, groundwater chemical and radiological data from most confined aquifer wells in these other areas do not exhibit evidence of contamination. Exceptions are wells that were previously open to both the unconfined and confined aquifers, thus providing conduits for the downward transport of contamination.

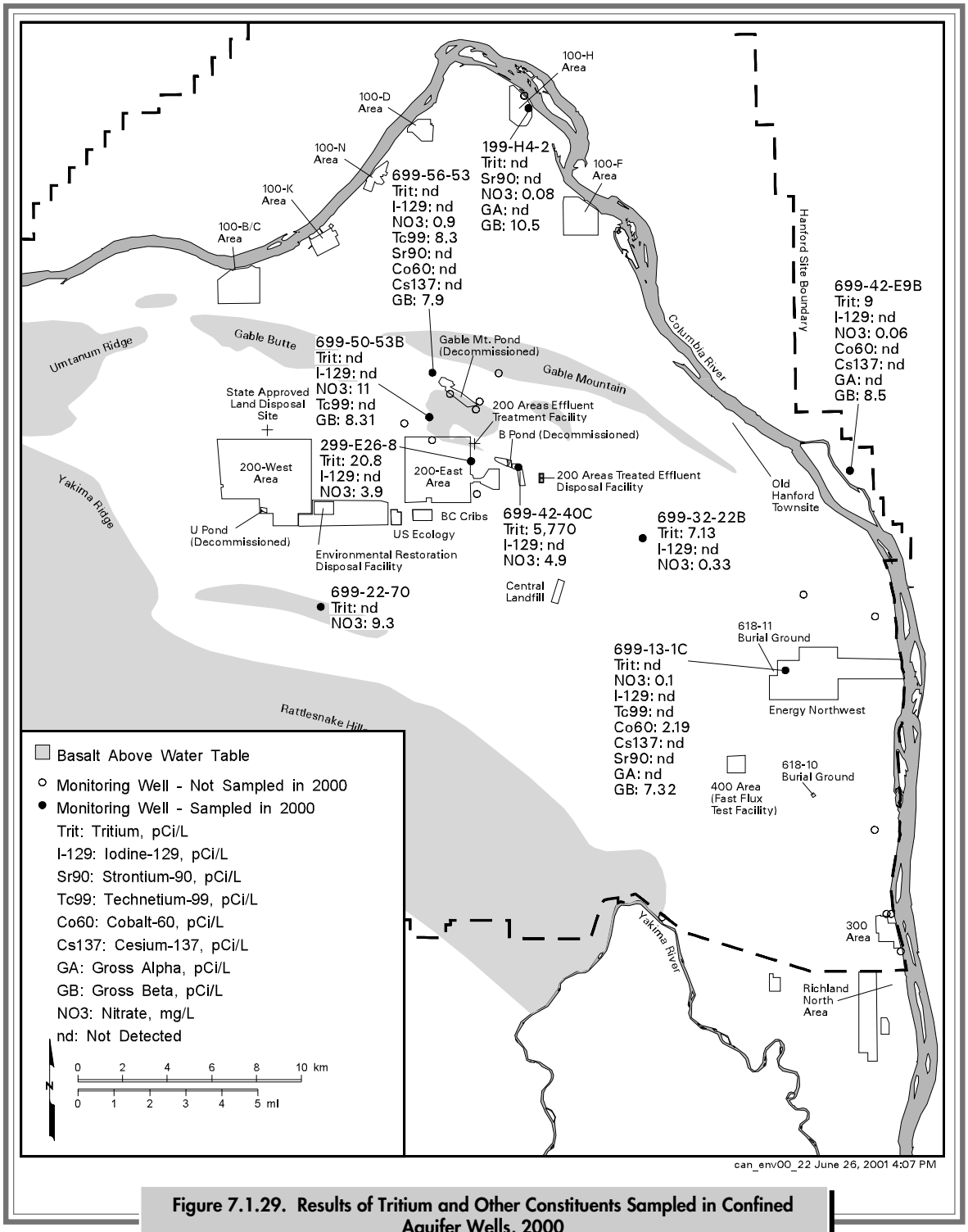

Figure 7.1.29. Results of Tritium and Other Constituents Sampled in Confined Aquifer Wells, 2000

7.1.7 RCRA Summary

More than 60 treatment, storage, and disposal units are recognized under the RCRA permit for the Hanford Site. Of these, 25 required groundwater monitoring during 2000. Locations of these groundwater monitoring sites were given in Figure 7.1.10. This section provides a summary of groundwater monitoring activities and results for these sites during calendar year 2000. Additional information, including complete listings of radioactive and chemical constituents measured in monitoring wells from October 1999 through September 2000, is available in PNNL-13404.

RCRA 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 change 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-12086.

If a statistically significant change 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 2.2.2 in Section 2.2 lists the phase pertaining to each of the RCRA groundwater monitoring projects at the end of 2000.

7.1.7.1 100 Areas Facilities

183-H Solar Evaporation Basins. This facility consisted of four separate concrete basins surrounded by an earthen berm. The basins have been demolished and contaminated soil removed from the site. Between 1973 and 1985, the basins were used to store liquid waste, primarily from nuclear fuel fabrication activities conducted in the 300 Area. Solar evaporation reduced the volume of liquid waste. The waste was predominantly acid etch solution that had been neutralized with sodium hydroxide before being discharged into the basins. The solution included chromic, hydrofluoric, nitric, and sulfuric acids and also contained various metallic and radioactive constituents. Groundwater in the vicinity of these basins is characterized by elevated levels of chromium, nitrate, technetium-99, and uranium. All of these constituents were present in waste discharged to the basins when they were in use.

This site continued to be monitored under a final status corrective-action program during 2000 (WAC 173-303-645). Groundwater remediation is integrated with the 100-HR-3 operable unit, where remediation for chromium is under way. While the pump-and-treat system is operating, RCRA monitoring consists of annual sampling of four wells for chromium, fluoride, nitrate, technetium-99, and

uranium. The wells were sampled in November 2000. Contaminant concentrations fluctuate in response to changes in river stage, and continued to exceed concentration limits in one or more wells.

1301-N and 1325-N Liquid Waste Disposal Facilities. These facilities contaminated groundwater with radionuclides, most notably strontium-90 and tritium, as discussed in Section 7.1.6.1. A pump-and-treat system is active as a CERCLA interim action to reduce the amount of strontium-90 flowing into the Columbia River at the 100-N Area. RCRA monitoring focuses on the hazardous (non-radioactive) constituents discharged to the 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 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. Beginning in July 2000, contaminated sediment and concrete from the trench was excavated and disposed in the Environmental Restoration Disposal Facility near the 200 West Area. Remediation of the trench and crib continues in 2001.

During 2000, upgradient and downgradient wells at the 1301-N and 1325-N facilities were sampled twice. At the 1301-N facility, total organic carbon in downgradient well 199-N-3 exceeded the critical mean value in September 2000. DOE notified the Washington State Department of Ecology of a previous exceedance in this well in February 1999. Because no organic constituents of concern have been identified in 1301-N waste or sediment, the contamination is assumed to come from another source, and the site remains in indicator evaluation status.

Average specific conductance values in downgradient well 199-N-41 at the 1325-N facility continued to exceed the critical mean value in 2000. DOE notified the Washington State Department of Ecology of a previous exceedance and submitted an assessment report that concluded the exceedance did not indicate contamination from the facility and originated at an upgradient source.

Of the dangerous waste constituents or byproduct discharged to these facilities, only nitrate exceeded the maximum contaminant level, and the sources are unclear (see Section 2.4.3 of PNNL-13116). The 1301-N and 1325-N facilities have contaminated the groundwater with tritium and strontium-90, but radionuclides are not monitored as part of the RCRA program at these facilities.

The closure plan for these facilities was revised and incorporated into a modification of the Hanford Site RCRA Permit (Ecology 1994) in 1999. Remedial actions will be integrated with the 100-NR-1 and 100-NR-2 operable units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038).

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 neutralizing 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 in wells downgradient of the 1324-N/NA site continued to exceed the critical mean value in 2000. A previous groundwater quality assessment indicated that the high specific conductance is caused by the non-hazardous constituents sulfate and sodium (WHC-SD-EN-EV-003). Because an assessment has been completed already and non-hazardous constituents caused the high conductance, no further action was needed.

The closure plan for these facilities was revised and incorporated into a modification of the Hanford Site RCRA Permit (Ecology 1994) in 1999. Remedial action will be integrated with the 100-NR-1 and 100-NR-2 operable units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038).

7.1.7.2 200 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 parts of RCRA Waste Management Areas A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U. 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 waste generated by reprocessing fuel irradiated in Hanford Site reactors. The single-shell tanks received mixtures of organic and inorganic liquids that contain radionuclides, solvents, and metals that were originally discharged to the tanks as alkaline slurries. Subsequent waste management operations combined waste streams from different processes. In many tanks, waste have been concentrated by removing water through evaporation.

Waste Management Area A-AX. This RCRA site continued to be monitored under an interim status indicator evaluation program in 2000. Wells were sampled twice for indicator and site-specific parameters. Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to those established from the upgradient wells. The indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed critical mean values during 2000.

The well network for this site may not be adequate for RCRA monitoring. It was designed for groundwater flow toward the southwest, but recent studies have suggested flow may be eastward. In addition, the aquifer is less than 5 meters (16 feet) thick and the water table is declining so wells may go dry. However, the rate of decline decreased in 2000, and if this rate continues, the RCRA compliant wells in the monitoring network will remain usable for at least 15 to 20 years.

Waste Management Area B-BX-BY. RCRA assessment monitoring continued at this waste management area in 2000. Exceedances of the critical mean value for specific conductance in February 1996 at well 299-E33-32 initiated assessment monitoring. Results of the initial assessment investigation indicated that tank waste from this waste management area had reached the groundwater (PNNL-11826). Monitoring in 2000 continued to indicate the presence of three distinct plumes in the area, based on groundwater chemistry, spatial relationships, historic plume movement, and chemical ratios. Groundwater beneath the BY cribs, north of the waste management area, has the highest level of technetium-99 in the vicinity. This contamination is attributed to discharges to the cribs in the 1950s and forms an extensive plume that now is moving to the south, affecting the groundwater under Waste Management Area B-BX-BY. The highest concentration of nitrate is detected under the 216-B-8 crib, located

east of the waste management area. This contamination is believed to be mostly associated with discharges to the crib in the late 1940s. A local depression in the basalt bedrock exists in this area, and the contamination may be sitting in a partially stagnant pool. Technetium-99, nitrate, and nitrite have recently increased in wells near the BY tank farm. This contamination may have originated from past leaks within Waste Management Area B-BX-BY.

Fiscal year 2000 studies helped refine the interpretation of the direction of groundwater flow in and near Waste Management Area B-BX-BY. Although the data showed local variability, the overall direction of flow appears to be toward the south beneath the waste management area. In the past, when the water table beneath the 200 Areas was higher, groundwater flowed to the northwest. Three new monitoring wells will be installed in 2001.

Waste Management Area C. This RCRA site continued to be monitored under an interim status indicator evaluation program in 2000. Wells were sampled monthly in 2000 to assess the potential impact of removal and sluicing of tank contents (no impact was detected). In addition, the required detection sampling was conducted twice for indicator and site-specific parameters. Indicator parameter data from upgradient wells were statistically evaluated. Values from downgradient wells were compared to values established from the upgradient wells. The indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed critical mean values during 2000.

Currently, the well network for this site appears to comply only marginally with the required placement of groundwater monitoring wells because of changes and uncertainty in the direction of flow.

Waste Management Area S-SX. This RCRA site continued to be monitored under an interim status assessment program during 2000. DOE initiated the assessment program in response to a directive from the Washington State Department of Ecology in 1996. The directive cited anomalous trends in technetium-99 and high specific conductance as primary reasons for the assessment. A report on the results of the assessment (PNNL-11810) concluded that sources within the waste management area contributed to groundwater contamination.

Assessment activities continued in 2000 with installation of new wells, hydrologic and tracer testing, and additional sampling and analysis to evaluate the rate of contaminant movement and the extent and concentrations of contaminants. The most significant finding during the year was the persistent and gradually increasing trend in technetium-99 in a new well in the southwestern corner of the SX tank farm. Technetium-99 concentrations increased from 39,000 pCi/L on October 1999 to 72,300 pCi/L in December 2000. The contamination is attributed to previous tank waste leaks to the soil in that area. Circumstantial evidence suggests leakage from a nearby water line may be a recent driving force for transport of vadose zone contamination to groundwater. Water lines in this area are being isolated during 2001 as one interim corrective measure.

Although the occurrence of technetium-99 at the SX tank farm is the highest concentration detected in groundwater at the Hanford Site, the contaminant plume appears to be localized and moving very slowly (<50 meters per year) to the east-southeast. Other tank waste constituents of concern (strontium-90, cesium-137, neptunium-237, plutonium-239/240, americium-241 and iodine-129) were analyzed in key network wells but all were below detection limits. Based on the groundwater data collected to date, only the more mobile tank waste constituents (e.g., technetium-99, nitrate, hexavalent chromium, tritium) have reached groundwater beneath Waste Management Area S-SX.

Waste Management Area T. This RCRA site continued to be monitored under an interim status assessment program during 2000. Waste Management Areas T and TX-TY began assessment monitoring in November 1992 because of high specific conductance in downgradient wells. Assessment findings (PNNL-11809) indicated that contaminants in well 299-W10-15 are a result of sources outside the waste management area. There is strong evidence, however, that contaminants observed in well 299-W11-27, which include chromium, cobalt-60, nitrate, technetium-99, and tritium, are a result of sources within the waste management area, so assessment work has continued. The plume detected in well 299-W11-27 has reached well 299-W11-23, located to the east of 299-W11-27, apparently as a result of changed groundwater flow direction at Waste Management Area T.

Assessment activities at Waste Management Area T continued in 2000 with the addition of new wells, hydrologic testing, and sampling and analysis to aid in evaluation of the rate of contaminant transport, and the concentration and extent of contamination. Groundwater flow direction maintained a fairly constant direction, slightly north of east, during 2000. Relatively high concentrations of nitrate, chromium, and fluoride have been reported in a number of wells as a result of an upgradient contaminant plume moving across the area. Values of nitrate exceeding 1,000 mg/L have been detected in several wells. Samples collected during drilling near the northeastern corner of the waste management area, coupled with chemical data from an existing well, indicate that the top portion of the aquifer is relatively impermeable and contains a high-technetium plume. Deeper portions of the aquifer are more permeable and groundwater is characterized by high nitrate, similar to the upgradient plume.

The water table beneath Waste Management Area T continued to decline in 2000. Four new downgradient wells were installed to replace dry wells and to account for changes in the direction of groundwater flow.

Waste Management Area TX-TY. This RCRA unit also continued to be monitored under an interim status assessment program during 2000. Waste Management Area TX-TY began assessment monitoring in November 1991 because of high specific conductance in wells 299-W10-17 and 299-W14-12. The exceedance in well 299-W14-12 was accompanied by elevated cobalt-60, iodine-129, technetium-99, and tritium. Assessment results (PNNL-11809) indicated that contaminants in well 299-W10-17 are a result of sources outside the waste management area. Assessment results for well 299-W14-12 indicate that the contamination is consistent with a source within the waste management area, though upgradient sources are also possible. Because there was no direct evidence for upgradient sources, assessment continues at the site.

Assessment activities continued in 2000 with the addition of new wells, hydrologic testing, and sampling and analysis to aid in evaluation of the rate of contaminant transport and the concentration and extent of contamination. A plume with high levels of technetium-99 and a separate plume with high concentrations of tritium and iodine-129 and low levels of technetium-99 continued to be detected in the central portion of the waste management area. Tritium concentrations reached 2.9 million pCi/L and iodine-129 reached 48 pCi/L in a downgradient well east of the waste management area. The most likely source for the tritium and iodine-129 plume is the 242-T evaporator, located between the TX and TY tank farms. Increases in technetium-99 concentrations were detected in wells south of the waste management area, indicating the possibility that contaminants are being drawn toward a groundwater pump-and-treat system. The operation of a pump-and-treat system in an area south of Waste Management Area TX-TY has changed the direction of groundwater flow over the past several years. Beneath the

southern part of the waste management area, flow is primarily to the south, which may be causing tank-related contaminants to move southward. Five new monitoring wells were installed downgradient of Waste Management Area TX-TY in 2000 to account for the changing flow direction and to track the plume farther from the waste management area.

Waste Management Area U. This site was placed in assessment in late 1999 because of an exceedance in the indicator parameter specific conductance. It remains in assessment because of elevated concentrations of chromium, nitrate, and technetium-99. Concentrations of these constituents were below drinking water standards, but they were above upgradient concentrations and a plausible upgradient source could not be identified.

The direction of groundwater flow beneath Waste Management Area U has been strongly influenced by the 200-ZP-1 pump-and-treat operations to remove carbon tetrachloride, particularly in the northern portion of the waste management area. One upgradient well went dry in fiscal year 2000. There are plans to replace this well and to drill several downgradient wells to improve the efficiency of the monitoring network.

7.1.7.3 200 Areas Liquid Effluent Disposal Facilities

216-A-10, 216-A-36B, and 216-A-37-1 Cribs. These inactive cribs in the 200-East Area received liquid waste from the Plutonium-Uranium Extraction Plant and contributed to the widespread plumes of tritium, iodine-129, and nitrate described in Sections 7.1.6.1 and 7.1.6.2. 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 tritium, cobalt-60, strontium-90, ruthenium-106, iodine-129, cesium-137, and uranium. The 216-A-37-1 crib received process condensate from the 242-A evaporator. The process condensate contained radionuclides, spent halogenated and non-halogenated solvents, and ammonia. The radionuclides included cobalt-60, strontium-90, ruthenium-106, cesium-137, uranium, and plutonium.

The 216-A-10, 216-A-36B, and 216-A-37-1 cribs were monitored under a RCRA assessment program in 2000. The sites are monitored together under an assessment program because they have similar hydrogeology and waste constituents and appear to have contaminated groundwater. Combining these cribs into one RCRA groundwater monitoring area saves sampling and analysis costs because the number of near-field wells is reduced. Many of the far-field wells that formerly were sampled annually are now sampled every 3 years. These wells mainly track the extent and flow rate of the extensive iodine-129, nitrate, and tritium plumes that typically change very little in a 3-year period.

During 2000, iodine-129, nitrate, and tritium continued to exceed interim drinking water standards or maximum contaminant levels in large areas downgradient of the cribs. Strontium-90, a beta emitter, and gross beta exceed the interim drinking water standards only in well 299-E17-14, which is near the 216-A-36B crib.

216-A-29 Ditch. This is an inactive earthen ditch ~2 kilometers (1.2 mile) long in the 200-East Area 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 RCRA 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.

This RCRA unit continued to be monitored under an interim status indicator evaluation program in 2000 and did not have an adverse impact on groundwater. Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. Average specific conductance values at downgradient wells 299-E25-35 and 299-E25-48 exceeded the critical mean value and were linked to increases in sulfate, nitrate, calcium, and sodium from upgradient sources. DOE informed the Washington State Department of Ecology of the exceedances. Because the ditch was not the cause, indicator evaluation monitoring continues.

216-B-3 Pond (B Pond). This former pond in the 200-East Area consisted of a main pond and three expansion ponds (216-B-3A, 216-B-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 1994, the main pond was filled with clean soil, and the expansion ponds were clean-closed (i.e., deemed free of dangerous waste and no longer regulated under RCRA). 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. In its later years, B Pond received non-dangerous, non-radioactive effluent primarily from the Plutonium-Uranium Extraction Plant and B Plant.

In 2000, groundwater monitoring at B Pond continued under an interim status indicator evaluation program. Groundwater beneath the site apparently was affected by tritium and nitrate from past discharges to B Pond. However, all replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during 2000.

216-B-63 Trench. This 200 East Area trench 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 raw water. Past releases to the trench also included sulfuric acid and sodium hydroxide solutions. Radioactive soil was dredged from the trench in August 1970, but no records exist of radioactive waste disposal to the trench.

In 2000, RCRA monitoring continued to indicate that no dangerous non-radioactive constituents from the site have entered groundwater. The well network was sampled twice for the indicator parameters pH, specific conductance, total organic carbon, and total organic halides. All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during 2000.

216-U-12 Crib. This crib in the 200-West Area received wastewater containing dangerous chemical waste and radionuclides from April 1960 until February 1988. It continued to be monitored under an interim status assessment program in 2000. Assessment monitoring began in 1993 because of high specific conductance in two downgradient wells. The crib will not receive additional effluent and is scheduled, according to provisions of the Hanford Site RCRA Permit (Ecology 1994), to be closed under RCRA final status regulations in 2005.

In 2000, network monitoring wells were sampled quarterly for constituents of interest. Based on the results of the assessment investigation (PNNL-11574), the site remains in interim status assessment monitoring because of continued elevated levels of nitrate and technetium-99. However, the objective of the assessment monitoring,

rather than delineating the existing plumes, is to 1) determine whether the flux of constituents into the groundwater is increasing, staying the same, or decreasing; 2) monitor the known constituents until a near-term interim corrective action is defined; and 3) monitor until a final status plan is implemented. Nitrate, which had a source at this crib, remained elevated above the 45-mg/L standard in downgradient wells in 2000. Nitrate and technetium-99 concentrations are decreasing in most of the wells.

Currently, the 216-U-12 crib is monitored by two downgradient wells. Declining water levels rendered the upgradient well dry in the past year; other downgradient wells went dry in 1999. The groundwater monitoring network requires upgrading to satisfy RCRA interim status monitoring requirements. The Washington State Department of Ecology and DOE annually negotiate installation of future monitoring wells under an Interim Milestone agreement (M-24).

216-S-10 Pond and Ditch. The facility consisted of an open, unlined ditch and an open, unlined percolation pond in the 200-West Area. 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 non-dangerous, unregulated wastewater from 1985 through 1991.

During 2000, this facility continued to be monitored semiannually under a RCRA interim status indicator evaluation program. Statistical evaluation of indicator parameter data from downgradient wells indicates that the site is not affecting groundwater quality.

Chromium, which was elevated above the 100-μg/L standard in the upgradient well since 1992, declined sharply in 2000, averaging less than 20 μg/L. Because the upgradient well is located adjacent to the 216-S-10 pond, it is unclear if the elevated chromium was from an upgradient source or from past discharges to the pond.

Currently, the 216-S-10 pond and ditch are monitored by only one upgradient well and two shallow downgradient wells because other wells have gone dry. The groundwater monitoring network requires upgrading to satisfy RCRA interim status requirements. At the current rate of water table decline, the downgradient wells are expected to go dry in 2001 and 2002. The Washington State Department of Ecology and DOE annually negotiate installation of future monitoring wells under an Interim Milestone agreement (M-24).

7.1.7.4 200 Areas Low-Level Burial Grounds

The low-level burial grounds are divided into five low-level waste management areas in the 200 Areas (see Figure 7.1.10). However, Low-Level Waste Management Area 5 has not been monitored for groundwater since 1996 because the site never received waste. The remaining low-level waste management areas are in the indicator parameter phase of RCRA groundwater monitoring.

Low-Level Waste Management Area 1. This waste management area in the 200-East Area consists of the 218-E-10 burial ground. 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.

Groundwater monitoring under interim status requirements continued at this RCRA site in 2000. Downgradient monitoring well 299-E33-34 continued to exceed the critical mean for specific conductance. This exceedance appears to be related to the nitrate plume and is not related to Low-Level Waste Management Area 1. DOE informed the Washington State Department of Ecology of a previous exceedance. Because no waste has been placed in the northern portion of this site and there is a

nitrate plume from an upgradient source, no further action is necessary.

Low-Level Waste Management Area 2. This waste management area in the 200-East Area 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.

This RCRA site continued in interim status indicator evaluation in 2000. Upgradient well 299-E34-7 exceeded the critical mean value for specific conductance. The major contributors to the increase are sulfate and calcium. The source of these constituents is not known. However, there is only 0.6 meter (2 feet) of water remaining in this well, which is completed at the top of basalt, and the increase may be related to the basalt chemistry. This well also exceeded the comparison value for total organic carbon in 2000. All results of volatile and semi-volatile organic analyses were less than detection limits except bis (2-ethylhexyl) phthalate at 1.7 μg/L. This does not explain the elevated total organic carbon. Additional investigations are planned.

Low-Level Waste Management Area 3. The 218-W-3A, 218-W-3AE, and 218-W-5 burial grounds in the 200-West Area make up this area. Burial ground 218-W-3A began accepting waste in 1970 and received primarily ion-exchange resins and failed equipment (e.g., tanks, pumps, ovens, agitators, heaters, hoods, vehicles, accessories). Burial ground 218-W-3AE began operating in 1981 and contains low-level and mixed waste, including rags, paper, rubber gloves, tools, and industrial waste. Burial ground 218-W-5 first received waste in 1986, and contains low-level and low-level-mixed waste, including lead bricks and shielding.

This site continued to be monitored under interim status indicator evaluation requirements in 2000. Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. The critical mean value for specific conductance was exceeded in samples collected from an upgradient well in 2000. The upward trend was noted and reported earlier, and is caused by increases in sulfate and nitrate from upgradient sources. Other contamination indicator parameters were not exceeded in any of the wells monitoring this waste management area.

Several of the groundwater monitoring wells are approaching the point where representative sampling will no longer be possible because of the declining water table. Replacement wells are proposed, but are subject to funding priorities and negotiations with the Washington State Department of Ecology.

Low-Level Waste Management Area 4. This area in the 200-West Area consists of the 218-W-4B and 218-W-4C burial grounds. Burial ground 218-W-4B first received waste in 1968 and contains mixed and retrievable transuranic waste in trenches and caissons. One caisson is believed to contain mixed waste. Waste was first deposited in burial ground 218-W-4C in 1978 and was classified as transuranic, mixed, or low-level and included contaminated soil, decommissioned equipment, and remote-handled transuranic waste.

Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. The critical mean value for total organic halides continued to be exceeded in one downgradient well in 2000. This well used to be an upgradient well, and the exceedance is believed to be caused by carbon tetrachloride from an upgradient source.

7.1.7.5 Liquid Effluent Retention Facility

This facility consists of three lined 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, tritium, strontium-90, ruthenium-106, and cesium-137.

This facility is subject to final status monitoring and is included in the Hanford Site RCRA Permit (Ecology 1994). Groundwater was monitored under the existing interim status plan in 2000 pending regulator approval. In 2000, groundwater monitoring indicated that no dangerous, non-radioactive constituents from the site have entered the groundwater. Specific conductance in two downgradient wells exceeded the critical mean value in 2000. DOE notified the Washington State Department of Ecology of a previous exceedance and submitted a groundwater quality assessment plan and report in 1999. The plan concluded that the Liquid Effluent Retention Facility was not the source of the high specific conductance and detection monitoring should continue.

In 2000, the Liquid Effluent Retention Facility was monitored by one upgradient and two downgradient wells because the other wells went dry in 1999. The water table is dropping below the top of the basalt in the area so there is virtually no unconfined aquifer beneath the facility. In January 2001, another downgradient well went dry and the Washington State Department of Ecology directed DOE to cease statistical evaluation of groundwater data.

7.1.7.6 316-5 Area Process Trenches

These two unlined trenches in the 300 Area were used for the disposal of liquid waste generated in the 300 Area, beginning in 1975, and received uranium and other radioactive and chemical constituents. From 1985 through 1991, the trenches received non-dangerous effluent, and all discharges ceased in 1991.

This site continued to be monitored with a final status corrective-action network in 2000. The objective of groundwater monitoring during the corrective-action period is to monitor the trend of the constituents of concern to determine if they are naturally attenuating, as expected by the CERCLA record of decision for the 300-FF-5 Operable Unit (Record of Decision 1996). A proposed groundwater monitoring plan for corrective action calls for samples from the same wells as in the compliance period, but with fewer independent samples from each well during each sampling period (i.e., four to one). Also, each well showing an exceedance of one of the constituents of concern will be sampled quarterly to better follow the trends of contaminant concentration. The other wells in the network will continue to be sampled semiannually. The proposed plan is being reviewed by the regulator. Until the proposed plan is implemented, the final status compliance monitoring program remains in effect. This plan calls for four independent groundwater samples from each network well (eight) during each semiannual sampling period.

In 2000, uranium and cis-1,2-dichloroethene continued to exceed concentration limits specified in the permit. Uranium and gross alpha exceeded maximum contaminant levels in one or more wells monitoring near the water table. Cis-1,2-dichloroethene exceeded standards in one downgradient well that monitors the base of the unconfined aquifer. DOE reported these data and other monitoring results to the Washington State Department of Ecology via semiannual letter reports.[b]

(b) Letter report, *Resource Conservation and Recovery Act (RCRA) Final Status Corrective Action Semiannual Reports*, from J. G. Morse, U.S. Department of Energy, Richland Operations Office, Richland, Washington, to J. Hedges, Washington State Department of Ecology, Kennewick, Washington, dated November 30, 2000.

7.1.7.7 Nonradioactive Dangerous Waste Landfill

The Nonradioactive Dangerous Waste Landfill (Central Landfill) in the 600 Area southeast of the 200-East Area received waste from 1975 through 1985 that included asbestos, miscellaneous laboratory waste, solvents, paints, sewage, acids, batteries, and mercury.

This site continued to be monitored under an interim status indicator evaluation program in 2000. Statistical evaluations indicated the site has not adversely affected groundwater quality. However, average values of specific conductance in three downgradient wells are increasing and approaching the critical mean.

7.2 Vadose Zone Characterization, Monitoring, and Technology Demonstrations

D. G. Horton

The vadose zone is the region between the ground surface and the top of the water table. Current waste management practices are approved by state and federal regulators and strive to protect to protect groundwater. However, radioactive and hazardous waste in the soil column from past intentional liquid waste disposals, unplanned leaks, solid waste burial grounds, and underground tanks at the Hanford Site are potential sources of continuing and future vadose zone and groundwater contamination. Subsurface source characterization and vadose zone monitoring, soil-vapor monitoring, sediment sampling and characterization, and vadose zone remediation were conducted in 2000 to better understand and characterize the spread of subsurface contamination. This section summarizes major findings from these efforts, focused primarily on vadose zone soil contamination associated with past operations including reactor operations, single-shell tank leaks, and liquid disposal to ground.

7.2.1 Vadose Zone Characterization

During 2000, one new characterization borehole was drilled and sampled in the SX single-shell tank farm, 200-West Area, to better understand sediment properties, contaminant distribution, and transport mechanisms operating in the vadose zone. Baseline spectral gamma logging of selected wells in single-shell tank farms also was completed. The logging was follow-up to the baseline characterization effort that occurred in all single-shell tank farms between 1995 and 1999.

Semi-quantitative mineral analyses were completed of samples from one borehole in the SX tank farm and four samples designed to be "standards" for the Hanford and Ringold Formations at the Hanford Site. Such analyses have not been done previously at the Hanford Site and will help interpret mechanisms of contaminant transport in the vadose zone.

In 2000, DOE's Environmental Management Science Program began a 3-year study of clastic dikes and their influence on movement of subsurface contamination. The study is designed to describe the geometric and hydrologic properties of clastic dikes and extrapolate those properties to the subsurface of waste disposal and storage sites.

Vadose zone characterization activities were conducted at four sites in the 200 Areas to support remediation of sites that received cooling water waste (200-CW-1 Operable Unit) and at one site in the 100-DR Area to support chromate remediation using in situ gaseous reduction technology.

Finally, four comprehensive data packages were published in 2000 to support the 2005 Immobilized Low-Activity Waste Performance Assessment. Those data packages describe the current knowledge about the vadose zone geology, geochemistry, hydrology, and recharge at the proposed Immobilized Low-Activity Waste Disposal Facility site in south-central 200-East Area.

7.2.1.1 River Protection Project Vadose Zone Characterization Activities at Single-Shell Tanks

D. A. Myers

The River Protection Project operated by CH2M HILL Hanford Group conducted a series of investigations at the S and SX tank farms in the 200-West Area during the year 2000.

In January and February, a cone penetrometer was used adjacent to tanks S-102 and S-104. In addition to standard measurements, the cone penetrometer tools included a sodium-iodide spectral gamma detector. Samples were obtained and analyzed from zones identified by the spectral gamma detector as containing significant contamination. The cone penetrometer work identified a gamma peak above the base of tank S-104 and below the elevation of several spare inlet ports that had been built in the tank. Tank S-104 had been overfilled during its operating history, and the possibility exists that losses from this tank may have been through the spare inlet ports. The cone penetrometer work lends support to this hypothesis, though it does not eliminate the possibility that the tank itself may have developed a leak.

The major activity conducted in and near the Waste Management Area S-SX was the construction of two slant boreholes that were extended into the lower Hanford formation or Plio-Pleistocene Unit. Both boreholes were drilled 30 degrees from vertical. The first of these boreholes was constructed south of the SX tank farm as a demonstration of the new drilling and sampling approach and to train tank farm personnel before deploying the system inside the farm. Upon completion of the demonstration and training effort, the rig was set up inside the farm for the second hole (Figure 7.2.1). During the test

Figure 7.2.1. Slant Borehole Drilling Rig Set Up in the 200-West Area SX Tank Farm

and demonstration, ground acceleration measurements were taken to provide data for analysis of the drilling technique's impact on the sidewalls and bases of the tanks.

The second borehole was aligned to pass beneath tank SX-108, through a zone of highly contaminated soil and "bottom-out" in the Plio-Pleistocene Unit at a vertical depth of 45 meters (148 feet), ~3 meters (10 feet) due south of the tank center. Figure 7.2.2 shows the projection of the borehole relative to the geologic formations and the tank. Samples were successfully collected from 16 of 17 preselected locations. One sample was lost, probably due to the coarse nature and dryness of the soil that allowed it to fall from the sampler. All other samples were sent for laboratory analysis; the complete results of those analyses will be available in 2001 and will be summarized in the next annual report.

Upon completion, the borehole was geophysically logged and then decommissioned by extracting the casing and filling the borehole with bentonite. Both spectral gamma and downhole temperature logs were obtained, and Figure 7.2.3 shows the logging results. The figure shows good correlation between the available laboratory results and the geophysical logs. Samples from this borehole have provided the highest levels of soil contaminant concentrations recovered from Hanford Site tank farms to date.

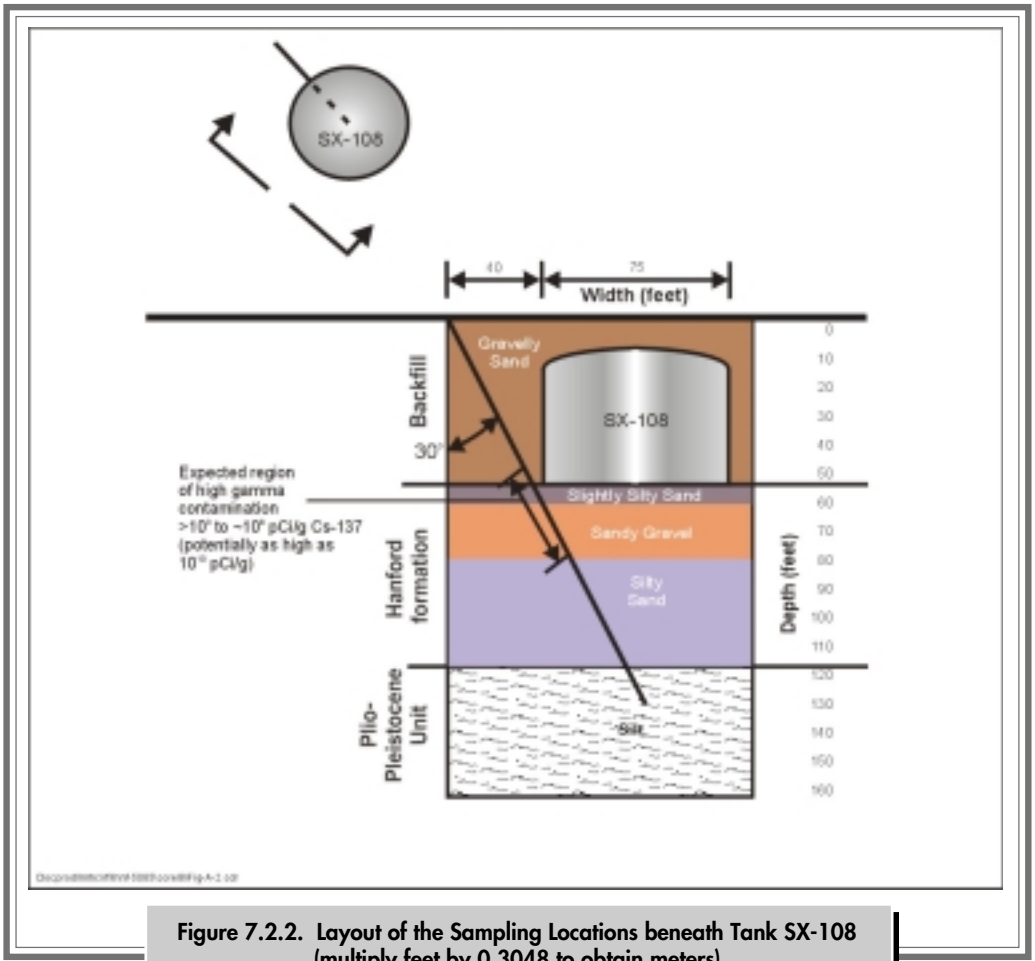

Figure 7.2.2. Layout of the Sampling Locations beneath Tank SX-108 (multiply feet by 0.3048 to obtain meters)

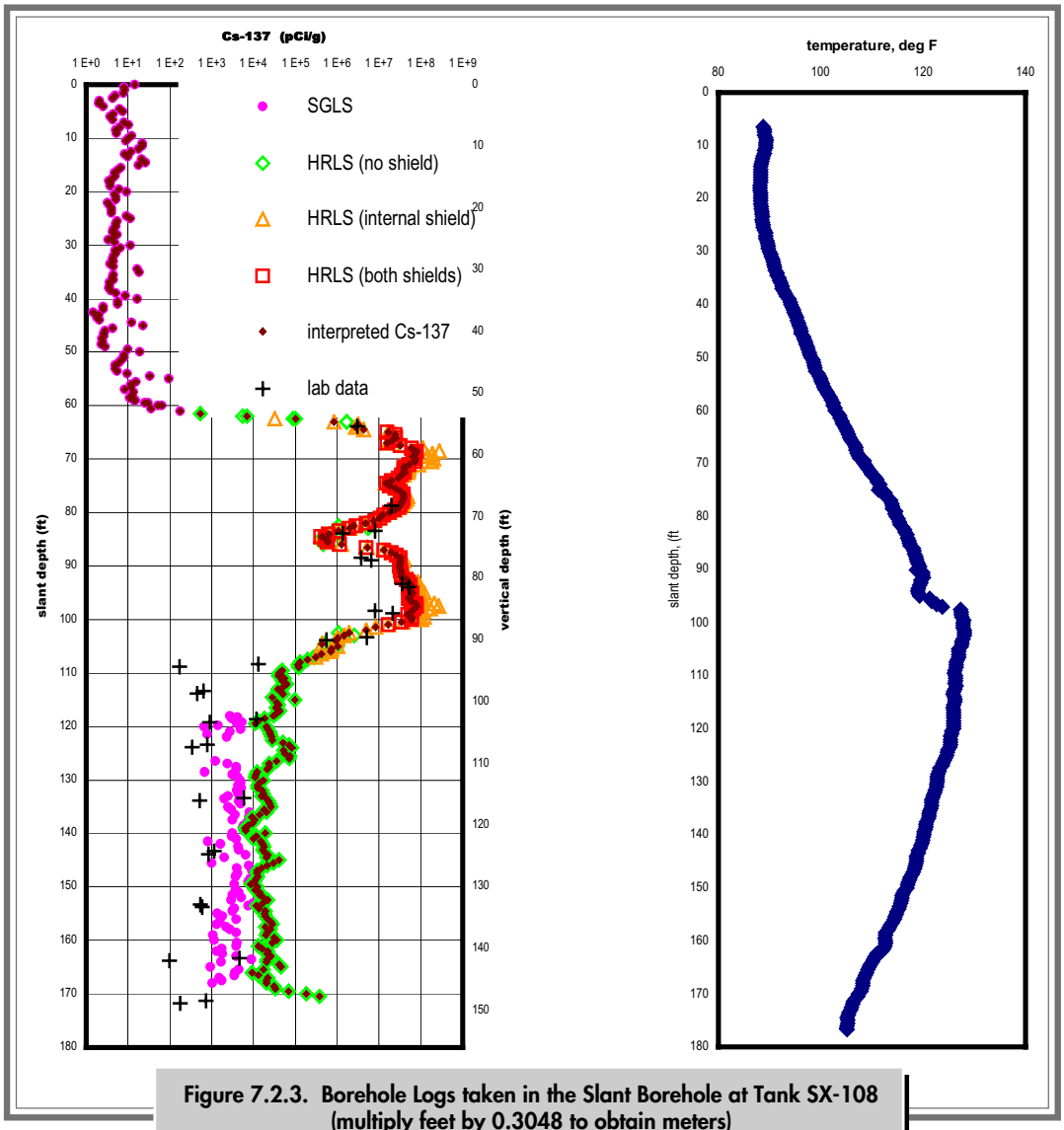

Figure 7.2.3. Borehole Logs taken in the Slant Borehole at Tank SX-108 (multiply feet by 0.3048 to obtain meters)

7.2.1.2 Mineral Characterization of Borehole 41-09-39 at Single-Shell Tank SX-109

H. T. Schaef, D. G. Horton, and D. A. Myers

Borehole 41-09-39 is located adjacent to single-shell tank SX-109 in the SX tank farm in the Hanford Site's 200-West Area. The borehole was originally constructed in 1996 to determine the distribution of cesium-137 at depths of 24 to 40 meters (79 to 131 feet) below ground surface. The borehole was deepened in 1997 and decommissioned in 1999. As part of the decommissioning effort, sidewall samples were collected at previously unsampled portions of the borehole and submitted for chemical, radiological, and mineralogical analyses.

Summaries of the results of chemical and radiological testing on samples from borehole 41-09-39 were reported in PNNL-13230. This section summarizes the results of mineralogical testing conducted in

2000. These analyses are the first reported semi-quantitative mineral abundances from radionuclide contaminated sediment at the Hanford Site. The results will help interpret chemical reactions between the sediment and contaminants and will help understand the distribution of radiocontaminants in the subsurface. X-ray diffraction analyses were done on five samples from the Hanford formation. Semi-quantitative mineral abundances were determined for both the bulk sample and the <2 μm (8×10^{-5} in.) size fraction.

Results for bulk samples show that the sediment is about 35 to 50 wt.% quartz and about 25 to 55 wt.% feldspars with lesser amounts of mica and chlorite. Plagioclase feldspar is 2 to 10 times more abundant than is potassium feldspar. Minor amounts of amphibole and calcite also were detected in the bulk sediment. The bulk mineralogy determined by this study is similar to that determined by Tallman et al. (RHO-ST-23) for uncontaminated samples from the southern part of 200-West Area.

The <2 μm (8×10^{-5} in.) size fractions are dominated by four clay minerals: illite, smectite, chlorite, and kaolinite. Minor amounts of quartz and feldspar and trace amounts of amphibole were identified in some samples (abundances of amphibole were not determined). Overall, illite is the dominant mineral in the <2 μm fraction ranging from 20 to 35 wt.% of the samples. Smectite ranged from 5 wt.% to as much as 20 wt.% of the samples and chlorite made up between about 10 and 30 wt.% of the samples. Minor amounts of kaolinite (<10 wt.%) were detected in all samples and quartz and feldspars made up about 5 to 20 wt.%.

7.2.1.3 Baseline Spectral Gamma-Ray Logging at Tank Farms

P. D. Henwood and R. G. McCain

Since 1995, baseline vadose zone characterization in single-shell tank farms has been conducted by the DOE Grand Junction Office (DOE-GJO) and its subcontractor, MACTEC-ERS. By the end of fiscal year 1999, the baseline data had been reported in tank summary data reports for all 133 single-shell tanks with capacities of 2 million liters (528,344 gallons) or greater (100-series tanks), and in reports for each of the 12 single-shell tank farms. Since the original baseline data were acquired, additional data have been collected, new analysis techniques have been developed, and additional insights into the nature and distribution of contamination in the vadose zone have been gained. An addendum to each tank farm report was prepared during fiscal year 2000 to present these additional data and to report revised interpretations of subsurface contaminant distribution. With submittal of these reports, the baseline characterization was completed. Results of the Tank Farms Vadose Zone Characterization Program are posted on the Internet at http://www.doegjpo.com/programs/hanf/HTFVZ.html.

Spectral Gamma Logging Methods

Log data in the form of gamma spectra were collected using a high-purity germanium semiconductor detector. This combination of detector and logging truck is referred to as the spectral gamma logging system and is able to quantify radionuclide concentrations from background levels up to several thousand picocuries per gram. Frequently, zones of more intense radiation are encountered in which the detector becomes saturated and ineffective. In order to provide data in these highly contaminated zones, the high-rate logging system, was developed and deployed.

The high-rate logging system uses the same logging trucks and electronics system as the spectral gamma logging system but has a much smaller detector and two optional shields that allow measurement of cesium-137 concentrations up to about 100 million pCi/g. High-rate logging operations were completed in 2000. The spectral gamma logging system and high-rate logging system data were collected in accordance with procedures documented in

MAC-VZCP 1.7.10-1 and analyzed in accordance with MAC-VZCP 1.7.9.

Additional Data and Analysis

Logging was conducted using the high-rate logging system in all borehole intervals where the original baseline spectral gamma logging system indicated zones of detector saturation resulting from very high gamma contamination levels. Data from both the spectral gamma logging system and the high-rate logging system were used together so that the final logs were a composite of the two.

Other data collected since the original tank farm reports were issued include repeat logging measurements acquired up to 4 years after the initial baseline data were collected. Boreholes were selected for repeat logging primarily to check for possible contaminant movement over time. To compare the original baseline and the repeat logging data, baseline data were adjusted for radionuclide decay. Continued movement of radionuclides was detected in some boreholes.

A data analysis method known as shape factor analysis has been in use since the first tank farm report was issued. This method is used to discriminate among contamination on the inside or outside of the borehole casing, uniformly distributed contamination in the formation, or a discrete contaminant source at a distance from a borehole. Depth intervals in which contamination was localized to the borehole were removed from the data sets used to create visualizations of subsurface contamination. Removal of these intervals led to significant modifications to the original visualizations of contaminant distribution presented in the tank farm reports. Addenda were issued during 2000 for each tank farm report that presented revised visualizations based on results of shape factor analysis, repeat logging, high-rate logging, and other information.

Antimony-125, cesium-137, cobalt-60, europium-152, europium-154, uranium-235, uranium-238, and possibly strontium-90 have been detected in tank farms using the spectral gamma logging systems. The visualizations illustrate how gamma-emitting contaminants that have leaked from tanks may be distributed in the vadose zone sediment. A valuable attribute of the visualizations is that they can be used to define areas of concern in which to focus future characterization, monitoring, and remediation efforts. Figure 7.2.4 presents an example of a revised data visualization that includes high-rate logging data and excludes contamination localized to a borehole.

Results

Results of baseline logging conducted from 1995 to 1999 for single-shell tanks were reported in prior Hanford Site Environmental Reports (e.g., PNNL-13230 and PNNL-12088). Results also were reported in individual tank summary data reports and tank farm reports (http://www.doegjpo.com/programs/hanf/HTFVZ.html). Conclusions reported in those documents have not changed substantially as a result of incorporating shape factor analysis and high-rate logging data. Inclusion of the high-rate logging data in creating the three-dimensional visualizations had a relatively minor impact on the interpreted spatial distribution of contaminant plumes, but had a substantial impact on the estimated total curie activity within the plume volume. Although evaluation of shape factor results and other data provided a justification for eliminating many contamination intervals in some boreholes, most intervals of significant contamination remain and only relatively low-concentration "ghost" plumes were eliminated from the visualizations. Table 7.2.1 summarizes the results of the tank farm baseline characterization effort.

High-rate logging data were collected in 51 boreholes in the Hanford Site tank farms. Of these 51 boreholes, 39 exhibited high gamma contamination zones below the operating level of the tanks. Contamination in the remaining 12 boreholes was at depths above the tank operating level and was typically associated with contamination related to tank farm infrastructure, such as buried transfer lines, that are not related to tank leaks. The maximum

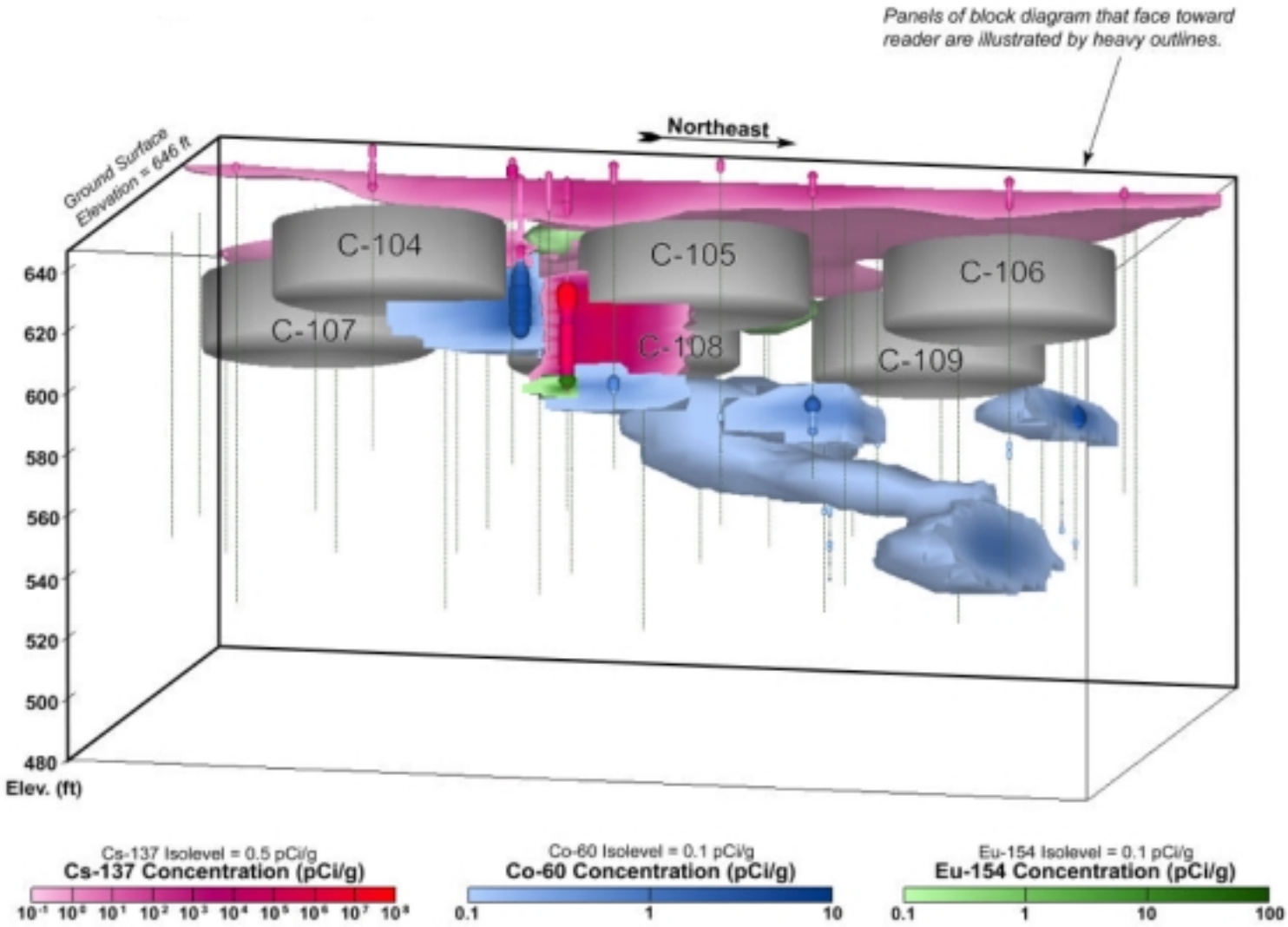

Figure 7.2.4. Example of a Revised Visualization from the C Tank Farm in the 200-East Area (multiply feet by 0.3048 to obtain meters)

Table 7.2.1. Summary of Hanford Site Tank Farm Baseline Geophysical Logging Characterization Results

Farm	Plumes Detected[a]	Predominant Gamma-Emitting Radionuclides	Maximum Concentration (pCi/g)[b]	Maximum Depth (m)[c]	Movement Detected	Comment
A	1	^{60}Co, ^{154}Eu, ^{137}Cs	10^2 (^{60}Co)	25.9	No	Historical plumes identified at 24.4 m.
AX	1	^{137}Cs	10^2 (^{137}Cs)	12.2	No	Historical plumes identified at 21.3 m.
B	6	^{60}Co, ^{154}Eu, ^{137}Cs	10^7 (^{137}Cs)	32.6	No	Possible ^{90}Sr plume identified.
BX	5	^{60}Co, ^{137}Cs, ^{154}Eu, ^{125}Sb, ^{235}U, ^{238}U	10^7 (^{137}Cs)	45.7	Yes	Plume may reach groundwater (70.1 m).
BY	5	^{60}Co, ^{137}Cs, ^{125}Sb	20 (^{60}Co)	42.7	Yes	Plume may reach groundwater (76.2 m).
C	5	^{60}Co, ^{154}Eu, ^{137}Cs	10^7 (^{137}Cs)	38.1	Yes	Boreholes by assumed leakers C-101, -110, and -111 show no current contamination. Downward ^{60}Co movement detected near C-106.
S	3	^{60}Co, ^{137}Cs	10^6 (^{137}Cs)	21.3	No	^{99}Tc detected in groundwater (PNNL-12114).
SX	5	^{60}Co, ^{137}Cs	10^8 (^{137}Cs)	41.1	Yes	Tank SX-102 may be a leaker; possible ^{90}Sr plume identified. ^{99}Tc detected in groundwater (PNNL-12114).
T	6	^{60}Co, ^{154}Eu, ^{94}Nb, ^{137}Cs, ^{126}Sn, ^{125}Sb	10^7 (^{137}Cs)	37.5	Yes	Plumes from tank waste and adjacent waste sites may have commingled.
TX	4	^{60}Co, ^{154}Eu, ^{137}Cs, ^{235}U, ^{238}U, ^{125}Sb	10^4 (^{137}Cs)	30.5	Yes	Possible ^{90}Sr plume identified.
TY	3	^{60}Co, ^{137}Cs	10^7 (^{137}Cs)	45.1	Yes	Plume may reach groundwater (67.1 m).
U	4	^{60}Co, ^{137}Cs ^{235}U, ^{238}U	10^7 (^{137}Cs)	30.5	Yes	Infiltrating surface H_2O may be remobilizing tank waste (PNNL-13282).

(a) Approximate number of plumes identified below the operating level of a tank.
(b) Approximate highest concentration observed of all measured radionuclides and may not be the radionuclide that is most pervasive.
(c) In some cases, the maximum depth is limited by the depth of the borehole and the vertical extent of contamination is not fully defined.

concentration measured in any zone was about 100 million pCi/g. The acquisition of high-rate logging data completed the baseline characterization of tank farms and allowed determination of maximum concentrations in contamination plumes. This capability provides a basis on which to estimate the volume of contaminated soil and contaminant inventory in the vadose zone. It also provides a method for future quantitative comparisons of contaminant movement in high gamma contamination zones by repeated logging through time.

Repeat log data were collected with the spectral gamma logging system in all tank farms from selected depth intervals in 88 boreholes. The log intervals measured in 80 of the boreholes were below the operating level of the tanks. Data acquired in 22 borehole intervals below the operating levels of the tanks indicated possible concentration increases that would suggest the possibility of continued contaminant movement through the vadose zone from tanks that had leaked in the past.

7.2.1.4 Hydrologic Influence of Clastic Dikes on Vadose Zone Transport

C. J. Murray, D. G. Horton, G. W. Gee, and A. L. Ward

A 3-year study of clastic dikes and their influence on vertical movement of moisture and contaminants in the vadose zone began in fiscal year 2000. The goal is to describe the geometry and hydrologic properties of clastic dikes and dike networks and extrapolate those properties to the vadose zone beneath waste storage and disposal facilities. Clastic dikes are potentially important subsurface features because, depending on their features, they may enhance or inhibit movement of contaminants to groundwater.

Clastic dikes are common sedimentary structures in the vadose zone at the Hanford Site (BHI-01103). The dikes consist of vertical to subvertical structures that are often contorted and irregular, and cross-cut the normal subhorizontal sand and silt beds of the Hanford formation (Figure 7.2.5). The dikes vary in width from less than 1 centimeter (0.4 inch) to more than 2 meters (6.6 feet) and have vertical extents that range from less than 1 meter (3.3 feet) to more than 50 meters (164 feet), with a large number greater than 20 meters (66 feet). Previous investigators have proposed that the dikes may provide a preferential path for contaminated water leaking from waste tanks to move through the thick unsaturated zone to the unconfined aquifer. However, there is insufficient evidence to determine if that speculation is accurate.

In 2000, the project used remote sensing and ground-penetrating radar surveys to describe the large-scale distribution of the clastic dikes along Army Loop Road in the 600 Area and at the 216-S-16 pond near the 200-West Area. Figure 7.2.6 shows the dikes at the two sites as mapped into a Geographic Information System from air photographs. The Geographic Information System then was used to extract the lengths, area of the polygons, and azimuth of the dikes and simple statistical analyses were made. The mean length of 3,835 dikes is 62 meters (203 feet), and the average width of the surface expression of 58 dikes is just over 2 meters (6.6 feet). Spatial analysis of 3835 dikes shows a slight preferential orientation to the dikes in the network, with many of the dikes occurring in two conjugate sets.

Surface ground-penetrating radar surveys were conducted at three areas: square grid surveys at the Army Loop Road site and at the 216-S-16 pond, and a 6.9-kilometer (4.3-mile) traverse in the 600 Area (see Figure 7.2.6). The surveys were to aid mapping the dikes and to detect smaller dikes not visible on air photos or the ground surface. Figures 7.2.7 and 7.2.8 show examples from the ground-penetrating radar survey at Army Loop Road. Figure 7.2.7 shows four northeast-southwest profiles. The white area at ~30 meters (98 feet) distance in the northeast-southwest direction on each traverse is a clastic dike.

Figure 7.2.5. Photograph of Clastic Dikes in the Hanford Formation at the Environmental Restoration Disposal Facility, 200-West Area (from BHI-00230)

Figure 7.2.6. Distribution of Clastic Dikes at the Army Loop Road Site and the 216-S-16 Pond

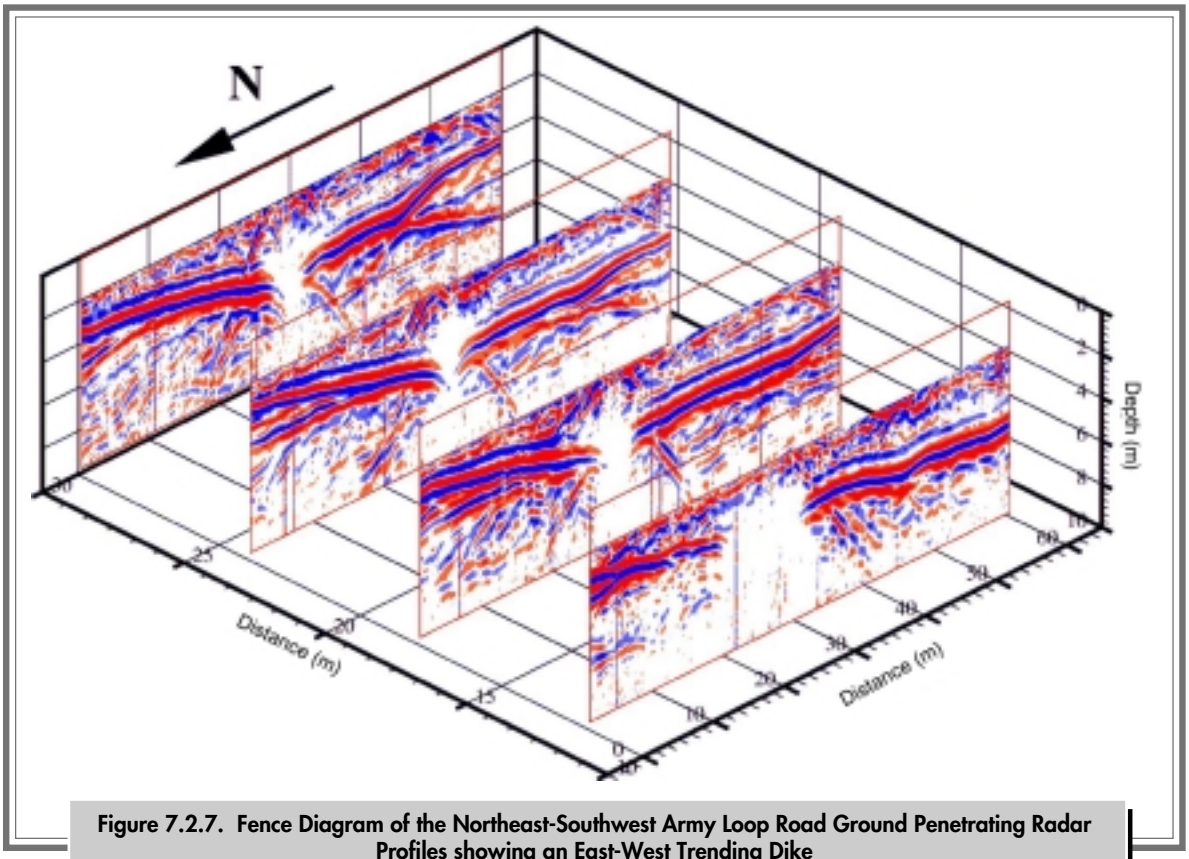

Figure 7.2.7. Fence Diagram of the Northeast-Southwest Army Loop Road Ground Penetrating Radar Profiles showing an East-West Trending Dike

Figure 7.2.8 is a three-dimensional view of the same area. The white area along the plot's surface corresponds to the subsurface expression of a clastic dike. A second dike can be seen at ~10 meters (33 feet) on the east-west face of the plot. The second dike intersects the first dike near the center of the diagram.

The ground-penetrating radar survey and the air photo and field mapping were used to select a site to trench across a clastic dike. In August 2000, a clastic dike at the 216-S-16 pond was trenched with a backhoe to a depth of ~3.5 meters (11.5 feet) (Figure 7.2.9). The exposed clastic dike is in the sand-dominated facies of the Hanford formation. The dike is ~0.7 meter (2.3 feet) thick at the bottom of the trench but becomes extremely narrow (~8 to 10 centimeters [3.2 to 3.9 inches]) within ~1 meter (3.3 feet) of the surface.

In the exposure of the bottom half of the trench, the host material is very different on each side of the dike (see Figure 7.2.9). The material to the west of the dike (to the left in Figure 7.2.9) is medium to coarse-grained plane laminated sand containing some silt and sand rip-up clasts. The material to the east of the dike consists of finer grained, silty fine to medium sand. In addition, a clastic sill (a structure similar to a clastic dike but concordant with horizontal bedding) is exposed east of the dike, near the base of the trench. The sill is seen in Figure 7.2.9 as the ~8-centimeters-thick (3.2-inches-thick), fine-grained unit to the right of the dike in the lower part of the trench. The heterogeneities within both the host sediment and within the dike complicate comparison of physical property data from samples of dike and host.

The trench was terraced at four levels. The dike and host sediment were characterized by air permeability measurements and infrared imagining on each level except the first. In addition, samples

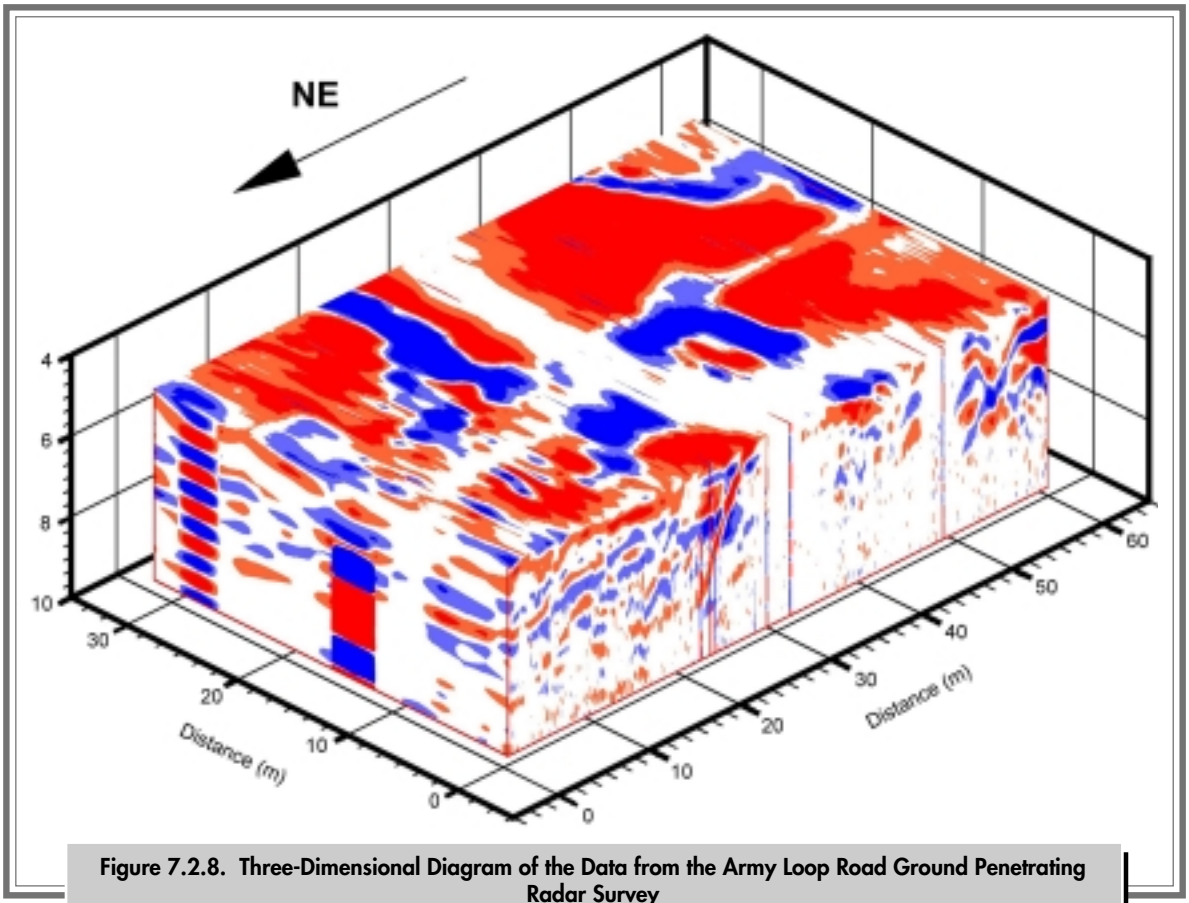

Figure 7.2.8. Three-Dimensional Diagram of the Data from the Army Loop Road Ground Penetrating Radar Survey

were taken for moisture analyses, grain size distribution, and mineralogy (x-ray diffraction).

Moisture content was determined from several samples collected in the trench. As expected, the moisture content was higher in the dike than in the host sediment. The average moisture content of dike samples was about 15 volume percent whereas that for the sediment was about 2.5 volume percent. Nineteen samples were submitted for analysis of particle size distribution. In general, the samples from the dike tended to be much finer grained than did samples of host sediment.

Figure 7.2.10 shows two composite photographs of the lowest level in the trench. The lower photo is a normal photograph and the upper photo is an infrared photograph. The contrast in the infrared photo is due to variation in the moisture content of the sediment; darker colors indicate more moisture. The dark vertical band on the left side of the infrared photo is the clastic dike and the dark horizontal band is the clastic sill. The photo shows that clastic dikes tend to hold more moisture than the surrounding host sediment.

Several hundred air permeability measurements were obtained from the exposures in the trench. Air permeability of the dike ranged from about 0.025 to 0.6 darcy and averaged about 0.2 darcy. (A darcy is a unit of permeability and is defined as the permeability that will lead to a discharge of 1 cm/sec.) The host sediment had a slightly higher permeability ranging from about 0.7 to 1.12 darcies with an average of 0.9 darcy. The dike and sill exposed in the trench tend to be finer-grained than the host material and, therefore, have a higher moisture content and lower permeability than the host material.

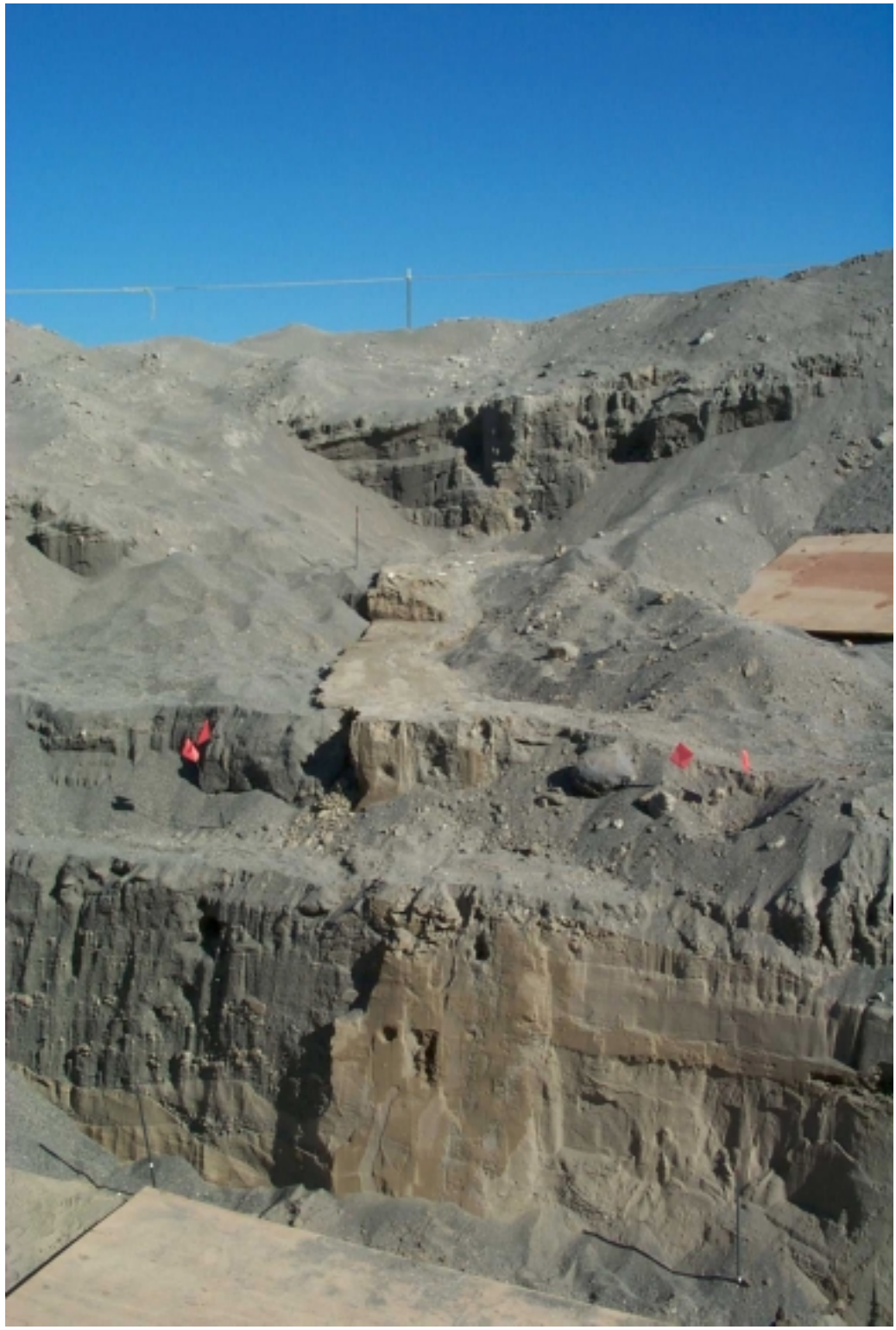

Figure 7.2.9. Clastic Dike Exposed in Trench at 216-S-16 Pond. The dike is approximately 0.7 meter (2.3 feet) wide at the bottom of the trench.

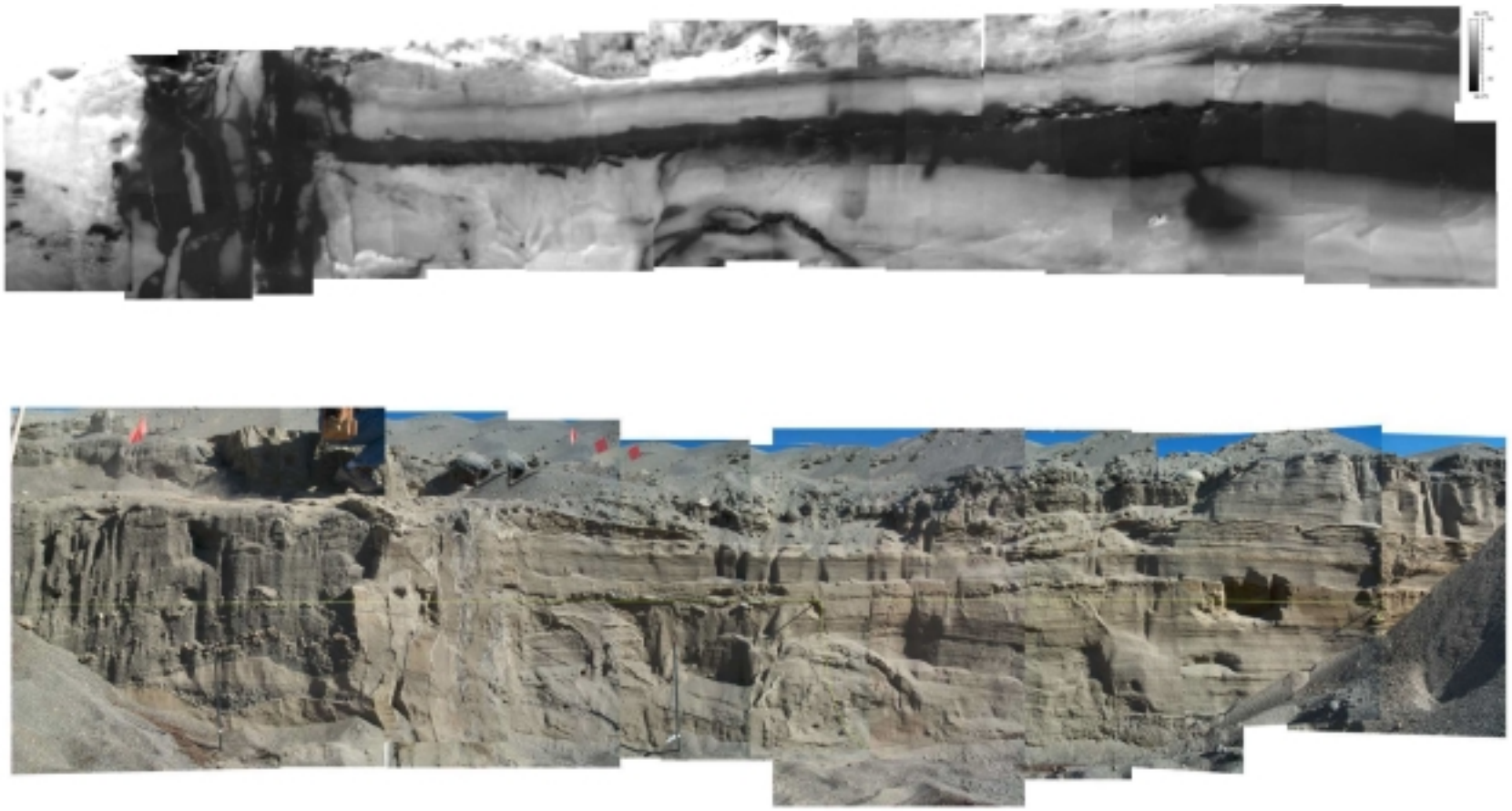

Figure 7.2.10. Composite Photograph of the Lower Part of the Trench at the 216-S-Pond. The upper photo is an infrared image and the lower photo is a normal photograph.

Samples were collected from the dike and host sediment to compare the mineralogy and grain size distribution between the dike and host sediment. Qualitative x-ray diffraction analysis of 21 samples showed that the mineral composition of both the dike and the host sediment were similar.

In addition to the above tests, drip-irrigation and dye-tracer studies were done at the excavation. A drip irrigation system with lines spaced ~5 centimeters (2 inches) apart was used to uniformly deliver known amounts of water. A vertical and horizontal array of probes was used to measure moisture flow. Also, soil-water pressure head and field-saturated conductivity were monitored.

Figure 7.2.11 shows an example of the water content for three different sediment materials. The data show that the fine-grained material of the dike had the highest water content whereas the coarse-grained host sediment west of the dike (to the left on Figure 7.2.9) had the lowest water content.

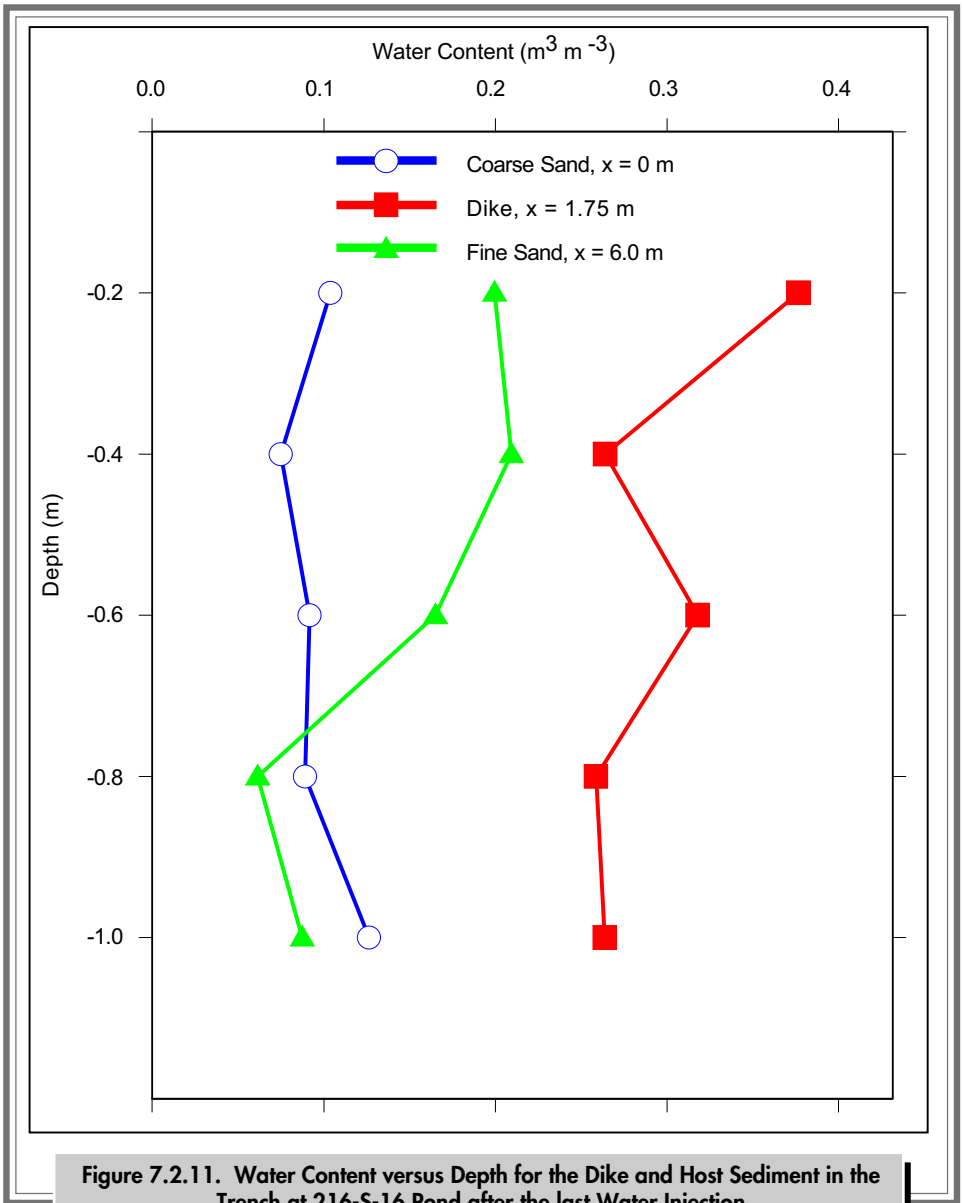

Figure 7.2.11. Water Content versus Depth for the Dike and Host Sediment in the Trench at 216-S-16 Pond after the last Water Injection

The finer-grained host material, to the east of the dike, had intermediate water content.

There were five injections of water during the experiment totaling 738 liters (195 gallons). Figure 7.2.12 shows the distribution of soil moisture three days after the first injection. The figure shows that the wetting front appears deeper in the dike than in the relatively coarser grained host sediment. This is, in part, due to capillary wicking of the finer sediment in the dike. The water was applied so that the soil remained unsaturated; therefore, capillary wicking was quite important. After nearly a week, the entire exposed face on the west of the dike (to the left on Figure 7.2.12) was visibly wet to a depth of greater than 1 meter (3.3 feet), whereas on the east side, the sediment appeared to be uniformly wet to a depth of ~75 centimeters (30 inches), or ~20 centimeters (8 inches) below the bottom of the horizontal clastic sill. This suggests that clastic sills retard vertical movement of moisture.

Brilliant Blue dye was mixed with the water for the last injection. Figure 7.2.13 shows the distribution of dye 1 day after the dye injection and 8 days after the start of the first injection. The dye injection preferentially infiltrates the coarser-grained parts of the dike and the coarse-grained host sediment. The dye trace results suggest that clastic dikes containing fine sediment may actually retard vertical flow rather than act as conduits to fluids applied at the upper surface of the dike. Also, it suggests that such features may act as cutoff walls, limiting the spread of fluids, which otherwise could move significant distances laterally in response to large scale features such as graded horizontal layering, typical of most Hanford sediment.

The trench and dike studies completed in fiscal year 2000 are preliminary tests to prepare for larger scale studies to be done in fiscal year 2001. The main test to be done in the future is a large-scale infiltration test. The infiltration test and geostatistical

Figure 7.2.12. Distribution of Soil Moisture Three Days after the First Injection of Water for the Infiltration Experiment at the 216-S-16 Pond

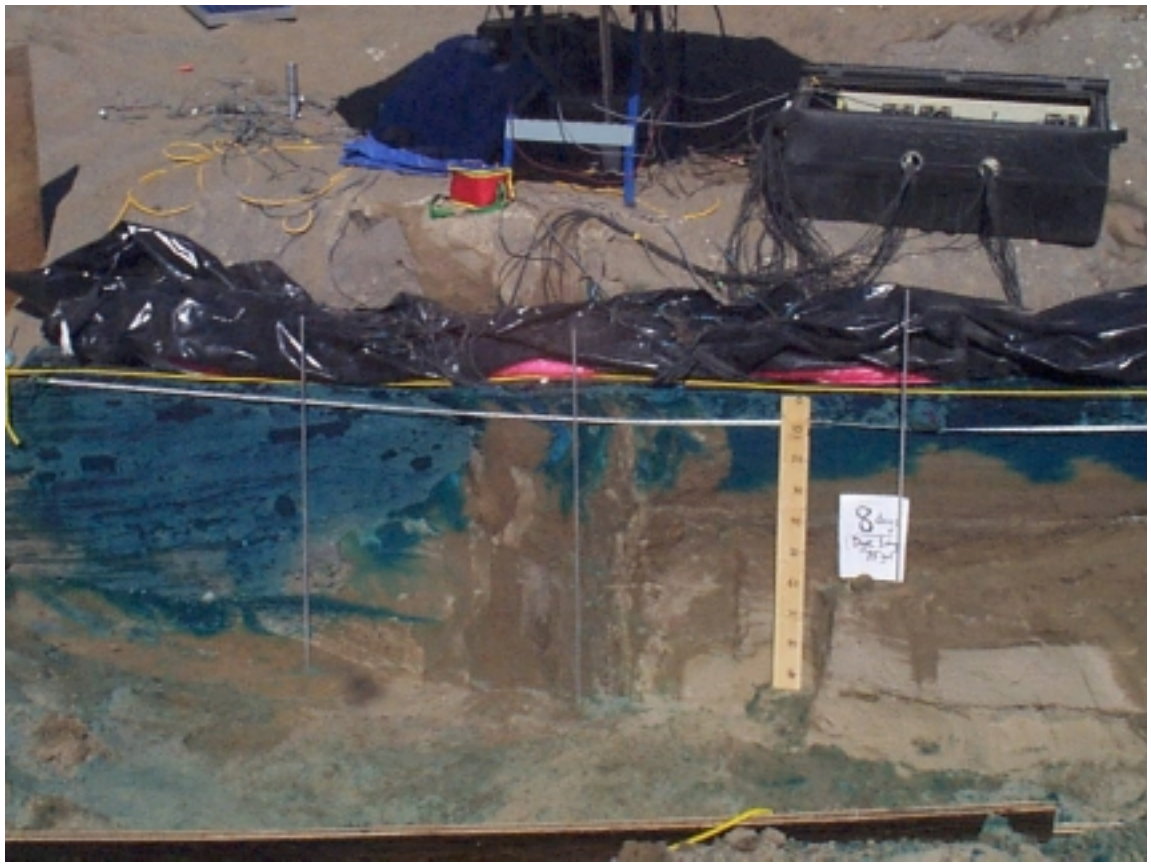

Figure 7.2.13. Dye and Water Distribution in Clastic Dike and Adjacent Host Sediment 1 Day after Dye Injection and 8 Days after the Start of the First Injection

techniques will be used to integrate all data and construct quantitative hydrologic models of the dike and enclosing sediment.

7.2.1.5 Characterization of the 183-DR Site to Support In Situ Gaseous Reduction Demonstration

E. C. Thornton, T. J Gilmore, K. B. Olsen, R. Schalla, and K. J. Cantrell

In 2000, both field and laboratory investigations were conducted to support an in situ gaseous reduction technology demonstration in the 100-DR Area. In situ gaseous reduction technology is being developed for remediation of hexavalent chromium at soil waste sites. The technology involves injecting a mixture of hydrogen sulfide gas mixed with nitrogen or air into chromate contaminated soil through a borehole. The mixture is drawn through the soil by a vacuum applied to extraction wells located around the injection well. Hexavalent chromium is reduced to the trivalent oxidation state as the gas mixture contacts the contaminated soil. The result is immobilization and detoxification of the chromium.

A large plume of groundwater contaminated with chromate exists at the former 183-DR water treatment facility in the 100-DR Area. The shape of the plume suggests that the source is the 183-DR site. If a vadose zone source of hexavalent chromium can be identified and treated, the groundwater plume will eventually dissipate.

Two trenches were excavated and two boreholes drilled to evaluate the distribution of hexavalent chromium in the vadose zone at the former 183-DR water treatment facility. One borehole was drilled to a depth of 30.7 meters (100 feet) and the second to 26.3 meters (86 feet). The deeper borehole was completed as a groundwater monitoring well. Essentially no significant chromium contamination was found in samples from the two boreholes.

In addition to the borehole samples, fifty samples were collected from the trenches and were analyzed for hexavalent chromium. Generally, no significant chromium concentrations were detected.

Laboratory Treatment Testing

Because field characterization at the 183-DR site did not locate a vadose zone source of hexavalent chromium, it is not possible to proceed with an in situ gaseous reduction demonstration at this time. Such a demonstration awaits the discovery of a vadose zone source of hexavalent chromium contamination in the Hanford Site 100 Areas.

7.2.1.6 Characterization at 200-CW-1 Operable Unit

C. S. Cearlock, K. M. Singleton, M. E. Todd, and D. B. Barnett

Bechtel Hanford, Inc. and CH2M HILL Hanford, Inc. characterized the contaminant distribution at four inactive waste sites in 2000 as part of the remedial investigation for the 200-CW-1 Operable Unit (BHI-01367). The waste sites were 216-B-2-2 ditch, 216-B-3-3 ditch, 216-B-3 pond (Main B Pond), and 216-A-25 pond (Gable Mountain Pond), which are all in or near the 200-East Area. All four ditches and ponds are no longer used and have been backfilled. Characterization was accomplished by geologic and geophysical logging, analysis of soil physical properties, and sampling and analysis for chemical and radiochemical constituents. The data collected will be used to evaluate remedial actions for 24 other analogous sites. This section summarizes the results of the study, which showed no immediate threat to groundwater. A complete description of characterization activities can be found in BHI-01367.

Samples were collected for laboratory analyses from 29 test pits and two boreholes. Two hundred and ten samples were collected from the test pits including 38 quality control samples.

Boreholes were drilled by cable tool and sampled by split spoon methods. Twenty-five samples were collected from the boreholes including eight quality control samples.

Borehole geophysical logging was performed on two new boreholes (B8757 and 699-43-44) and three existing groundwater monitoring wells (699-53-47A, 699-54-49, and 699-55-50) adjacent to Gable Mountain Pond. Spectral gamma and neutron-neutron moisture surveys were conducted in new boreholes drilled through B Pond and Gable Mountain Pond. Only spectral gamma surveys were performed in existing wells. Small-diameter geophysical logging was also conducted at B Pond and the 216-B-2-2 Ditch using the Geoprobe™.[a] Details of this investigation are presented in BHI-01352 and summarized in Section 7.2.3.2 of this report.

Several metals and anions were found to exceed background levels but most were well below *Model Toxics Control Act* (WAC 173-340) cleanup levels for direct contract. With several exceptions, there were variations in spatial distributions of contaminants with respect to position in the ponds and ditches. As might be expected, higher concentrations tended to be found in the interior of ponds and at the head end of ditches. Also, the highest concentrations of contaminants were in the pond and ditch bottom sediment and concentrations tended to decrease rapidly with depth. Details are provided in BHI-01367 and summarized in the following sections.

(a) Geoprobe is a registered trademark of Geoprobe Systems, Salinas, Kansas.

Gable Mountain Pond

Gable Mountain Pond was a 28.7-hectare (70-acre) natural depression south of Gable Mountain. Gable Mountain Pond routinely received cooling water and other low-level radioactive effluent from several facilities between 1957 and 1987 (DOE/RL-99-07). The pond received 307 billion liters (81 billion gallons) of liquid waste.

Figure 7.2.14 shows the location of the 16 test pits and one borehole (B8757) used for characterization at Gable Mountain Pond. Beneath the pond is basalt overlain by up to ~4 meters (13 feet) of sediment typical of the Hanford formation. Overlying the Hanford formation are 1.5 meters (5 feet) or less of pond sediment. This zone also contains plant material, red and yellow staining, and elevated beta-gamma activity (BHI-01367). Overlying the pond sediment, and extending to the surface, are backfill materials.

Barium, beryllium, nickel, and vanadium were detected in most samples from Gable Mountain Pond near or below the Hanford Site background concentrations (see DOE/RL-92-24 for background values of non-radionuclide constituents). Total chromium, copper, lead, and zinc were detected at concentrations above Hanford Site background but less than the *Model Toxics Control Act* (WAC-173-340) Method B cleanup levels for direct contact (BHI-01367). Four samples contained cadmium at concentrations up to 1.7 mg/kg exceeding the state background level of 1.0 mg/kg. Twelve samples contained arsenic at greater than the Hanford Site background value of 6.5 mg/kg with a maximum concentration of 33.8 mg/kg.

The anions ammonia, chloride, nitrate, and sulfate were detected in most samples. Although the elevated concentrations in several samples were above Hanford Site background levels, all concentrations were less than 25% of the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367). The maximum anion concentrations were found typically in the pond bottom samples and concentrations decreased with depth.

No semi-volatile compound or volatile organic compound exceeded the *Model Toxics Control Act* Method B cleanup level for direct contact.

Strontium-90 and cesium-137 were the predominant manmade radionuclides detected in samples from Gable Mountain Pond with maximum concentrations of 58.8 and 7,180 pCi/g, respectively. Figure 7.2.15 shows the distribution of these radionuclides. High concentrations of cesium-137 generally were associated with sediment from the pond bottom and were one to two orders of magnitude higher than concentrations 0.3 to 0.6 meter (1 to 2 feet) deeper. Strontium-90 concentrations tended to increase with depth, and the greatest concentrations were found in the deepest sample from some test pits (7.6 meters or 25 feet). Also, strontium-90 concentrations tended to be higher in the interior of the pond than near the edges.

In addition to cesium-137 and strontium-90, europium-154 was identified in three test pits at a maximum concentration of 3.37 pCi/g and americium-241 was identified in two test pits at a maximum concentration of 1.28 pCi/g. Technetium-99 was identified in one sample at an estimated concentration of 0.458 pCi/g (BHI-01367).

The only manmade radionuclide identified by spectral gamma-ray logging of borehole B8757 at Gable Mountain Pond was cesium-137. The main zone of contamination was relatively thin, between a depth of 3.5 and 3.8 meters (11.5 and 12.5 feet) below ground surface with a maximum concentration of 573 pCi/g.

B Pond (216-B-3 Pond)

B Pond was located adjacent to the northeast corner of the 200-East Area. Throughout its operational lifetime, B Pond varied in size from about 5.7 to 18.6 hectares (14 to 45 acres) (DOE/RL-99-07).

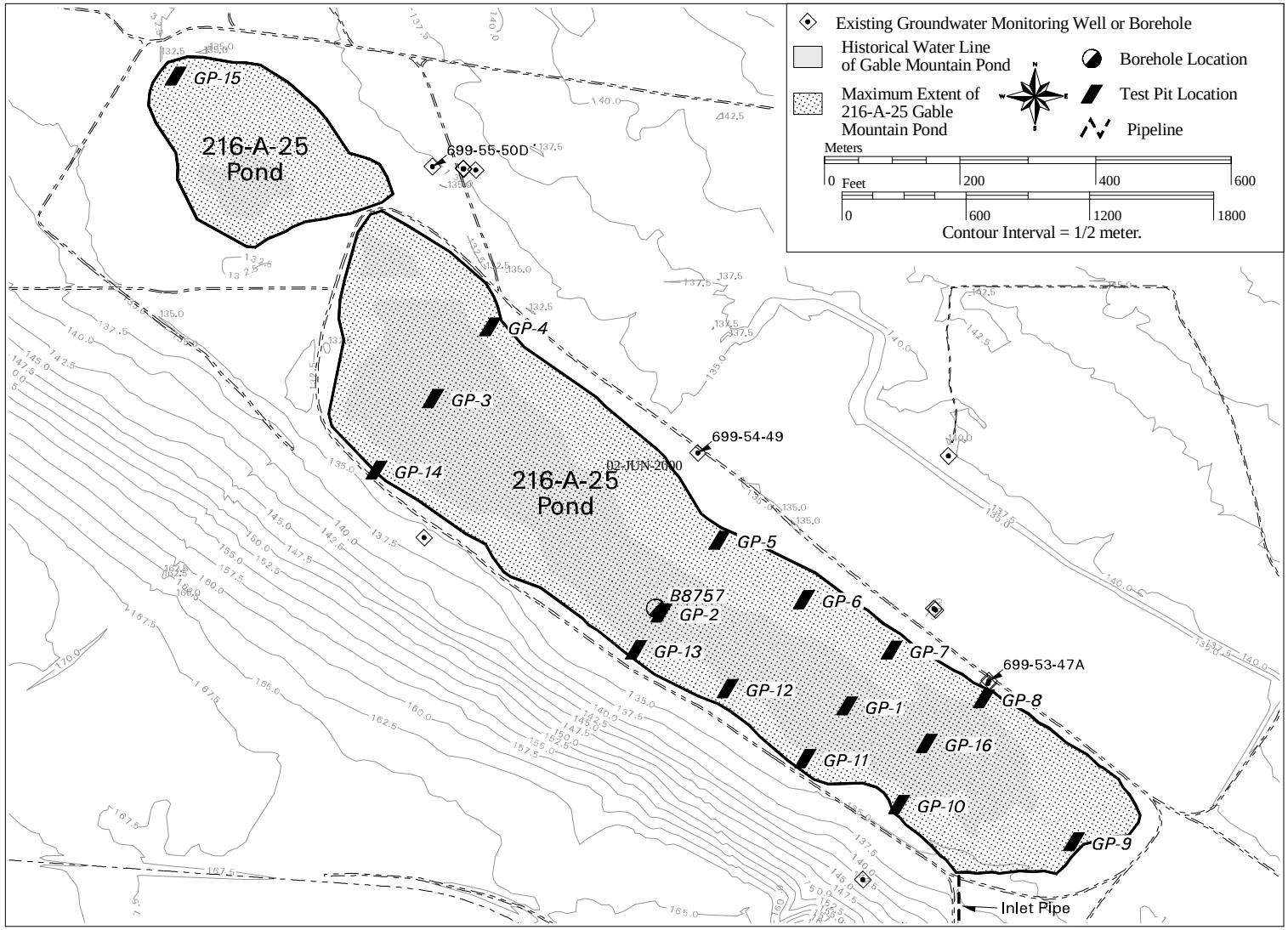

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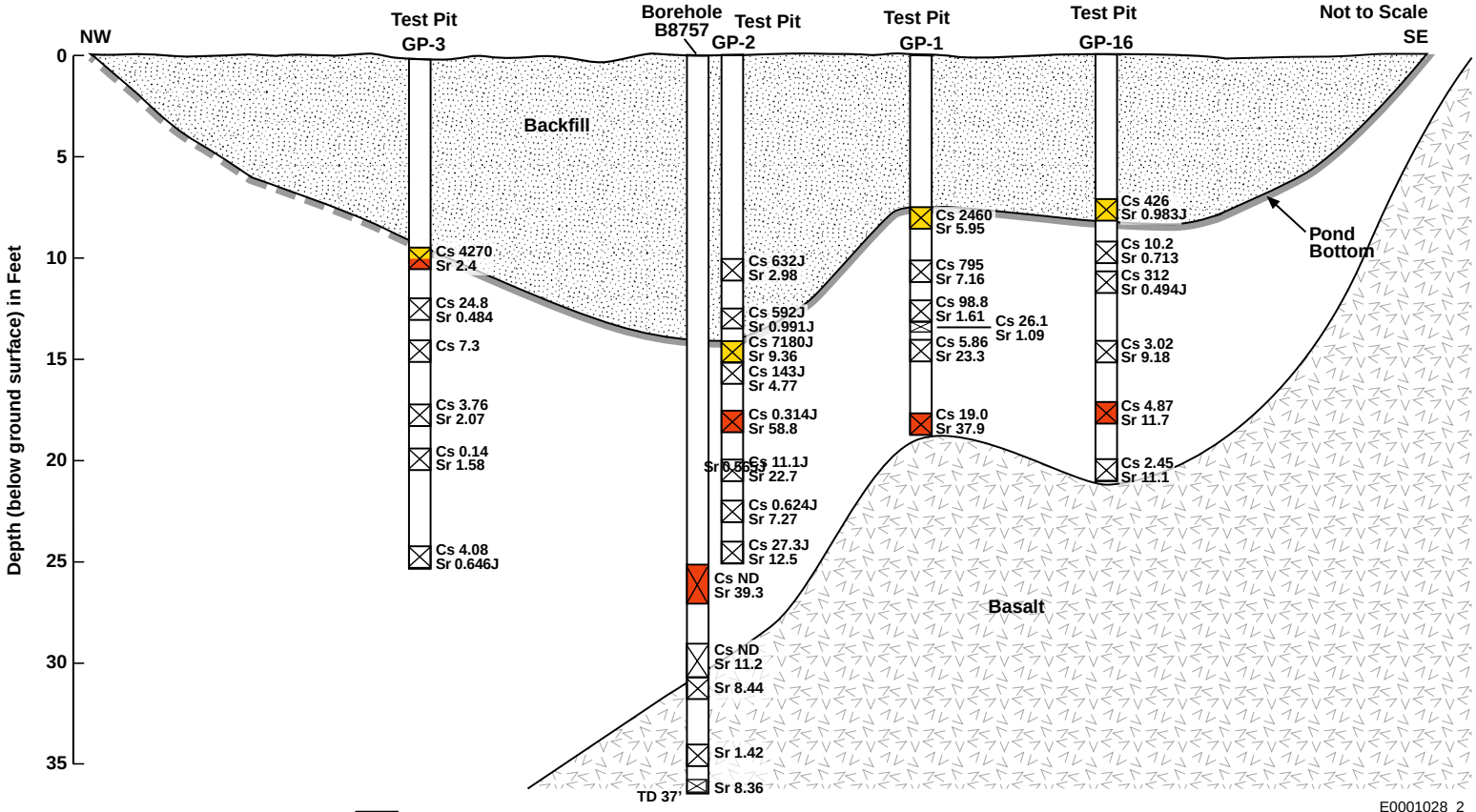
Figure 7.2.14. Location of the Test Pits and Borehole B8757 at the Former Gable Mountain Pond (from BHI-01367)

Gable Mountain Pond



Cs – Cesium 137
Sr – Total Strontium
ND – Not Detected
TD – Total Depth
GP – Test Pit ID
J – Estimated Quantity

Highest CesiumConcentration in pCi/g for each location
Highest Strontium Concentration in pCi/g for each location
Sample Interval

Figure 7.2.15. Cross Section of Former Gable Mountain Pond showing the Distribution of Cesium-137 and Strontium-90 (from BHI-01367)

B Pond received an estimated 240 billion liters (63.4 billion gallons) of effluent between 1945 and 1991. The effluent consisted mostly of cooling water and steam condensate.

Figure 7.2.16 shows the location of the five test pits and one borehole (699-43-44, B8758) at B Pond. Beneath the pond is basalt overlain by the lower mud unit of the Ringold Formation. Overlying the Ringold Formation is sandy gravel, gravelly sand, and sand of the Hanford formation. Overlying the Hanford formation are 0.6 to 1.5 meters (2 to 5 feet) of pond sediment and overlying the pond sediment, and extending to the surface, are 1.7 to 3.7 meters (5.5 to 12 feet) of backfill material.

Arsenic, barium, beryllium, chromium, nickel, and vanadium were detected in most samples from B Pond near or below the Hanford Site background concentrations. Copper and zinc were detected at concentrations above Hanford Site background but less than the *Model Toxics Control Act* (WAC 173-340) Method B cleanup levels for direct contact (BHI-01367). Seven samples contained cadmium at concentrations up to 7.3 mg/kg and exceeding the state background level of 1.0 mg/kg. Lead concentrations ranged from 2 to 573 mg/kg of which only the highest concentration exceeded the *Model Toxics Control Act* cleanup level of 253 mg/kg. Four samples contained silver between 0.29 and 9.6 mg/kg with only the highest concentration exceeding the 8 mg/kg *Model Toxics Control Act* cleanup level. Eleven samples contained mercury between 0.05 and 11.9 mg/kg. The maximum concentrations of cadmium, lead, silver, and mercury were in samples of the pond bottom sediments.

The anions chloride, nitrate, and sulfate were detected in most samples. Although the elevated concentrations in several samples were above Hanford Site background levels, all concentrations were less than 10% of the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367). The maximum anion concentrations were found typically in the pond bottom samples and concentrations decreased with depth.

No semi-volatile compound or volatile organic compound exceeded the *Model Toxics Control Act* Method B cleanup levels for direct contact.

Cesium-137, plutonium-239/240, and strontium-90 were the predominant manmade radionuclides detected in samples from B Pond. The maximum concentration of strontium-90 was 99.9 pCi/g, the maximum cesium-137 was 1,000 pCi/g, and the maximum plutonium-239/240 was 27.5 pCi/g. Americium-241 was found in three test pits with concentrations between 0.083 and 4.96 pCi/g. Figure 7.2.17 shows the distribution of these radioisotopes. The maximum concentrations of americium-241, cesium-137, and plutonium-239/240 generally were associated with the sediment from the bottom of B Pond and were one to two orders of magnitude higher than concentrations 1.5 to 1.8 meters (5 to 6 feet) deeper. Strontium-90 concentrations tend to increase with depth in the test pits, and the maximum strontium-90 concentration was at the bottom of test pit BP-1. In borehole 699-43-44, strontium-90 was not detected below 15.2 meters (50 feet). As at Gable Mountain Pond, concentrations of radioisotopes in B Pond samples tended to be higher in the interior of the pond than near the edges (BHI-01367).

The only manmade radionuclide identified by spectral gamma-ray logging of borehole 699-43-44 at B Pond was cesium-137. Concentrations ranged between 0.9 and 21 pCi/g.

216-B-2-2 Ditch

The 216-B-2-2 ditch carried effluent to B Pond between 1963 and 1970. The ditch has since been backfilled. Three test pits were excavated at the 216-B-2-2 ditch for characterization. Figure 7.2.18 shows the location of the pits. Excavation of the test pits showed that fill material, consisting of silty sandy gravel with minor sand layers, extends from

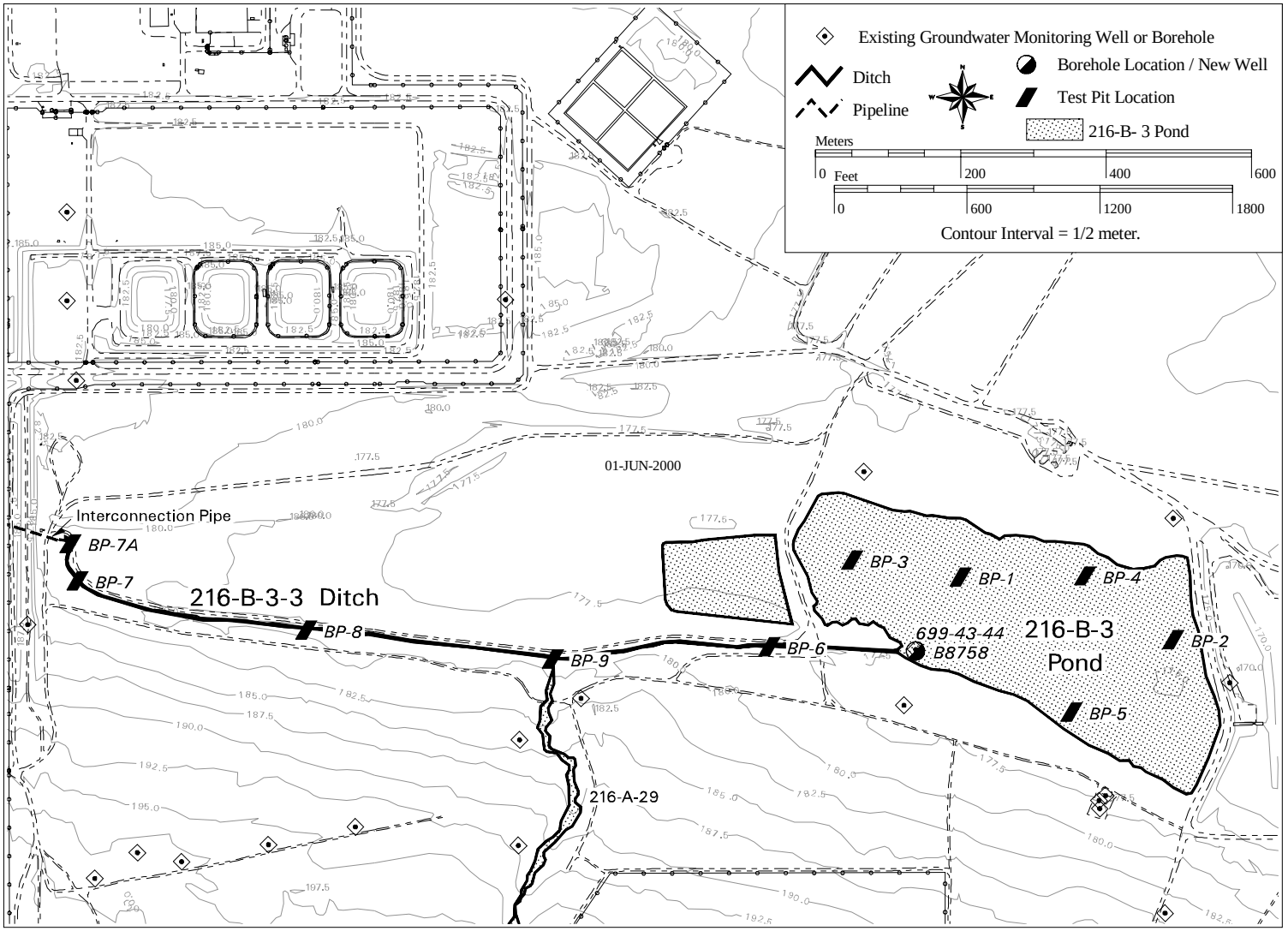


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Figure 7.2.16. Location of Test Pits and Borehole 699-43-44 (B8758) at the Former B Pond and Test Pits at 216-B-3-3 Ditch (from BHI-01367)

216-B-3 Pond

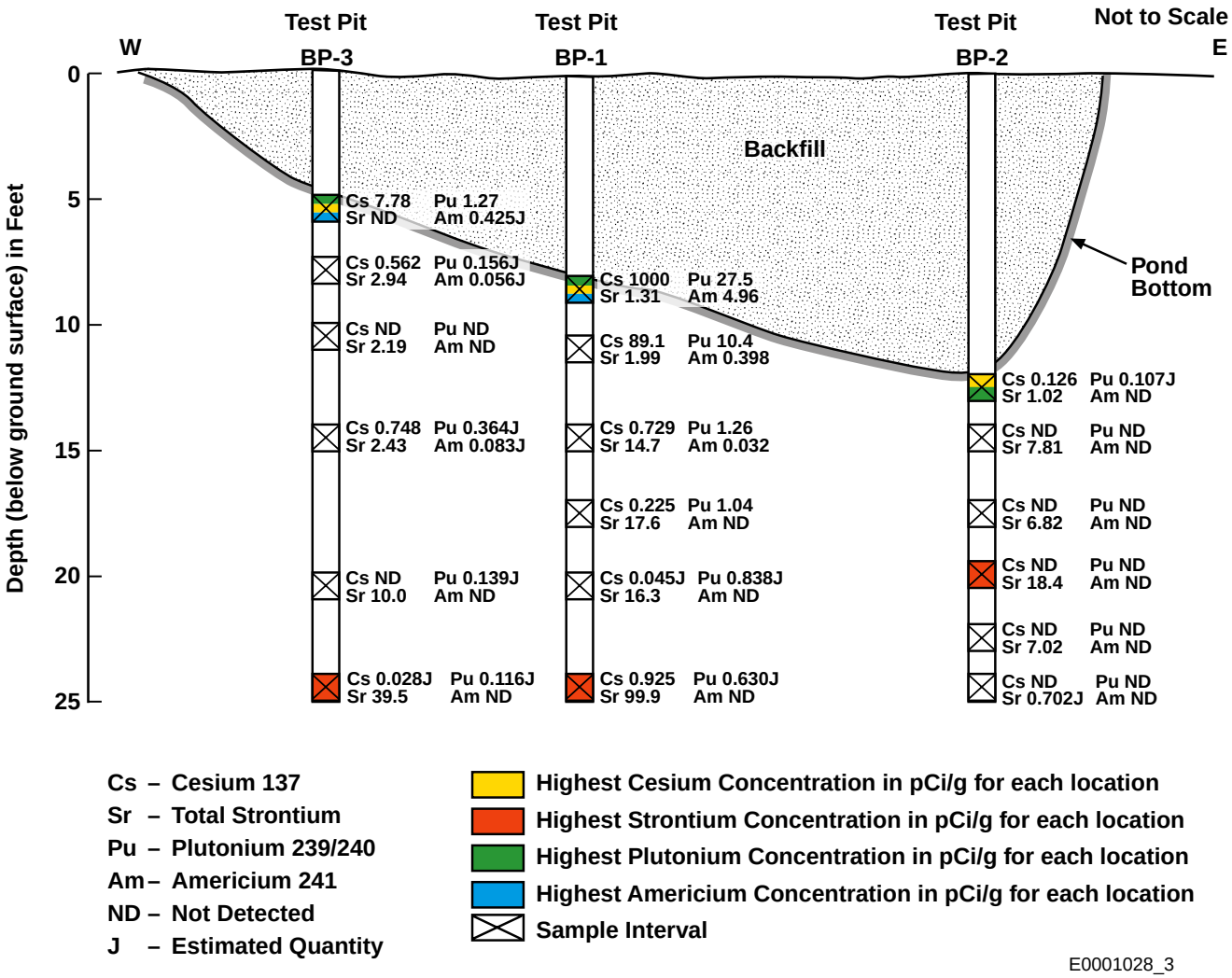

Figure 7.2.17. Cross Section of the Former B Pond showing the Distribution of Radionuclides beneath the Pond (from BHI-01367)

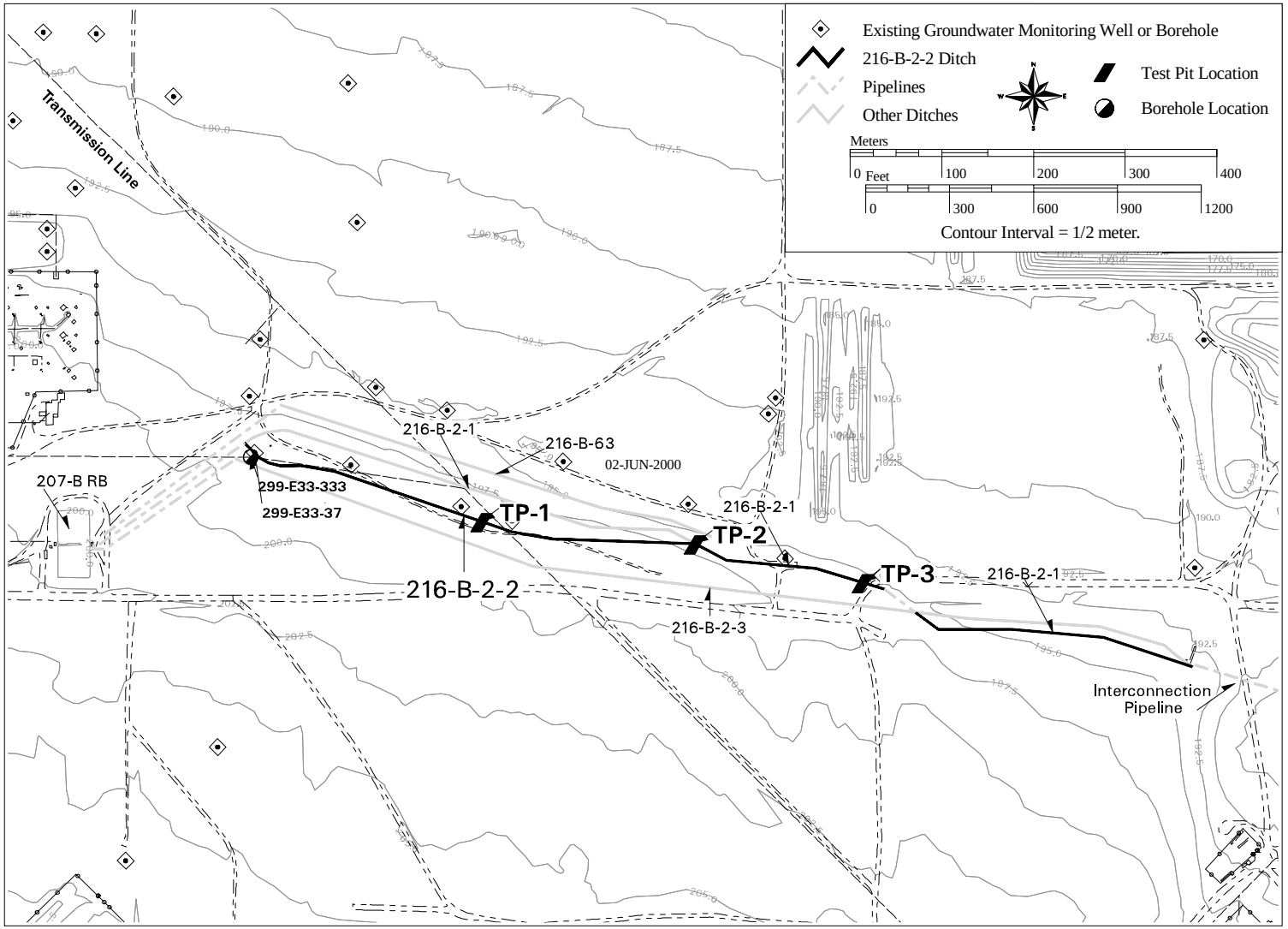

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Figure 7.2.18. Location of the 216-B-2-2 Ditch Test Pits (from BHI-01367)

the surface to a depth of 1.8 to 2.7 meters (6 to 9 feet). The bottom of the ditch is represented by less than 1.8 meters (6 feet) of silty sandy gravel and silty sand with localized reddish stains. Hanford formation sediment extends from the ditch bottom to the base of the test pits (BHI-01367).

Arsenic, barium, beryllium, cadmium, chromium, copper, and vanadium were detected in most samples from the test pits near or below the Hanford Site background concentrations. Lead and zinc were detected at concentrations above Hanford Site background but less than the *Model Toxics Control Act* (WAC 173-340) Method B cleanup levels for direct contact. Mercury and silver were detected in bottom sediment from the ditch in test pit TP-1 (see Figure 7.2.18 for location) at 0.93 and 8.4 mg/kg, respectively (less than cleanup levels). Nickel was found at the slightly elevated concentration of 44.8 mg/kg at 0.6 meter (2 feet) below the ditch bottom in test pit TP-1.

The anions ammonia, chloride, nitrate, and sulfate were detected in most samples. Although the elevated concentrations in several samples were above Hanford Site background levels, all concentrations were less than 10% of the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367).

No semi-volatile compound or volatile organic compound exceeded the *Model Toxics Control Act* Method B cleanup level for direct contact.

The polychlorinated biphenyl (PCB) Aroclor-1260 was identified between 2.4 and 4.6 meters (8 and 15 feet) below ground surface and between 1.3 and 33 mg/kg in test pit TP-1. Also, 6.5 mg/kg of diesel organics were found in a sample from the ditch bottom in pit TP-1, and waste oil constituents were found at three locations between concentrations of 78 and 1,100 mg/kg.

Cesium-137 and strontium-90 were the predominant manmade radionuclides detected in samples from 216-B-2-2 ditch with maximum concentrations of 721 and 12,100 pCi/g, respectively. The highest concentrations of cesium-137 and strontium-90 were in a sample of the ditch bottom in test pit TP-1 and were one to two orders of magnitude greater than concentrations 0.3 to 0.6 meter (1 to 2 feet) deeper. Small amounts of americium-241 and europium-154 were found in test pit TP-1 and 0.064 pCi/g plutonium-238 was in one sample from pit TP-3 (BHI-01367). Test pit TP-1 is the nearest pit to the head end of the 216-B-2-2 ditch. The distribution of radionuclides among the three test pits suggests that most contamination remains at the head end of the ditch.

216-B-3-3 Ditch

The 216-B-3-3 ditch began carrying effluent to B Pond in 1970. The ditch has since been backfilled. Five test pits were excavated at the 216-B-3-3 ditch. Figure 7.2.16 shows the location of the pits. Excavation of the test pits showed that fill material, consisting mostly of silty sandy gravel, extends from the surface to a depth of ~1.8 meters (6 feet). The bottom of the ditch is represented by the contact of fill material with up to 3 meters (10 feet) of gravel, sand, and silt. A layer of plant debris was found in this zone. Sediment typical of the Hanford formation extends from a depth of ~3 meters (10 feet) to the base of the pits (BHI-01367).

Barium, beryllium, cadmium, chromium, nickel, vanadium, and zinc were detected near or below the Hanford Site background concentrations in most samples from the 216-B-3-3 ditch. Lead, copper, and silver were found above Hanford Site background levels but less than *Model Toxics Control Act* (WAC 173-340) Method B cleanup levels for direct contact. The highest concentration of mercury was 0.51 mg/kg in test pit BP-9, and arsenic was 14.7 mg/kg in pit BP-6.

The anions ammonia, chloride, nitrate, and sulfate were detected in most samples. Although the elevated concentrations in several samples were above Hanford Site background levels, all

concentrations were less than 5% of the *Model Toxics Control Act* Method B cleanup levels for direct contact (BHI-01367).

No semi-volatile compound or volatile organic compound exceeded the *Model Toxics Control Act* Method B cleanup level for direct contact.

The PCBs Aroclor-1254 and Aroclor-1260 were identified in three of five test pits. Aroclor-1254, up to 38 µg/kg, was in samples from pit BP-9 and Aroclor-1260, between 35 and 440 µg/kg, was identified in pits BP-6 and BP-7A. At all three locations, the highest concentrations of PCBs were found in the ditch bottom sediment. Waste oil was found in pit BP-9 with the maximum concentration of 78 mg/kg in ditch bottom sediment.

Cesium-137 and strontium-90 were the predominant manmade radionuclides detected in samples from 216-B-3-3 ditch with maximum concentrations of 188 and 9.79 pCi/g, respectively, in test pit BP-7A. The highest concentrations of cesium-137 and strontium-90 were in samples of ditch bottom sediment (except in pit BP-9) and were one to two orders of magnitude greater than concentrations 0.3 to 0.6 meter (1 to 2 feet) deeper. Plutonium-239/240 was found in all test pits with concentration between 0.032 to 5.73 pCi/g. There were no significant concentrations of manmade radionuclides found deeper than 4.6 meters (15 feet) below the ground surface (BHI-01367).

7.2.1.7 Immobilized Low-Activity Waste

D. G. Horton

The DOE Office of River Protection is responsible for safely disposing of the portion of single- and double-shell tank waste that is classified as low-activity waste. The current plan is to vitrify the waste and bury the low activity portion as solid waste in shallow, near-surface facilities. The Hanford Immobilized Low-Activity Tank Waste Performance Assessment is currently underway to assess the performance of the disposal facilities. The goal is to provide a reasonable expectation that the disposal of the waste protects the general public and environmental resources. Fifteen data packages were issued in fiscal year 2000 to support the 2001 Immobilized Low-Activity Waste Performance Assessment (HNF-5636). This section summarizes four of those data packages that pertain directly to the vadose zone:

- *Geologic Data Package for 2001 Immobilized Low-Activity Waste Performance Assessment* (PNNL-12257)
- *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment* (PNNL-13033)
- *Geochemistry Data Package for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (PNNL-13037)
- *Far-Field Hydrology Data Package for Immobilized Low-Activity Tank Waste Performance Assessment* (HNF-4769).

Geology

Geologic information was compiled for two proposed immobilized low-activity waste disposal sites. The first site is the area of the former grout treatment facility east of the 200-East Area. The second is an area in the south-central part of the 200-East Area. Data were compiled from both surface and subsurface sources including published geologic maps, driller's and geologist's logs, archived samples, and geophysical logs. Uncertainty in the data is mainly related to borehole information. Variations in sampling and drilling techniques cause some correlation uncertainties across the sites.

The information consists of tables of geologic contacts from all wells and boreholes associated with the two sites. From this information, cross sections, structure contour maps, and fence diagrams were made depicting the subsurface lithology, stratigraphy and structure. The seismicity of the areas was

also discussed. Few earthquakes have occurred in the area and most were less than coda magnitude 3.0 (coda magnitude is a local magnitude that approximates the Richter magnitude).

The data supplied in the geology data package are used to construct conceptual models considered in the remaining three data packages.

Recharge

Estimates of recharge rates were made for both current conditions and long-term scenarios involving the shallow land disposal of immobilized low-activity waste to support the 2001 Performance Assessment. The Performance Assessment requires recharge estimates for the surface cover, the cover sideslope, the immediately surrounding soil, and a degraded cover. The following discussion is from PNNL-13033.

Table 7.2.2 gives the recharge estimates for the best estimate case and upper and lower bounding cases. The best estimate case is the situation for which all disposal facility features function as expected, a shrub-steppe plant community surrounds the site, the climate is the same as today, and no irrigated farming occurs at the site. The lower bounding case assumes the same conditions as the best estimate case but with the lowest possible recharge. The upper bounding case assumed the best estimate case conditions with the exception of either erosion of part of the surface cover or sand deposition on the surface cover and a sparse shrub-steppe cover on the surround soil. The recharge estimates for each case were derived from lysimeter and tracer data and from modeling analyses.

The most important feature of the disposal facility is expected to be a modified RCRA Subtitle C cover. This uses a 1-meter-thick (3.3-feet-thick) silt loam over sand and gravel layers to create a capillary break. A 0.15-meter-thick (0.5-foot-thick) asphalt layer underlies the sand and gravel to promote lateral drainage. Sideslopes are expected to be sandy gravel at a 1:10 (vertical to horizontal) slope.

Table 7.2.2. Recharge Estimates for the Best Estimate Case and Reasonable Bounding Cases during each Period of Interest to the Immobilized Low-Activity Waste Performance Assessment (from PNNL-13033)

	Estimated Recharge Rates for the Best Estimated Case (and Reasonable Bounding Cases) (mm/yr)			
		Time Period of Recharge Evaluation		
Surface Feature	Pre-Hanford Site	During Disposal Operations	During Surface Cover Design Life	After Surface Cover Design Life
Modified RCRA Subtitle C Cover	NA	NA	0.1 (0.01, 4.0)	0.1 (0.01, 4.0)
Cover Sideslope	NA	NA	50 (4.2, 86.4)	50 (4.2, 86.4)
Rupert Sand	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)
Burbank Loamy Sand	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)
Hanford formation	NA	55.4 (50, 86.4)	NA	NA

NA = Not applicable.

A recharge rate of 0.1 mm/yr (0.004 in./yr) is estimated for the surface cover (PNNL-13033). Although the cover design goal is 0.05 mm/yr (0.02 in./yr), the rate of 0.1 mm/yr is used because it is closer to actual rates measured with lysimeters. Modeling results showed that erosion of the top 20% of the cover or deposition of 20 centimeters (8 inches) of sand on the cover did not impair performance.

A recharge rate of 50 mm/yr (2 in./yr) is estimated for the sideslope, which is lower than the 75 mm/yr (3 in./yr) used in the 1998 Performance Assessment. For a soil type known as the Rupert sand with shrub-steppe plant community, an estimate of 0.9 mm/yr (0.04 in./yr) is given, which is lower than the 3 mm/yr (0.12 in./yr) rate used in the 1998 Performance Assessment. For a soil type known as the Burbank loamy sand with the same plant community, an estimated rate of 4.2 mm/yr (0.16 in./yr) is given. Finally, a recharge rate of 55.4 mm/yr (2.2 in./yr) is given for Hanford formation sediment during construction. Neither the Burbank loamy sand or the Hanford formation were considered in the 1998 Performance Assessment.

Modeling sensitivity tests showed that the cover limited recharge to less than 0.1 mm/yr (0.004 in./yr) regardless of plant type, the presence of plants, or any reasonable climate change. However, recharge rates into the Rupert sand and the Burbank loamy sand increased when the vegetation type or the climate were changed. A complete description of the work can be found in PNNL-13033.

Geochemistry

The geochemical properties of the materials comprising the Immobilized Low-Activity Waste Disposal Facility, the disturbed region around the facility, and the physically undisturbed sediments below the facility were estimated to support the Immobilized Low-Activity Waste 2001 Performance Assessment. The geochemical parameters that were estimated are the distribution coefficient (K_d), which is used to quantify adsorption, and the solution concentration limit, used to quantify solubility. A complete discussion of the estimates and their sources can be found in PNNL-13037 from which the following summary was taken.

Best estimates were made for K_ds and solution concentration limits for each of five expected environments in the disposal system. One of the five environments was a concrete vault. The current design for the disposal facility does not include the vault. The five environments and the geochemical characteristics used to evaluate K_ds are shown in Table 7.2.3.

Most probable "empirical" K_d values and/or solubility values, reasonable lower-bounding estimates, and a likely range of values are given in PNNL-13037 for each radionuclide considered in the 1998 Performance Assessment in each geochemical environment. Where possible, estimates were based on specific Hanford Site experiments. Literature or offsite data were used where no site-specific data were available. Attempts were made to choose literature values that were appropriate for the Hanford Site. In a few cases, no data were available and estimates were based on "expert judgement."

K_ds for the radionuclides in the gravel-dominated environment were corrected for gravel content. The correction was based on the assumption that the gravel fraction had no sorption capacity and was made according to $K_{dgc} = (1\text{-}g)K_d$ where K_{dgc} is the gravel-corrected distribution coefficient, g is the weight fraction of gravel in the sample, and K_d is the measured or literature value from samples containing no gravel. The correction provides more conservative K_ds for the Immobilized Low-Activity Waste Performance Assessment than do uncorrected values.

The conservative K_ds are reasonable lower-bounding values that consider conditions that may enhance radionuclide transport. The lower value from the range of values was usually taken as the reasonable conservative K_d. The best estimates were selected as the central value of the available data

Table 7.2.3. Five Conceptual Geochemical Environments Associated with the Immobilized Low-Activity Waste Disposal Facility (from PNNL-13037)

Zone	Solid Phases	Aqueous Phase	Appropriate Geochemical Parameters
Near field	Glass, secondary phases from glass degradation, backfill, engineered barrier materials	Glass leachate: high pH, high ionic strength, high radionuclide concentrations	K_d Solubility constraints
Degraded concrete vault	Three assemblages based on concrete age: fresh concrete with pH = 12.5, moderately aged concrete with pH ~10.5, and completely aged concrete with pH ~8.5	Three leachate chemistries controlled by different aged concrete: pH values of 12.5, 10.5, and 8.5 to match solid phases; generally high ionic strength and high radionuclide concentration	K_d Solubility constraints
Chemically impacted far field in Hanford formation sand sequence	Sand-dominated sequence altered because of contact with moderately caustic aqueous phase	pH 8 to 11, ionic strength 0.01 to 0.1, low radionuclide concentration	K_d
Chemically impacted far field in Hanford formation gravel sequence	Gravel-dominated sequence altered because of contact with moderately caustic aqueous phase	pH 8 to 11, ionic strength 0.01 to 0.1, low radionuclide concentration	K_{dgc}
Far field in a Hanford formation gravel sequence	Unaltered Hanford formation gravel sequence	Unaltered Hanford Site groundwater with trace of radionuclides	K_{dgc}

and on expert judgement. Supporting references for the selection of all values are given in PNNL-13037.

Hydrology

The hydrologic data needed to perform far-field vadose zone flow and transport modeling for the Immobilized Low-Activity Waste Performance Assessment were compiled in fiscal year 2000. This section summarizes the content of the material in the data package. The actual data along with discussions of the data are presented in HNF-4769.

The hydrologic data package presented results of previously determined laboratory measurements of physical and hydraulic properties measured from core samples of the Hanford formation sand-dominated sequence obtained at the Immobilized Low-Activity Waste Disposal Facility in south-central 200-East Area and samples of the Hanford formation gravel-dominated sequence obtained from the 100 Areas and extrapolated to the disposal site. Laboratory measurements were compiled for moisture retention, particle-size distribution, saturated and unsaturated hydraulic conductivity, and bulk density.

The numerical models of flow and transport of fluids and contaminants in the unsaturated zone require hydraulic properties scaled to discrete grid blocks (scales on the order of meters). The laboratory measured hydraulic properties were obtained from core samples and are applicable to scales of a few centimeters. Therefore, hydraulic parameter estimates need to be extrapolated from the laboratory scale to the field scale. The hydrologic data package presents the methodology and results of extrapolating the flow parameters of moisture retention and saturated and unsaturated hydraulic conductivity and the transport parameters of bulk density, diffusivity, and macrodispersivity. Extrapolated parameters are presented for both the sand-dominated and the gravel-dominated sediment of the Hanford formation.

The data package presents a method to estimate uncertainties in model predictions of far-field hydrologic behavior. Uncertainty estimates on model predictions include 1) variations in model configurations, 2) uncertainties in the calculated mean solution for concentration, and 3) variance around the calculated mean solution for concentration. Variations in model configuration include variations in stratigraphy, presence of discontinuities such as clastic dikes, the degree of homogeneity in the stratigraphy, and the orientation of the sedimentary layers (dip). Uncertainties in the calculated mean solution for concentration include the variations in the conceptual model mentioned above and sensitivity of the model predictions due to variations in extrapolated input parameters.

Uncertainties in far-field hydrologic behavior predicted by the numerical models will be calculated as part of the Immobilized Low-Activity Waste Performance Assessment.

7.2.1.8 Characterization of Standard Hanford and Ringold Formation Samples

H. T. Schaef and D. G. Horton

Pacific Northwest National Laboratory, Bechtel Hanford Inc., and CH2M HILL Hanford Group collected large quantities of Ringold and Hanford Formation sediment in fiscal year 1999. The purpose of the samples was to establish well characterized "standards" to be made available to researchers throughout the Hanford Site, the DOE complex, and academia that wish to study problems associated with the cleanup of the Hanford Site.

Characterization was conducted throughout the year 2000 and included determinations of

- water content
- particle size distribution
- particle density
- calcium carbonate and organic carbon content
- bulk chemical composition
- cation exchange capacity
- pore water composition
- 1:1 water extract pH and cation, anion, and trace element compositions
- nitric acid extract compositions
- mineralogy of the bulk sample and the silt and clay fractions.

This section summarizes the mineralogy results available in 2000.

The Samples

Three areas were sampled on or adjacent to the Hanford Site: the 218-E-12B burial ground (submarine pit) in 200-East Area, the Environmental Restoration Disposal Facility near 200-West Area, and the White Bluffs located east of the Columbia River in Franklin County. Only samples from the 218-E-12B burial ground and the White Bluffs were characterized in 2000. The White Bluffs' sample consisted of silt from the Upper Ringold Formation. Samples from the 218-E-12B burial ground were 1) pebbly sand (hereafter termed Hanford coarse sand) representing the sand-dominated facies of the Hanford formation and 2) silty, fine sand (called the Hanford fine sand) representing the silt-dominated facies of the Hanford formation.

A fourth sample was a composite of sediment from drill cores obtained from borehole 299-W22-50 located east of the SX tank farm in 200-West Area. The borehole sample was a slightly silty medium to fine sand (called the borehole fine sand in this description) of the Hanford formation and represents the fine-grained strata underlying many of the single-shell tanks in 200-West Area.

All samples were air dried and homogenized prior to any testing.

Semi-quantitative mineralogy of the four "standard" samples was determined by x-ray diffraction on both the bulk sediment samples and on the separated ≤2 μm size fractions (clay fractions) of the samples.

Summary of Results

X-ray diffraction analysis of the bulk sediment shows that the samples are mostly quartz (30 to 80 wt.%) and plagioclase feldspar (5 to 20 wt.%), with minor amounts of potassium feldspar (<10 wt.%) and amphibole. Calcite was identified in the Ringold Formation sediment at <5 wt.%. Mica and/or clay minerals are evident in the bulk sample but were not quantified. Mica and chlorite are more abundant in the Ringold Formation silt than in the Hanford formation sediment.

The <2 μm size fraction of all four samples is dominated by four clay minerals: illite (15 to 40 wt.%), smectite (30 to 40 wt.%), chlorite (~15 to 20 wt.%), and minor kaolinite. Minor amounts of quartz, feldspars, and amphibole are also present.

In addition to the x-ray diffraction analyses, some transmission electron microscopy was done on the samples. The analyses show that the mineral illite and not just detrital muscovite occurs in the clay size fraction. This distinction is important when considering the nature and types of cation exchange sites available for contaminant sorption. The cation exchange capacity of muscovite mica can be 75% less than that of illite; thus, illite has a greater capacity to sorb some contaminants.

7.2.2 Vadose Zone Monitoring

D. G. Horton

Vadose zone monitoring occurred at four sites at the Hanford Site in the year 2000. Leachate and soil gas monitoring continued at the Solid Waste Landfill and the Environmental Restoration Disposal Facility and historical results from the 3-year period 1996 to 1999 were summarized for the Environmental Restoration Disposal Facility. Also, soil gas monitoring at the carbon tetrachloride expedited response action site continued during 2000. Finally, soil gas monitoring was done at the 618-11 burial ground in response to elevated levels of tritium discovered during 2000. This section summarizes the vadose zone monitoring efforts that occurred during the past year.

7.2.2.1 Helium-3/Helium-4 Ratios in Soil Gas as an Indicator of Subsurface Tritium Contamination at the 618-11 Burial Ground Site

K. B. Olsen, P. E. Dresel, J. C. Evans, G. W. Patton, J. V. Borghese, R. W. Ovink, and J. M. Faurote

A groundwater sample collected in January 2000 from well 699-13-3A (see Figure 7.1.17 for location), located along the eastern fence line of the 618-11 burial ground, contained 8.1 million pCi/L of tritium. This is the highest concentration of tritium detected at the Hanford Site in recent years. An investigation to determine the extent of the groundwater contamination was begun in 2000. As part of the investigation, a soil gas survey was begun at the burial ground during the summer to determine the

distribution of tritium. Section 7.1.6 discusses the results of the groundwater investigation at the 618-11 burial ground. This section summarizes the soil gas investigation.

Samples of soil gas collected at the 618-11 burial ground were analyzed for helium-3 concentrations in an effort to locate tritium contamination in the subsurface. The technique is based on the decay of tritium, with a half-life of 12.32 years. Tritium decays to the stable, inert isotope helium-3. As tritium decays, its daughter isotope, helium-3, begins to build up in the vadose zone and groundwater at the rate of tritium decay. The helium-3 then diffuses away from the source and toward the surface. Throughout this process, helium-3 acts as a non-reactive tracer moving through the vadose zone. The soil gas monitoring at the 618-11 burial ground was based on the detection of helium-3 in the soil gas to identify vadose or groundwater sources of tritium in the subsurface environment.

Soil Gas Sampling and Analysis

Fifty-four soil gas sampling points were installed north and east of the 618-11 burial ground and up to 120 meters (395 feet) to the east of well 699-13-3A (Figure 7.2.19). All sampling points were completed at 6 meters (20 feet) below ground surface. Soil gas sampling points were installed using a truck mounted Geoprobe™ system equipped with a 1.25-inch-diameter probe and a detachable steel tip. Each sampling location was allowed to equilibrate for at least 24 hours before soil gas samples were collected. All samples were collected with a flexible diaphragm pump.

Fifty-milliliter (1.7-ounce) samples were collected for analysis of helium-3/helium-4 ratios from each sampling location near 618-11 burial ground. Helium-4 is the natural form of helium and does not change, whereas helium-3 increases as tritium decays. Thus, an increase in the helium-3/helium-4 ratio indicates an increase in tritium. After collection, soil gas samples were sent to the University of Rochester for helium isotope analysis. All helium-3/helium-4 ratios were reported relative to the atmospheric ratio (R_A), using air helium as the absolute standard.

Two groundwater samples also were collected to determine tritium concentrations; one sample was collected from the area with the highest helium-3/helium-4 ratio on the north side of the burial ground, and the second was collected ~60 meters to the east of well 699-13-3A (see Figure 7.2.19).

Results and Discussion

The results of soil gas analyses of samples from the west and south sides of the 618-11 burial ground were near background (that is, near the value of ambient air normalized to 1.0). Helium-3/helium-4 ratios from samples from the north and east sides of the burial ground, however, were larger than ambient air indicating tritium decay. The largest value was 62.5 times greater than the atmospheric ratio (see Figure 7.2.19). The largest values were about midway between the east and west ends of the burial ground, north of a series of disposal caissons. A groundwater grab sample collected from a well near the maximum helium-3/helium-4 value contained only 6,500 pCi/L tritium, however. This suggests that the helium-3 enrichment resulted from a vadose zone source of tritium in the area. The area of high helium-3/helium-4 may represent a "halo" of elevated helium-3 in the vadose zone surrounding the tritium source within the burial ground.

A second area of elevated helium-3/helium-4 occurs at the northeastern corner of the burial ground with a maximum ratio of 10.9. A groundwater sample has not been collected at this location. If the helium-3 at this location is from tritium in groundwater, then the concentration of tritium in groundwater can be estimated to be about 24 million pCi/L based on scaling the concentration of tritium in groundwater at well 699-13-3A (~8 million pCi/L) and the helium-3/helium-4 (3.69) directly adjacent to the well.

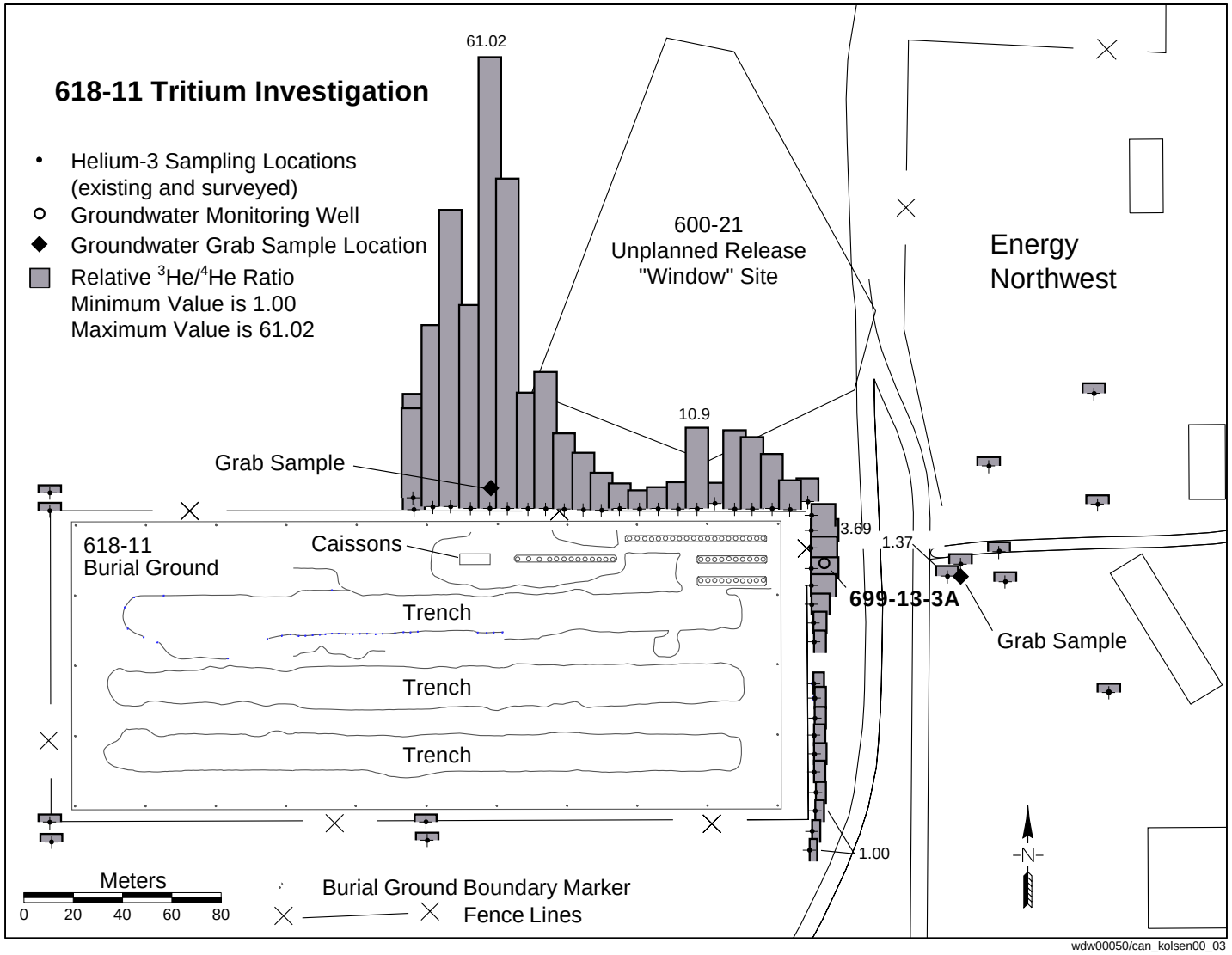

Figure 7.2.19. Relative Helium-3/Helium-4 Ratios at Soil Gas Sampling Locations around the 618-11 Burial Ground

A tritium concentration of 1.5 million pCi/L was measured in a groundwater sample collected from a borehole ~80 meters (260 feet) east of well 699-13-3A. This value is consistent with the helium-3/helium-4 ratio (1.37) that would be predicted by scaling the values given in the above paragraph.

Year 2001 studies are planned to further define the extent of the groundwater tritium plume. Helium-3/helium-4 ratios from additional soil gas monitoring points will be used to determine locations for collection of groundwater samples.

7.2.2.2 Leachate Monitoring at the Environmental Restoration Disposal Facility

J. M. Faurote

Bechtel Hanford, Inc. operates the Environmental Restoration Disposal Facility to dispose of radioactive, hazardous or dangerous, and mixed waste generated during waste management and remediation activities at the Hanford Site. In 2000, Bechtel Hanford, Inc. published the results of groundwater monitoring and sampling at the Environmental Restoration Disposal Facility during the first four years of operation (BHI-01382). Part of the published results contains laboratory analyses of leachate collected from beneath the facility. This section discusses those results.

The Environmental Restoration Disposal Facility began operation in July 1996. Located between the 200-East and 200-West Areas (see Figure 7.1.1), the facility is currently operating two trenches covering 10.3 hectares (25 acres). Each trench is lined to collect leachate resulting from water added as a dust suppressant and precipitation. The liner is sloped to a sump and the leachate is pumped from the sump to tanks. After about 757,080 liters (200,000 gallons) of leachate are collected, samples are taken and analyzed. Analyses are made for 41 volatile organics, 64 semi-volatile organics, 23 metals, and 9 radionuclides. Gross alpha and gross beta analyses are also done. The number of samples depends on the amount of leachate collected.

The purposes of the data are to provide an inventory to the Effluent Treatment Facility, where the leachate is disposed, and to determine whether additional analytes should be added to the groundwater-monitoring list.

Analyses of leachate collected from the Environmental Restoration Disposal Facility show that the liquid collected so far contains no elevated levels of contaminants of concern (BHI-01382). Small levels of common laboratory organics used during analyses are present. A few analytes showed statistically significant increases in groundwater samples since operations began. However, leachate samples contain no constituents of concern for groundwater and no leachate has been released to the soil column at the Environmental Restoration Disposal Facility.

7.2.2.3 Leachate and Soil Gas Monitoring at the Solid Waste Landfill

R. A. Del Mar and D. G. Horton

The Solid Waste Landfill is a land disposal facility in the center of the Hanford Site (labeled as Central Landfill on Figure 7.1.1). The Solid Waste Landfill began operation in 1973; it received nonhazardous, non-radioactive sanitary waste generated from site operations. The Solid Waste Landfill stopped receiving waste in 1996 and an "interim cover" was placed over all trenches. Current monitoring at the Solid Waste Landfill includes leachate, soil gas, and groundwater. Recent groundwater monitoring results are discussed in Section 7.1.6. This section summarizes the leachate and soil gas

results reported by DynCorp Environmental Programs and Compliance to the U.S. Department of Energy (DOE).[b,c]

One of the double trenches in the Solid Waste Landfill overlies a lined, basin lysimeter designed to collect leachate generated by infiltration through the overlying refuse. The lysimeter covers an area of about 88 square meters (947 square feet). A discharge pipe continuously drains leachate by gravity flow from the basin to a nearby collection pump (BHI-01063). Leachate is only collected from under two of more than 90 buried trenches and the two trenches are newer trenches built after implementation of regulations restricting land disposal practices. Therefore, the analytical results from the lysimeter may not reflect leachate draining from most trenches.

Figure 7.2.20 shows the volume of leachate collected since routine monitoring began in 1997. The volume collected is consistent with expected infiltration rates at the Solid Waste Landfill. Table 7.2.4 shows analytical results for several key indicator parameters, metals, anions, and organics in leachate samples during fiscal year 2000. The data show that some indicator parameters and some organic and metal constituents continue to be above the groundwater quality criteria (WAC 173-200) and/or maximum contaminant levels (WAC 246-290).

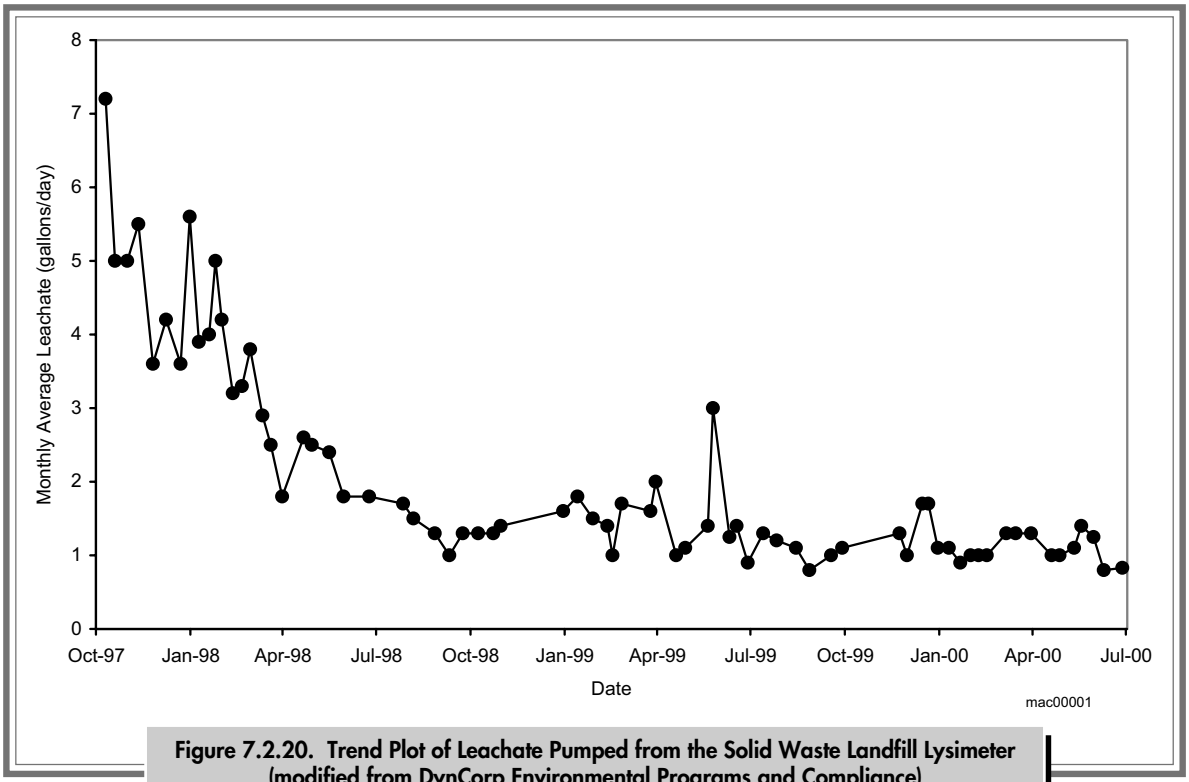

Figure 7.2.20. Trend Plot of Leachate Pumped from the Solid Waste Landfill Lysimeter (modified from DynCorp Environmental Programs and Compliance)

(b) Letter report FH-0001763, *Submittal of Solid Waste Landfill Leachate, Soil Gas, and Groundwater Monitoring Results from Fourth Quarter, Calendar Year 1999*, from D. S. Kelly, Fluor Hanford, Inc. to S. H. Wisness, DOE/RL, Richland, Washington, dated May 3, 2000.

(c) Letter report FH-0002667, *Submittal of Solid Waste Landfill Leachate, Soil Gas, and Groundwater Monitoring Results from First and Second Quarters, Calendar Year 2000*, from D. S. Kelly, Fluor Hanford, Inc. to S. T. Burnum, DOE/RL, Richland, Washington, dated September 20, 2000.

Table 7.2.4. Fiscal Year 2000 Leachate Monitoring Results from the Solid Waste Landfill

Parameter	Results			GWQC[a]	MCL[b]
	First Quarter	Second Quarter	Third Quarter		
pH	7.6	**6.14**	7.43	6.5 - 8.5	NA[c]
Conductivity (µS/cm)	**2,000**	**1,970**	**1,943**	NA	700
Sulfate (mg/L)	8	8	7.7	250	250
Chloride (mg/L)	238.9	223.5	188.3	250	250
Total dissolved solids (mg/L)	**1,300**	**1,288**	**1,297**	500	NA
Arsenic (µg/L)	**19.2**	**17.5**	**13**	0.05	50
Barium (µg/L)	458	444	384	1,000	2,000
Manganese (µg/L)	**2,480**	**2,480**	**2,310**	50	50
Nickel (µg/L)	**208**	**179**	**191**	NA	100
Cadmium (µg/L)	<0.5	0.45	0.29	10	5
Copper (µg/L)	7.97	4.05	2.78	1,000	NA
Selenium (µg/L)	3.65	2.79	2.48	10	50
Zinc (µg/L)	1,490	649	448	5,000	5,000
1,4-Dioxane (µg/L)	**180**	**150**	**57**	7	NA
1,4-Dichlorobenzene (µg/L)	**6**	**6**	**4**	4	NA
Total organic halides (µg/L)	742	586	945	NA	NA
Acetone (µg/L)	12	8	19	NA	NA
Methyl ethyl keytone (µg/L)	<3.1	<3.1	12	NA	NA
Tetrahydrofuran (µg/L)	22	24	21	NA	NA
Liquid volume (L)	483	398	344	NA	NA

Bold indicates values that exceeded groundwater quality criteria or maximum contaminant level.
(a) Groundwater quality criteria from WAC 173-200.
(b) Maximum contaminant level from WAC 246-290.
(c) NA = Not available.

The most notable change in the leachate between the second and third quarters of fiscal year 2000 was a statistically significant increase in total organic halide from 586 to 945 µg/L. The only specific organic halide detected was 1,4-dichlorobenzene at 6 and 4 µg/L for the first and second quarters, respectively. These small concentrations cannot account for the total organic halide values and the source for the total organic halide is unknown.

The increase in pH from 6.14 during the second quarter of fiscal year 2000, which is below the groundwater quality criteria of 6.5, to 7.43 during the third quarter suggests that the second quarter's pH value was low. A pH of 7.43 is within the normal range for historical measurements.

None of the contaminants of concern thus far detected in the leachate has been detected at significant levels in the groundwater (see Section 7.1.6).

Soil gas monitoring at the Solid Waste Landfill uses eight shallow monitoring stations located around the perimeter of the landfill. Each station consists of two soil gas probes at depths of ~2.7 and 4.6 meters (8.8 and 15 feet). Soil gas is monitored quarterly to determine concentrations of oxygen, carbon dioxide, methane, and several key volatile organic compounds. No contaminants of concern were discovered above reporting limits during the first three quarters of fiscal year 2000.

7.2.4 Carbon Tetrachloride Monitoring and Remediation

V. J. Rohay and L. C. Swanson

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200-West Area. EPA and the Washington State Department of Ecology authorized DOE to initiate this remediation in 1992 as a CERCLA expedited response action. The primary focus in the following discussion is on fiscal year 2000 activities associated with the carbon tetrachloride removal. For descriptions of past work, see BHI-00720 and Section 3.2 in PNNL-13116.

The 14.2 m^3/min (18.6 yd^3/min) soil-vapor extraction system operated from March 29 through June 28, 1999, at the 216-Z-9 well field and from June 30 through September 30, 1999, at the combined 216-Z-1A/-12/-18 well field (see PNNL-13080 for location maps of the well fields). The system was maintained in standby mode in fiscal year 2000. Soil vapor monitoring during non-operation of the soil-vapor extraction system has been in progress since July 1999. The 28.3 and 42.5 m^3/min (37 and 56 yd^3/min) soil-vapor extraction systems also were maintained in standby mode during fiscal years 1999 and 2000.

Remediation efforts during the year were directed toward monitoring carbon tetrachloride concentrations during non-operation of the soil-vapor extraction system, passive soil-vapor extraction, and continuation of the carbon tetrachloride innovative technology remediation demonstration program.

Soil-Vapor Extraction

As of September 1999, ~76,500 kilograms (168,872 pounds) of carbon tetrachloride had been removed from the vadose zone since extraction operations started in 1992 (Table 7.2.5). Since initiation, the extraction systems are estimated to have removed 7% of the residual mass at well field 216-Z-1A/-12/-18 and 22% of the mass at well field 216-Z-9. This estimate assumes that all of the mass that has not been lost to the atmosphere (21% of the original inventory), dissolved in groundwater (2% of the original inventory), or biodegraded (1% of the original inventory) is still available in the vadose zone as residual mass (BHI-00720; WHC-SD-EN-TI-101).

Monitoring at Off-Line Wells and Probes

During fiscal year 2000, soil-vapor concentrations of carbon tetrachloride were monitored near the ground surface, near the Plio-Pleistocene Unit (~40 meters (131 feet) below ground surface), and

Table 7.2.5. Carbon Tetrachloride Inventory in Primary Disposal Sites

Well Field	Estimated Mass Discharged 1955 to 1973[a] (kg)	Estimated Mass Lost to Atmosphere 1955 to 1990[b] (kg)	Mass Removed Using Soil-Vapor Extraction 1991 to 1999[c] (kg)
216-Z-1A	270,000	56,700	23,511[d]
216-Z-9	130,000 to 480,000	27,300 to 100,800	52,949
216-Z-18	170,000	35,700	
Total	570,000 to 920,000	119,700 to 196,800	76,460

(a) Based on DOE/RL-91-32.
(b) Based on WHC-SD-EN-TI-101.
(c) Based on BHI-00720.
(d) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.

near groundwater (~66 meters [216 feet] below ground surface) (see Figure 7.1.3). Soil-vapor concentrations were monitored near the ground surface and groundwater to assess whether non-operation of the soil-vapor extraction system is allowing carbon tetrachloride to migrate out of the vadose zone. The maximum concentration detected near the ground surface (between 2 and 10 meters [6.5 and 33 feet] below ground surface) was 9.4 ppmv. Near the groundwater, at a depth of 58 meters (190 feet) below ground surface, the maximum concentration was 20.4 ppmv.

Soil-vapor concentrations were also monitored above and within the Plio-Pleistocene Unit to provide an indication of concentrations that could be expected during restart of the soil-vapor extraction system. (The Plio-Pleistocene Unit is a geologic stratum that may be a confining layer to carbon tetrachloride vapors.) The maximum concentration detected near the Plio-Pleistocene Unit (between 25 and 41 meters [82 and 134 feet] below ground surface) was 442 ppmv in well 299-W15-217 (35 meters [115 feet] below ground surface) at the 216-Z-9 site. During monitoring in fiscal years 1997, 1998, and 1999, the highest carbon tetrachloride concentrations also were detected in this well.

At the 216-Z-1A/-12/-18 well field, the maximum carbon tetrachloride concentration detected near the Plio-Pleistocene Unit was 248 ppmv in well 299-W18-167 (37 meters [121 feet] below ground surface) in the 216-Z-1A tile field. The highest concentrations detected during the fiscal years 1998 and 1999 were detected at well 299-W18-158L also within the 216-Z-1A tile field.

The temporary suspension of soil-vapor extraction in fiscal year 2000 appears to have caused minimal detectable vertical transport of carbon tetrachloride through the soil surface to the atmosphere. This view is supported because carbon tetrachloride concentrations did not increase significantly at the near-surface probes monitored during the year. In addition, suspending operations of the soil-vapor extraction system appears to have had no negative impact on groundwater quality, because carbon tetrachloride concentrations have not increased significantly near the water table since that time.

Passive Soil-Vapor Extraction

Passive soil-vapor extraction is a remediation technology that uses naturally-induced pressure gradients between the subsurface and the surface to drive soil vapor to the surface. In general, falling atmospheric pressure causes subsurface vapor to move to the atmosphere through wells, while rising atmospheric pressure causes atmospheric air to move into the subsurface. Passive soil-vapor extraction systems are designed to use this phenomenon to remove carbon tetrachloride from the vadose zone.

Passive soil-vapor extraction systems were installed at the end of fiscal year 1999 at eight boreholes that are open near the vadose-groundwater interface at the 216-Z-1A/-12/-18 well field. The passive systems have a check valve that only allows soil-vapor flow out of the borehole (i.e., one way movement), and a canister holding granular activated carbon that adsorbs carbon tetrachloride before the soil vapor is vented to the atmosphere. The check valve prohibits flow of atmospheric air into the borehole during a reverse barometric pressure gradient, which tends to dilute and spread carbon tetrachloride vapors in the subsurface.

Three of eight boreholes measure hourly air pressure differentials between the ground surface and the bottom of the borehole, carbon tetrachloride concentrations, temperature, and flow rates. These data can be used to calculate an hourly estimate of the amount of mass removed from the well. The granular activated carbon in all eight boreholes is sampled monthly and analyzed quarterly using laboratory analytical services. The granular activated carbon samples provide a passive, time-integrated measure of the amount of mass removed through the well.

At the two instrumented boreholes near 216-Z-1A tile field, 299-W18-6L and 299-W18-252L,

the peak carbon tetrachloride concentration was 69.2 ppmv. Well 299-W18-247L located at the southeastern corner of the 216-Z-18 crib had a peak concentration of 8 ppmv. Flow rates measured at the wells ranged from 0 to as high as 0.3 m^3 (0.4 yd^3) per minute. Passive soil-vapor extraction is considered successful at these areas on the Hanford Site.

7.2.3 Technical Demonstrations

D. G. Horton

Technical demonstrations are designed to result in new, innovative methods for cleanup and monitoring at the Hanford Site. This section summarizes three technical demonstrations that occurred at the Hanford Site during 2000.

A small-diameter, passive neutron tool was demonstrated to be able to detect subsurface transuranics in the vadose zone under certain conditions. Also, a small-diameter spectral gamma logging tool was demonstrated at an environmental remediation site in the 100 Areas. Both tools could result in substantial cost savings over conventional methods of characterization and monitoring. In addition, the Vadose Zone Transport Field Study conducted a series of tests in 2000 to evaluate how contaminant plumes move in the vadose zone. Several geophysical methods to monitor moisture movement were tested. The year 2000 tests are the first of four field tests to be conducted at the Hanford Site.

7.2.3.1 Demonstration of a Passive Neutron Tool to Detect Transuranic-Contaminated Soil

R. G. Bauer, R. R. Randall, and R. K. Price

Bechtel Hanford, Inc., CH2M HILL Hanford, Inc., Three Rivers Scientific, and Pacific Northwest Geophysics evaluated the ability of a passive neutron tool to detect transuranic radionuclide contaminated soil in the subsurface during 2000. The demonstration was done in two boreholes that penetrated transuranic contaminated sediment at the 216-Z-1A tile field in the 200-West Area.

The demonstration had three objectives:

- test a small-diameter, bismuth-germanate gamma-ray detector designed for use with a small-diameter gamma logging system and small-diameter Geoprobe™ hydraulic driver
- determine whether the passive neutron detector could detect transuranic-contaminated soil at or near the 100 nCi/g threshold concentration
- determine whether a relationship exists between different transuranic radionuclides and neutron detector response in soil matrices.

The gamma-logging instrument used in the demonstration was a bismuth-germanate scintillator, housed in a probe 3.8 centimeters (1.5 inches) in diameter and 0.658 meter (2.2 feet) long. The passive neutron-logging instrument was a helium-3 detector, housed in a 3.8 centimeter (1.5 inch) by 0.57-meter (1.9-foot) probe.

Boreholes 299-W18-149 and 299-W18-167 were selected for logging. Borehole 299-W18-149 was chosen because it contains a known passive neutron flux and has a large range of transuranic concentration (PNNL-11978). Borehole 299-W18-167 was chosen because concentrations of transuranic radionuclides were potentially below the detection limit of the small-diameter tools and the ratio of americium-241 to plutonium-239 varies significantly between boreholes 299-W18-167 and 299-W18-149.

Results

The logging results show that the efficiency of the bismuth-germanate detector was sufficient to detect transuranic radionuclides at threshold levels equivalent to the high purity germanium detector used to log the boreholes in 1998 for a gross gamma determination. The electronics associated with the bismuth-germanate detector are faster responding and do not experience as much dead time as the high purity germanium detector. Dead time is the time interval during which a photon is detected and processes. During this time interval, the system cannot respond to another photon.

The range of passive neutron and transuranic radionuclide concentrations were found to be large in borehole 299-W18-149 and the magnitude of the neutron count rate is a function of the concentrations. The neutron measurements in borehole 299-W18-149 indicate an upward biased passive neutron detector response. This is most likely due to neutron streaming in the air-filled borehole. (Neutron streaming is the result of the lack of scattering and attenuation of neutrons in the air, which causes a stream of neutrons up and down the inside of the borehole. The result is a detectable flux of neutrons above and below the zone containing the transuranic radionuclides.)

The neutron count rate measured in borehole 299-W18-167 is much lower than that encountered in borehole 299-W22-149, and the background streaming in the air-filled borehole is lower. The estimated total concentration of transuranic radionuclides in 299-W18-167 is ~150 nCi/g. The passive neutron detector response indicates successful detection of transuranic concentrations just above 100 nCi/g. The vertical depth resolution is less for the neutron signal than for the gross gamma signal due to streaming in the borehole.

The bismuth germanate and high purity germanium data from borehole 299-W18-149 were analyzed to determine the relationship of the passive neutron response to increasing concentrations of transuranic radionuclides. The least squares fit of the data shows that the neutron count rate is exponentially proportional to the total transuranic concentration. An intercept near 1 count per second for the neutron count rate represents the minimum observable count rate in the data and is not the detection limit. Neutron streaming was found to make the minimum detection limit higher. Thus, when high concentrations of transuranic radionuclides are encountered, higher detection limits will result, as expected.

Conclusions

The initial evaluation to detect transuranic radionuclides with a small-diameter geophysical logging system gross gamma probe and a passive neutron detector was successful. Two objectives of the evaluation were met:

- a small-diameter geophysical logging system passive gamma probe for detection of transuranic-contaminated soil was demonstrated.
- the passive neutron detector was demonstrated to detect transuranic-contaminated soil at or near the 100 nCi/g concentration during the logging of borehole 299-W18-167.

A third objective to determine whether a relationship exists between different transuranic radionuclide concentrations and neutron detector response was not accomplished because there were significant differences between the two boreholes that were logged. These differences introduced too many variables to support a baseline comparison of neutron responses from americium-241 and plutonium-239.

7.2.3.2 Small-Diameter Geophysical Logging System Demonstration

K. A. Bergstrom, T. H. Mitchell, R. R. Randall, and R. K. Price

The results of a small-diameter geophysical logging system demonstration became available in 2000.

The system was designed to collect information on the distribution of subsurface gamma-emitting radionuclides. The purpose of the demonstration was to collect information to reduce remediation costs by minimizing the amount of excavated soils from the 126-F-1 ash pit in the Hanford Site's 100-F Area. Complete results of the demonstration can be found in BHI-01352. This section summarizes those results.

A truck mounted Geoprobe hydraulic driver was used for the demonstration. The logging tool was 2.12 centimeters (0.8 inch) in diameter, 20.5 centimeters (8 inches) long, and contained a cesium iodide scintillator crystal. The tool was lowered inside the push rods and measurements were taken at intervals of 15 centimeters (6 inches) with a count time of 200 seconds. (Push rods are the part of the system driven into the ground to make the borehole.) The detector was calibrated in the Hanford Site borehole calibration models. The minimum detection limit for cesium-137 was about 4 pCi/g and for cobalt-60 about 0.5 pCi/g.

The small-diameter geophysical logging system was used to geophysically log 42 probe holes at the 216-B-2-2 ditch, 216-B-3 pond (B Pond), and the 126-F-1 ash pit. Holes created during geophysical logging were decommissioned according to Washington State Department of Ecology guidelines (WAC 173-160) by sealing with grout.

Five small-diameter geophysical logging system probe holes were logged at B Pond. The rods were pushed to depths between 4.75 and 7.87 meters (15.6 and 26 feet). Cesium-137 was the only manmade radionuclide identified. Cesium-137 was primarily in a narrow zone ~2.5 to 3.5 meters (8.5 and 11.5 feet) below the ground surface. This agrees with laboratory data collected from another study (see Section 7.2.1.6). The maximum cesium-137 concentration was 488 pCi/g.

Five small-diameter probe holes were logged at the 216-B-2-2 ditch. The ditch had been covered previously with fill material, and its exact location was not known. The objective was to locate the ditch. The five holes were equally spaced at 3 meters (10 feet) along a line across the projected location of the ditch. Only one probe hole encountered contamination. Cesium-137 was identified at 2.3 meters (7.5 feet) below ground surface with a concentration of 11.53 pCi/g. A test pit was excavated at the site, and subsequent results suggest the pit was located in the ditch (BHI-01367).

The 126-F-1 ash pit is a solid waste site that received large amounts of coal ash sluiced with raw Columbia River water. The coal ash originated from the 100-F Area powerhouse. The initial remedial action for the site was planned to remove and dispose of 287,904 cubic meters (376,564 cubic yards) of contaminated material (BHI-01352). The site was contaminated by leaks from reactor effluent lines in the 1940s. Most of the contamination is believed to be contained north of an earthen dike built in the late 1940s. Forty-two small-diameter geophysical logging system probe holes along seven profiles were made in and adjacent to the ash pit in an attempt to better delineate contamination and potentially reduce the amount of material needing to be removed. All probe holes are believed to have penetrated through the ash and entered native soils. This is based on refusal of the push rods to extend deeper into the soil at approximately the same elevation at most probe holes. Refusal is believed to be due to a horizontally pervasive soil layer.

The small-diameter geophysical logging system demonstration identified cesium-137 and cobalt-60 in the northern part of the ash pit but found no contamination in the southern part. Based on the results of the investigation, a new volume of 148,000 cubic meters (193,575 cubic yards) is estimated to be contaminated. This is a reduction of about 50% and can result in substantial cost savings to the 126-F-1 ash pit remediation project.

7.2.3.3 Vadose Zone Transport Field Studies: Summary of Fiscal Year 2000 Activities

G. W. Gee and A. L. Ward

The scope of the Vadose Zone Transport Field Studies is to conduct a series of tests at the Hanford Site to evaluate how contaminant plumes move in the vadose zone. Planned experiments include two flow and transport tests at an uncontaminated site to simulate a tank leak, followed by two flow and transport tests in deeper Hanford formation sediment. During 2000, the first of the four planned field tests was completed at an uncontaminated site. This section provides a summary of the 2000 field test. Many contractors and individuals from national laboratories collaborated on this study.

The objectives of the Vadose Zone Transport Field Studies are to conduct controlled transport experiments at well-instrumented field sites at the Hanford Site to

- identify mechanisms controlling transport in soil typical of Hanford's waste disposal sites
- reduce uncertainty in conceptual models
- develop a detailed and accurate database of hydraulic and transport parameters for validation of three-dimensional numerical models
- identify and evaluate advanced, cost-effective characterization methods and to assess changing conditions in the vadose zone.

A test site was selected in 2000 at the 299-E24-111 experimental test well (RHO-ST-46P) located in the 200-East Area where an extensive amount of characterization has already been completed (RHO-ST-46P; NUREG/CR-5996; PNNL-10860). Ward and Gee (PNNL-13263) provide details of the site selection process. Figure 7.2.21 shows the test site location in the 200-East Area.

Figure 7.2.22 shows the site during instrument installation and sampling on May 31, 2000. A drill rig was used to place advanced tensiometers and provide core samples. Surface electrodes were placed for geophysical logging measurements.

More than 20 technologies were screened to identify those that could be used alone or in conjunction with others to reduce the uncertainty in plume delineation. With this objective in mind, a short list of possible technologies was identified based on the following criteria:

- the ability to identify key geologic features controlling water movement with a vertical resolution of 0.1 meter (0.3 foot) or better and a horizontal resolution of 1 meter (3.3 feet) or better
- the ability to locate wetting fronts and a change in water content of 0.01 m^3/m^3 (0.35 ft^3/35 ft^3) or better with a repeatability of at least 0.01 m^3/m^3
- the ability to determine the shape and extent of non-gamma-emitting contaminant plumes or their surrogates
- the ability to function and produce useful results in culturally noisy environments.

The nine technologies resulting from the screening process included neutron moisture logging, advanced tensiometry/suction lysimetry, electrical resistance tomography, cross hole radar tomography, cross hole seismic tomography, cross hole electromagnetic induction, high-resolution resistivity, and tracers (including isotopes) and coring. The details of each of the nine methods selected and the collaborators who helped deploy the selected methods are listed in the Vadose Zone Transport Field Studies test plan (PNNL-13263).

Neutron probes were used in the past to monitor water content at the Sisson and Lu injection site (RHO-ST-46P; NUREG/CR-5996; PNNL-10860). These probes also are used routinely to monitor water content in the field at the Hanford Site. For the

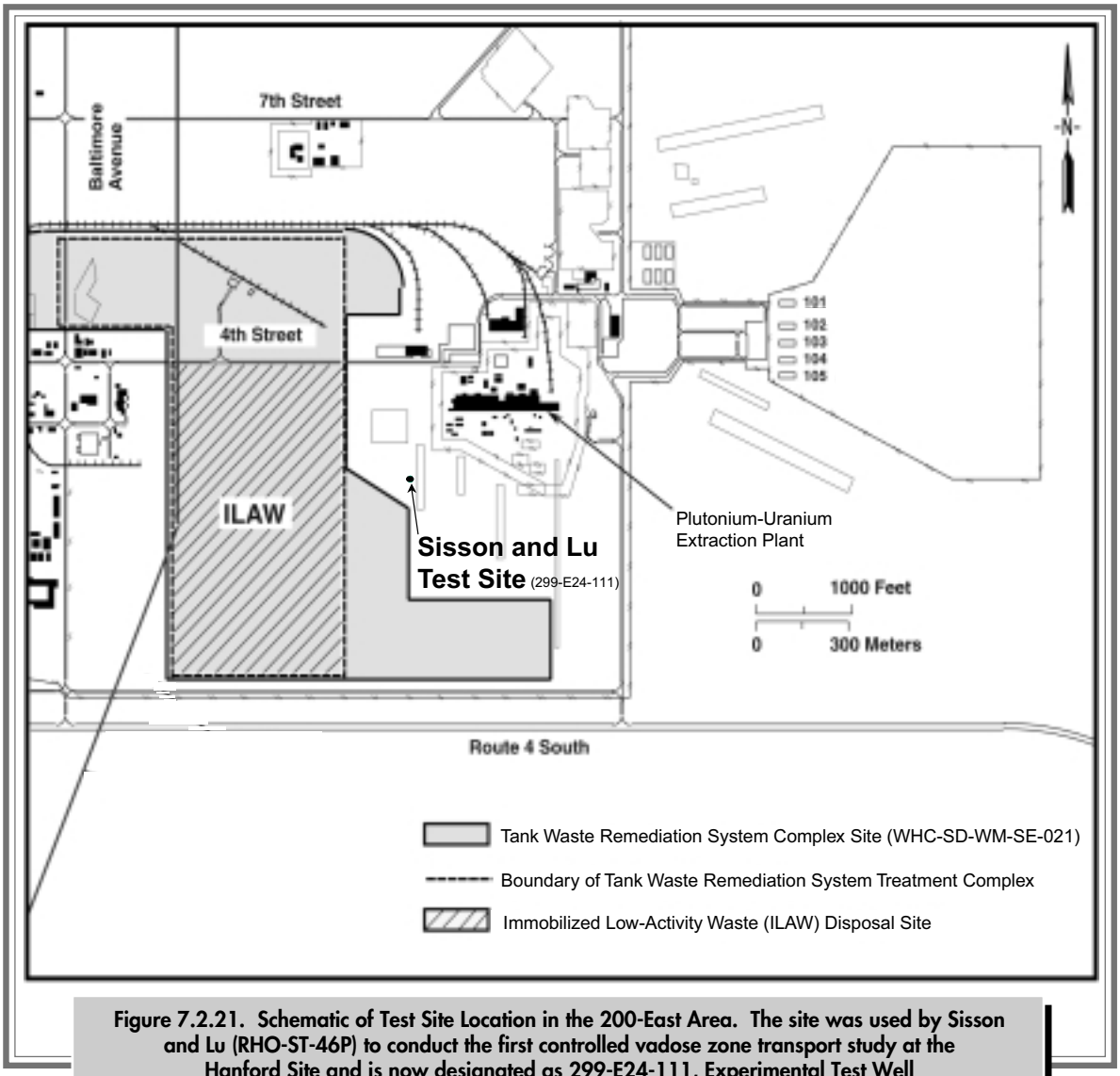

Figure 7.2.21. Schematic of Test Site Location in the 200-East Area. The site was used by Sisson and Lu (RHO-ST-46P) to conduct the first controlled vadose zone transport study at the Hanford Site and is now designated as 299-E24-111, Experimental Test Well Site, in the Hanford Waste Information Data System (WIDS).

2000 study, water content was the primary variable measured. Water content, as determined by neutron probe logging, was also selected as the primary standard against which the other geophysical methods could be compared. Details of the calibration of neutron probes for monitoring water content at the Sisson and Lu site is provided in PNNL-10860.

Water Injection Tests

After baseline data from all methods were obtained, a series of five water injections were conducted. Injections began on June 1, 2000, when 4,000 liters (1,057 gallons) of water were injected into the 5-meter-deep (16.4-feet-deep) injection well over a 6-hour period. Subsequent injections occurred weekly for a period of 5 weeks. Neutron logging of 32 steel-cased wells (surrounding the injection well) occurred before the initial injection and followed each of the five injections within a day, with the exception of the injection that occurred on June 26, 2000. On that day, a wildfire burned on the Hanford Site so that neutron logging occurred on

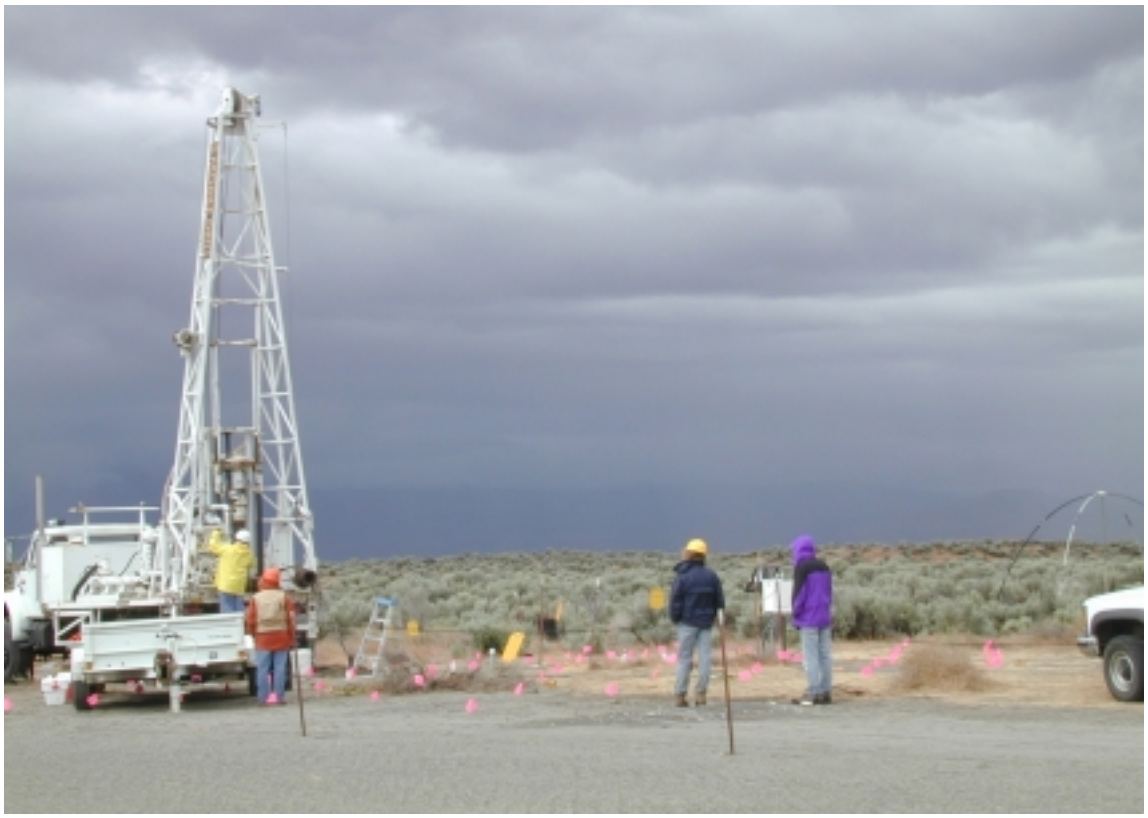

Figure 7.2.22. Instrumentation and Sampling of the Vadose Zone Transport Field Study Test Site on May 31, 2000

July 7, 2000. One additional 4,000-liter (1,057-gallon) injection was made on September 18, 2000. This injection was made to obtain in situ hydrologic properties using a combination of pressure measurements and neutron probe water content measurements at the same depth.

Preliminary Modeling of Fiscal Year 2000 Vadose Zone Transport Field Studies Injection Test

The 2000 test was simulated using STOMP (Subsurface Transport Over Multiple Phases), a multiphase (unsaturated) flow and transport code developed at Pacific Northwest National Laboratory (PNNL-11217). A conditional simulation of the five injections was made using methods developed by Rockhold et al. (1999). The simulations assumed an initial water content and water retention characteristics of Hanford Site soils that are similar, but not identical, to the soil found by Sisson and Lu (RHO-ST-46P).

The model results describe the general flow depths and directions of the plume but do not completely describe the extent of the lateral spreading of the plume. The improved and more site-specific hydraulic property data collected during the field test may be helpful in improving the prediction of the lateral spreading.

Summary

Pacific Northwest National Laboratory and collaborators conducted the first of four field tests at the 299-E24-111 injection site in the 200-East Area of the Hanford Site in 2000. Nine methods were tested to document a vadose zone plume produced from injecting a total of 20,000 liters (5,283 gallons) of

Columbia River water into a 5-meter-deep (16.4-foot-deep) injection well, in five increments of 4,000 liters (1,057 gallons) each over a period of 5 weeks. Water contents, obtained by neutron probe logging techniques, were used as baseline measurements upon which other geophysical measurements were compared. Prior to completing the test, the development of the water plume was simulated using conditional simulation techniques (Rockhold et al. 1999). The conditional simulation relied on estimates from hydrologic characterization of a limited number of samples previously taken from the site. While the computational results were in qualitative agreement with field measurements, they did not predict the observed lateral extent of the plume.

All methods were successful to some degree in identifying changes in subsurface water contents (or pressures) resulting from the five injections. Electrical resistance tomography showed promise in delineating the shape of the entire plume. However, the interpretation of signal responses was difficult, mostly because of interference between the electrical signal and the dense "forest" of more than 35 steel-cased wells. Apparent changes in electrical resistivity were observed at depths of 18 meters (59 feet) but on closer inspection, real changes were confined largely to depths of 6 and 12 meters (19.7 and 39.4 feet) in conformance with water content changes observed by neutron probe logging.

Cross-borehole radar was successful in identifying a section of the plume, and provided a good time lapse of the redistribution of one injection. The results compared well with neutron probe logging; however, the results were limited by the relatively narrow spacing of the plastic access tubes. Tests with electromagnetic induction and high-resolution resistivity were marginally successful in showing changes in electrical properties but the surface measurements were unable to provide sufficient vertical resolution to identify the depth of penetration of the wetting front, an important parameter for plume migration investigations. Seismic monitoring was successful in delineating stratigraphy at the site. Peak concentrations of isotopic tracers (e.g., deuterium) sampled from vertical cores matched well with the bromide tracer data taken from adjacent cores and indicated the peak concentrations of the tracer plume. Isotopic tracer distributions also confirmed that none of the new water injected penetrated the impeding layer at the 12-meter (39.4-foot) depth. Advanced tensiometers were only marginally successful in delineating the pressure profiles due to a series of pressure transducer failures in about half of the units.

The work accomplished in 2000 provides for a more intelligent choice of vadose zone monitoring technology to match a specific monitoring need. Also, the data collected in 2000 further the understanding of vadose zone processes such that contaminated movement can be better predicted.

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8.0 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 2000 to monitor the climatology and meteorology, to assess the status of ecological monitoring and compliance, to monitor and manage cultural resources, and to actively involve the public in environmental surveillance activities.

8.1 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 E, Tables E.5 and E.7 through E.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 site operations.

Local data to support the Hanford Meteorology Station operations are provided via the Hanford Meteorological Monitoring Network. This network consists of 30 remote monitoring stations that transmit data to the Hanford Meteorology Station via radio telemetry every 15 minutes. There are twenty-seven 9-meter (30-foot) towers and three 61-meter (200-foot) towers. Meteorological parameters collected at these stations include wind speed, wind direction, temperature, precipitation, atmospheric pressure, and relative humidity; however, not all parameters are collected at all stations. Figure 8.1.1 shows the 2000 wind roses (diagrams showing direction and frequencies of wind) measured at a height of 9 meters (30 feet) for the 30 meteorological monitoring stations on and around the Hanford Site.

Real-time and historical data from the Hanford Meteorological Station can be obtained at http://etd.pnl.gov:2080/HMS. Data on this web site include hourly weather observations, 15-minute data from the Hanford Meteorological Monitoring Network, monthly climatological summaries, and historical data.

The Cascade Range, beyond Yakima to the west, greatly influences the climate of the Hanford Site by means of its rain shadow effect. The regional temperatures, precipitation, and winds are greatly affected by the presence of mountain barriers. The Rocky Mountains and ranges in southern British Columbia are effective in protecting the inland basin from the more severe cold polar air masses moving southward across Canada and winter storms associated with them.

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 about 3 meters per second (6 to 7 miles per hour), and highest during summer, averaging about 4 meters per second (8 to 9 miles per hour). Wind speeds that are well above average are usually associated with southwesterly winds. However, summertime drainage winds are generally northwesterly and frequently exceed 13 meters per second (30 miles per hour). 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

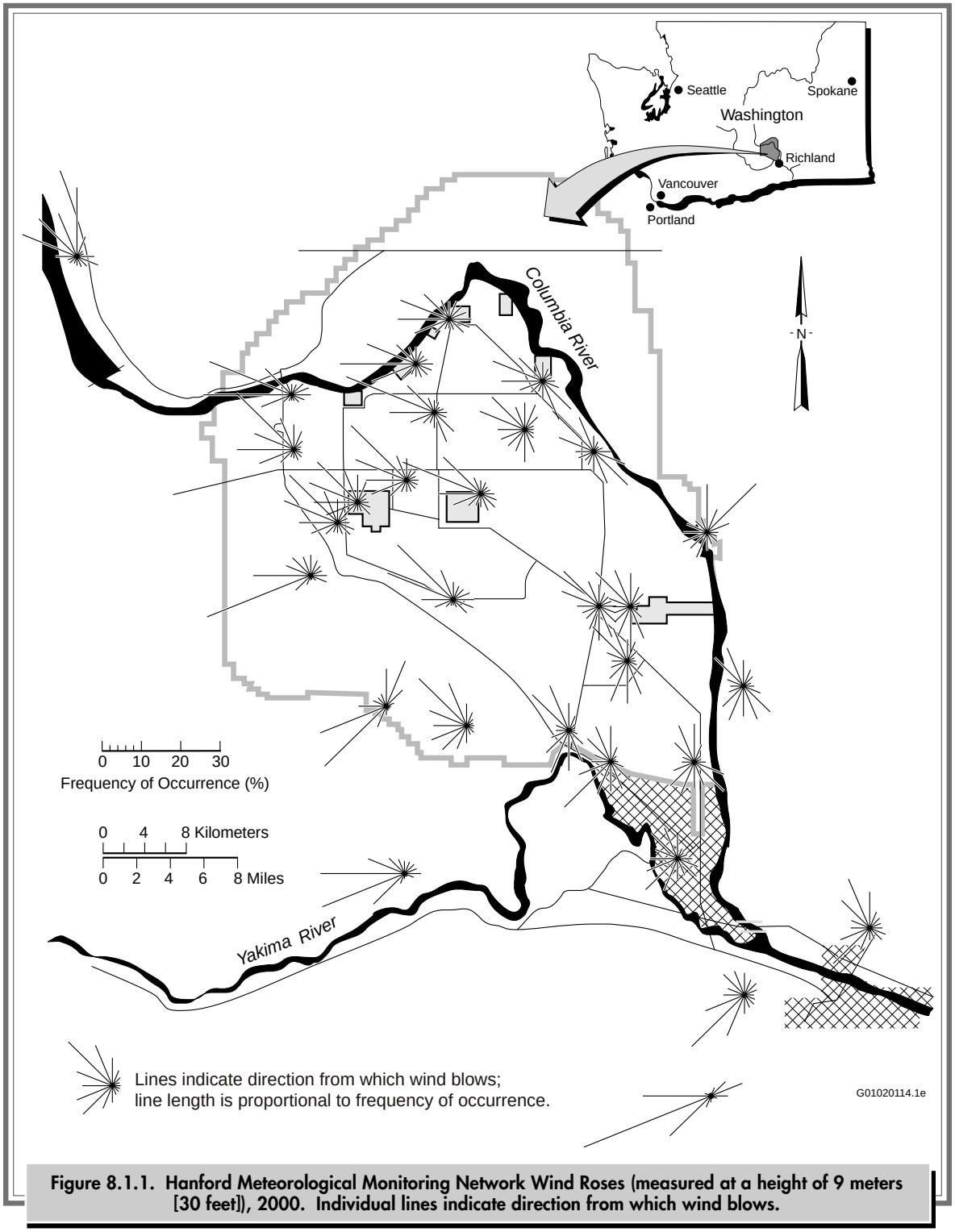

Figure 8.1.1. Hanford Meteorological Monitoring Network Wind Roses (measured at a height of 9 meters [30 feet]), 2000. Individual lines indicate direction from which wind blows.

dispersion conditions associated with neutral and unstable stratification exist ~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 moderate to extremely stable stratification exists ~66% of the time. Occasionally, there are extended periods of poor dispersion conditions, primarily during winter, that are associated with stagnant air in stationary high-pressure systems.

8.1.1 Historical Information

Daily and monthly averages and extremes of temperature, dew point temperature, and relative humidity for 1945 through 2000 are reported in PNNL-13469. From 1945 through 2000, 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 4.6°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 average annual relative humidity at the Hanford Meteorology Station is 54%. Humidity is highest during winter, averaging ~76%, and lowest during summer, averaging ~36%. Average annual precipitation at the Hanford Meteorology Station is 15.9 centimeters (6.26 inches). The wettest year on record, 1995, received 31 centimeters (12.3 inches) of precipitation; the driest, 1976, received 8 centimeters (2.99 inches). Most precipitation occurs during late autumn and winter, with more than half of the annual amount occurring from November through February. The snowiest winter on record, 1992-1993, received 142.5 centimeters (56.1 inches) of snow.

8.1.2 Results of 2000 Monitoring

Calendar year 2000 was slightly cooler than normal and precipitation was above normal.

The average temperature for 2000 was 11.4°C (52.6°F), which was 0.4°C (0.7°F) below normal (11.8°C [53.3°F]). Three months during 2000 were warmer than normal, two months were nearly normal, and seven months were cooler than normal. April had the greatest positive departure, 1.5°C (2.7°F); and November, at 3.4°C (6.2°F) below normal, had the greatest negative departure.

Precipitation for 2000 totaled 20.5 centimeters (8.08 inches), 129% of normal (15.9 centimeters [6.26 inches]). Snowfall for 2000 totaled 41.9 centimeters (16.5 inches) (compared to an annual normal snowfall of 35.1 centimeters [13.8 inches]).

The average wind speed for 2000 was 3.4 meters per second (7.5 miles per hour) which was 0.1 meters per second (0.2 miles per hour) below normal. The peak gust for the year was 25 meters per second (55 miles per hour) on November 4.

There were two dust storms recorded at the Hanford Meteorology Station during 2000. There have been an average of five dust storms per year at the Hanford Meteorology Station during the entire period of record (1945-2000).

Table 8.1.1 provides monthly and annual climatological data from the Hanford Meteorology Station for 2000.

Table 8.1.1. Monthly and Annual Climatological Data from the Hanford Meteorology Station, 2000

Hanford Meteorology Station, 40 kilometers (25 miles) northwest of Richland, Washington, latitude 46° 34'N, longitude 119° 35'W, elevation 223 meters (733 feet)

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, m/s	Departure[b]	Speed, m/s	Direction	Date
J	4.4	-3.4	0.5	+0.9	12.8	8[c]	-7.8	30[c]	2.8	+0.8	20.8	+10.9	79.7	+3.3	3.1	+0.2	23.7	SW	9
F	8.4	-0.9	3.8	+0.4	12.2	29	-6.1	25[c]	2.8	+1.3	1.3	-3.8	77.1	+6.8	2.9	-0.3	14.8	SW	2
M	13.6	0.6	7.1	-0.5	20.0	31	-4.4	7	2.4	+1.2	0	-0.8	59.7	+3.8	3.3	-0.4	19.2	WSW	14
A	20.8	5.2	13.0	+1.5	27.8	12	-1.7	5	1.5	+0.4	0	- T[d]	48.3	+1.1	3.5	-0.5	19.2	WSW	4
M	23.6	8.9	16.2	-0.1	30.6	21[c]	0.6	6	2.0	+0.7	0	0	44.2	+1.5	4.4	+0.4	22.8	WSW	9
J	29.1	13.0	21.1	+0.1	37.8	28	6.1	1	0.6	-0.3	0	0	39.0	+0.2	4.4	+0.3	19.7	W	14
J	33.1	15.3	24.2	-0.4	41.7	31	6.7	4	1.2	+0.7	0	0	35.7	+2.2	3.7	-0.2	19.7	NW	14
A	32.4	14.3	23.3	-0.6	40.0	9	9.4	19	T[d]	-0.7	0	0	33.7	-2.1	3.6	0	17.4	WNW	13
S	25.3	9.8	17.6	-1.2	33.3	14	0.0	23	1.4	+0.6	0	0	48.6	+5.9	3.4	0	20.6	W	8
O	17.7	4.7	11.2	-0.4	24.4	1	-1.1	22	1.4	+0.5	0	-0.3	61.8	+6.6	2.9	0	17.9	W	1
N	5.0	-2.8	1.1	-3.4	14.4	4	-7.8	15	2.7	+0.4	3.0	-1.5	79.5	+6.1	2.9	0	24.6	W	4
D	1.2	-3.8	-1.3	-0.9	9.4	17	-10.6	15[c]	1.7	-0.9	16.8	+2.3	85.2	+4.9	2.3	-0.3	20.1	W	17
Y[e]	17.9	5.1	11.4	-0.4	41.7	Jul 31	-10.6	Dec 15[c]	20.5	+4.6	41.9	+6.9	57.7	+3.4	3.4	-0.1	24.6	W	Nov 4

NOTE: See Appendix A, Table A.2 for unit conversion information.

(a) Measured on a tower 15 meters (50 feet) above the ground.

(b) Departure columns indicate positive or negative departure of meteorological parameters from 30-year (1961-1990) climatological normals.

(c) Latest of several occurrences.

(d) Trace.

(e) Yearly averages, extremes, and totals.

8.2 Ecosystem Monitoring and Ecological Compliance

L. L. Cadwell, J. L. Downs, R. P. Mueller, M. R. Sackschewsky, M. A. Simmons, B. L. Tiller, and K. A. Gano

The Hanford Site is a relatively undisturbed area of shrub-steppe that contains a rich, natural diversity of plant and animal species adapted to the region's semiarid environment. In a summary document based on 5 years of intense study, The Nature Conservancy of Washington (1999) reported that "The Hanford Site Biodiversity Inventory has produced remarkable findings in each of the biological subject areas that were addressed: plant communities, rare plants, noxious weeds, small mammals, insects (aquatic and terrestrial), amphibians and reptiles, and soil mosses and lichens (the microbiotic crust)." In 2000, the biodiversity of Hanford was further recognized as a national asset when portions of the site were designated as the Hanford Reach National Monument (65 FR 114). Ecosystem monitoring and ecological compliance have multiple objectives that support completion of Hanford's waste management and environmental restoration mission within this high quality and valued natural ecosystem. These objectives include:

- ensuring Hanford Site operational compliance with laws and regulations including the *Migratory Bird Treaty Act*, the *Bald and Golden Eagle Protection Act*, and the *Endangered Species Act*
- providing data for environmental impact and ecological risk assessments
- providing maps and information useful for biological resource impact mitigation during facilities expansion
- supporting Hanford Site land-use planning
- supporting natural resource protection within the DOE operated portions of the Hanford Site including the DOE managed portion of the Hanford Reach National Monument
- providing information useful to the tribes, Hanford natural resource stakeholders, and the public on the status of some of Hanford's most highly valued biological resources.

8.2.1 Chinook Salmon

Chinook salmon are an important resource in the Pacific Northwest; they are caught commercially and for recreation. Salmon are also of cultural importance to Native American tribes. 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 8.2.1). Between 1943 and 1971, a number of dams were constructed on the Columbia River. Their reservoirs eliminated most mainstem spawning areas, resulting in increased numbers of salmon spawning in the Hanford Reach. Fisheries management strategies aimed at maintaining spawning populations in the mainstem Columbia River also have contributed to the increases.

The number of fall chinook salmon redds counted in the Hanford Reach by aerial surveys

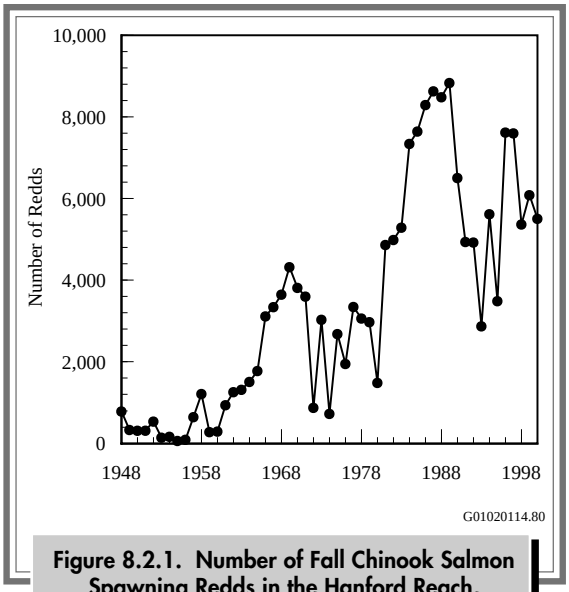

Figure 8.2.1. Number of Fall Chinook Salmon Spawning Redds in the Hanford Reach, 1948 through 2000

increased during the 1960s, 1970s, and 1980s until reaching a high in 1989 of nearly 9,000 (see Figure 8.2.1). In the early 1990s, redd counts declined to approximately one-third of the 1989 peak. The number of redds peaked again in 1996 and 1997 and has once again declined. In 2000, ~5,507 redds were observed, a decrease of 580 from 1999 and ~70% of the 1996 and 1997 totals. The main use areas were similar to previous years with the majority of redds occurring near Locke Island, the Columbia River islands between river miles 365–368 (Islands 8 through 10), and Vernita Bar. It should be noted that aerial surveys do not yield absolute redd counts because visibility varies, depending on water depth and other factors, and because the number of redds in high-density locations cannot be counted accurately. However, redd survey data generally agree with adult numbers obtained by counting migrating adult fish at fish ladders on the Columbia River. The Hanford Reach remains the most important spawning area for fall chinook salmon in the mainstem Columbia River.

8.2.2 Bald Eagle

The bald eagle is listed as a federally threatened species (50 CFR 17.11) and also as a Washington State threatened species (Washington State Department of Wildlife 1994); however, the bald eagle is currently under review for removal from the federal endangered species list. Protection for bald eagles on the Hanford Site is guided by the management plan contained in DOE/RL-94-150 and coordinated with representatives of the U.S. Fish and Wildlife Service.

Historically, bald eagles have wintered along the Hanford Reach of the Columbia River. The wintering eagles originate from various places, including interior Alaska, British Columbia, Northwest Territories, Saskatchewan, and possibly Manitoba. However, when monitoring began in the early 1960s, numbers were low (Figure 8.2.2). Following passage of the *Endangered Species Act* (Appendix G, Table G.1), the number of wintering bald eagles generally has

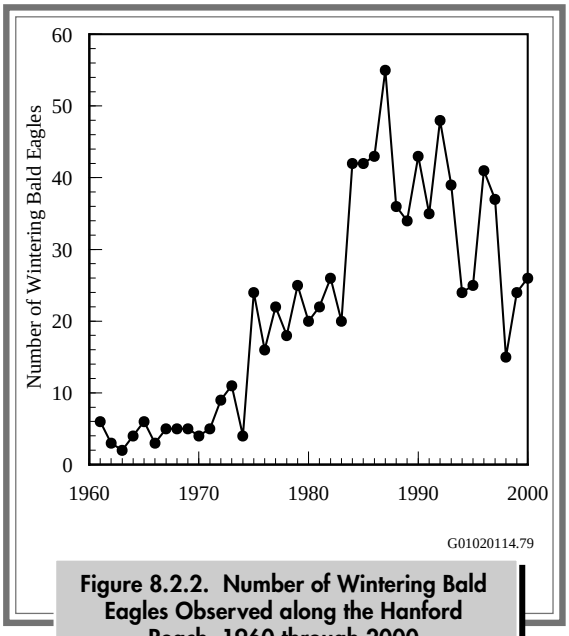

Figure 8.2.2. Number of Wintering Bald Eagles Observed along the Hanford Reach, 1960 through 2000

increased. Primary reasons for this increase are 1) reduced persecution in Alaska, 2) protection of bald eagles at nesting locations, and 3) nationwide elimination of dichlorodiphenyltrichloroethane (DDT) as an agricultural pesticide in 1972.

The number of nesting eagles was estimated at ~25,000 in the lower 48 states when the bird was adopted as our national symbol in 1782. From fewer than 450 nesting pairs in the early 1960s, there are now more than 4,000 nesting pairs in the lower 48 states. When eagles were federally listed as endangered, recovery goals included at least 800 nesting pairs collectively in California, Idaho, Montana, Oregon, Utah, and Washington (i.e., the Pacific states). In 1997, wildlife experts estimated more than 1,200 nesting pairs in the Pacific states region. Only two pairs of nesting eagles are known to occur in southeastern Washington.

A maximum count of 26 eagles (11 adults and 15 juveniles) was observed along the Hanford Reach in 2000. Five surveys were successfully completed between December 1, 2000 and January 26, 2001. This maximum count is similar to those seen in the late 1970s and early 1980s and indicates that the low count in 1998 was likely a reflection of changes in food availability near the birds nesting territories and hence winter migration patterns.

Changes in the number of eagles on the Hanford Site generally have corresponded to changes in the number of returning fall chinook salmon, a major fall and winter food source for eagles (compare Figures 8.2.1 and 8.2.2 to see similarity in the patterns of salmon redd counts and bald eagle counts). In 2000, one eagle pair defended an historic nest site through mid-March. This nesting attempt by an eagle pair, one of which was just reaching adulthood, suggests the birds were born and raised near this area. A nest site protection buffer of 0.8 kilometer (0.5 mile) around the nest was initiated for all Hanford activities in December 2000.

8.2.3 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. These structures are used extensively by nesting hawks on the site because of the relative scarcity of trees and cliffs. The ferruginous hawk is a Washington State threatened species (Washington State Department of Wildlife 1994) as well as a U.S. Fish and Wildlife Service species of concern for eastern Washington (50 CFR 17.11). Approximately one quarter of the state's ferruginous hawk nesting territories are located on the site.

Since 1995, the number of ferruginous hawks nesting on the Hanford Site has ranged from 7 to 12. There were eight active ferruginous hawk nests in 2000, the same number as in 1999. Additionally, an osprey (*Pandion haliaetus*) nest was seen in 2000 and was the first recorded nesting on the Hanford Site. 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 site and adjacent lands was completed in 1996 (Leary 1996). That work suggested that ferruginous hawks nest on the site because of suitable, disturbance-free habitat, and the proximity of agricultural fields available for foraging.

Ten ferruginous hawks nesting in south central Washington State were captured in 1999 and tagged with satellite telemetry transmitters. In 2000, two more birds were captured and tagged. The transmitters send signals to satellites that relay location information back to ground stations. From there, biologists retrieve the information daily via computer, within 2 to 6 hours of signal reception, to track

the hawk's movements. The 2-year study lead by the Washington State Department of Fish and Wildlife, in cooperation with Pacific Northwest National Laboratory, was initiated in 2000 to learn more about the bird's migration patterns and help recover their declining populations nationwide.

8.2.4 Rocky Mountain Elk

Rocky Mountain elk did not inhabit the Hanford Site when it was established in 1943. Elk were first observed on the Fitzner/Eberhardt Arid Lands Ecology Reserve in the winter of 1972. A few animals stayed and reproduced. The Rattlesnake Hills elk herd 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 747 animals at the end of the 1999 hunting season (Figure 8.2.3). A roundup conducted by the U.S. Fish and Wildlife Service and Washington State Department of Fish and Wildlife in mid-March 2000 resulted in the removal of 171 animals. Pacific Northwest National Laboratory estimated 32 calves (±2 calves standard error) per 100 cows were recruited into the population, bringing the total count to 660 animals in fall 2000. The 2000 minimum estimated harvest was ~207 animals, and census data after the hunting seasons found ~440 animals remaining in the Rattlesnake Hills.[a] The larger number of elk harvested in 2000 (~30% of the population) may be related to the hunting strategy developed in 1999, that established three separate hunting seasons prior to the opening of the season. In addition, the June wildfire (see Section 5.0) resulted in more elk using private range and crop lands adjacent to the Hanford Site during the hunting season.

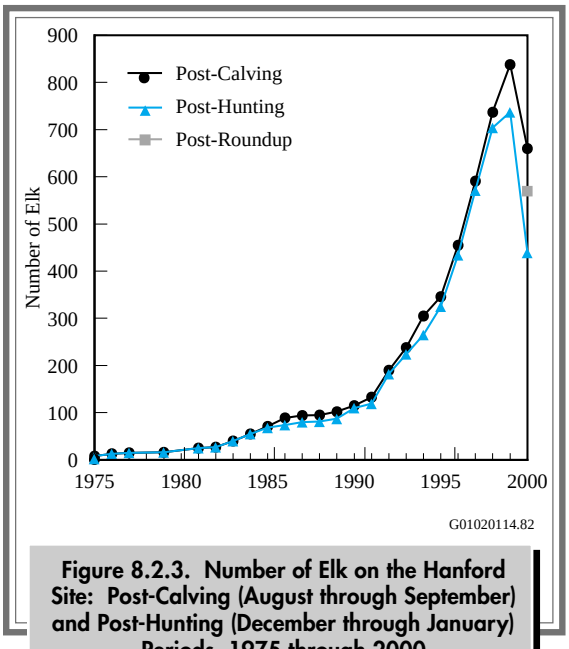

Figure 8.2.3. Number of Elk on the Hanford Site: Post-Calving (August through September) and Post-Hunting (December through January) Periods, 1975 through 2000

In 2000, elk were monitored as part of a special study of movement and the population dynamics of the Rattlesnake Hills elk herd (PNNL-13331). This work was intended to monitor the population characteristics of the herd and continue to provide the scientific information to detect any impact Hanford Site operations may have on the elk population. The information also contributes to the currently evolving Rattlesnake Hills elk herd management issues and documents the success of herd reduction efforts.

The frequency of elk crossing State Highway 240 and the occupancy of central Hanford by elk increased after the June 2000 fire.[b] There were four elk/vehicle collisions in calendar year 2000 as a result of the increased highway crossings. The collision sites generally corresponded to the location of a bull elk/vehicle collision on April 7, 1998 and another February 6, 1999 (Figure 8.2.4). All of these elk/vehicle collisions occurred between road-mile markers 13 and 19 and correspond to elk movements documented in PNNL-13331.

(a) Brett Tiller, Pacific Northwest National Laboratory, Richland, Washington, 2000, unpublished data.
(b) Ibid.

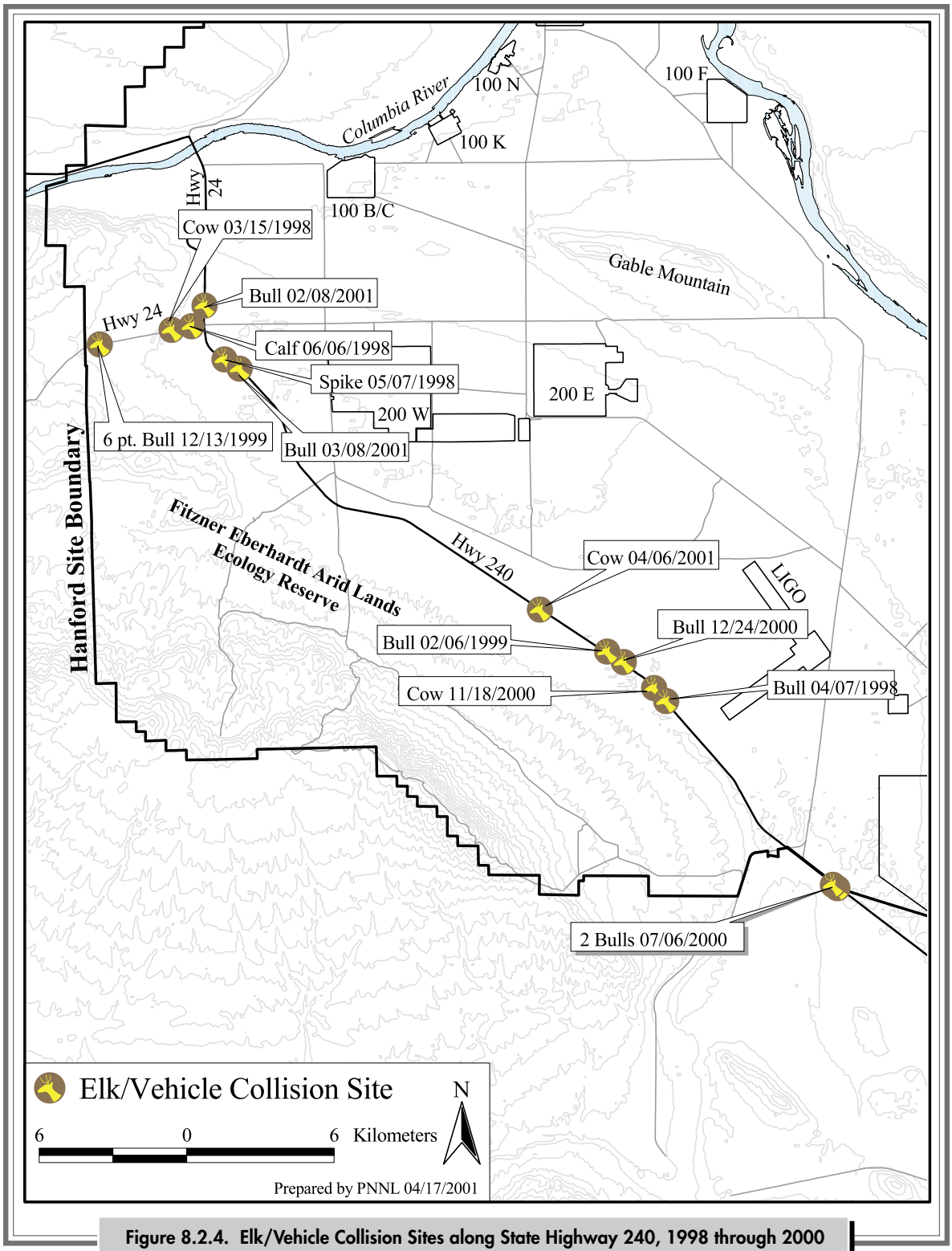

Figure 8.2.4. Elk/Vehicle Collision Sites along State Highway 240, 1998 through 2000

Weekly aerial surveys of 23 radio-collared elk showed that the number of times animals crossed into central Hanford in groups of one or more peaked at 15 during December 2000.[c] This represents the minimum number of times that animals crossed the highway since 1) single elk or entire herds may have crossed without radio-equipped animals present, 2) radio-equipped animals may have crossed State Highway 240 twice within a week and, therefore, did not get counted as crossing at all, and 3) radio-equipped animals may have crossed more than twice within any given week.

During fall and winter 2000-2001, the increasing number of elk crossing State Highway 240 resulted in an increased elk use of central Hanford. By mid-winter, ~80 animals were within the area bounded by State Highway 240 and the Columbia River. The majority of these animals occupied a site near a surface contamination area south of the 200-East Area; however, very few elk tracks or elk observations were within the posted radiation zone.[d] Tissue samples from 1999 and 2000 indicated the animals did not contain elevated levels of radionuclides from Hanford-derived sources (see Section 4.5). Long-term ecological impact plots are located in these areas and future monitoring will provide additional information for managing the elk population in this area.

8.2.5 Mule Deer

Systematic roadside observations have been conducted during the post-hunting (December-January) periods since 1993. The surveys are conducted to monitor trends in age and sex ratios of mule deer, to examine trends in the relative abundance of deer on the Hanford Site, and to monitor the frequency of testicular atrophy in mule deer. The survey route is divided into a north and south region just north of the Old Hanford Townsite.

Epidemiological data and microscopic examinations of mule deer (*Odocoileus hemionus*) residing on the Hanford Site in the early 1990s revealed that nearly one quarter of the mule deer (bucks) had undergone some level of testicular atrophy (degeneration of the testicles after maturity). A special study was initiated in 1992 to describe the occurrences on a spatial scale and to examine possible influences of contaminants from the Hanford Site. The results of this study (Tiller et al. 1997; PNNL-11518) found no single factor as the primary cause, and analyses of affected animal movement patterns revealed no spatial correlations with Hanford Site contamination plumes. In addition, contaminant levels found within the study animals were well below levels that have been shown to cause testicular atrophy in experimental cases. Also, enzyme activation analysis failed to indicate the presence of manmade contaminants in the livers of either normal or affected animals.

Tiller et al. (1997) described a positive relationship between the frequency of the anomaly and the age class distribution within the population. Severely degenerative/atrophic testes were found to occur only in 5- to 12-year-old bucks. Since hunting is not allowed on Hanford Site, deer survival rates are high and there is a corresponding increase in the number of animals in the older (5+ years) age classes, thus magnifying the frequency of this condition in the Hanford Site deer population.

Figure 8.2.5 illustrates trends in the observed frequency of bucks (number of affected males per 100 males) that exhibited signs of testicular atrophy (velvet-covered antlers) and atrophic (shrunken)

(c) Brett Tiller, Pacific Northwest National Laboratory, Richland, Washington, 2000, unpublished data.
(d) Ibid.

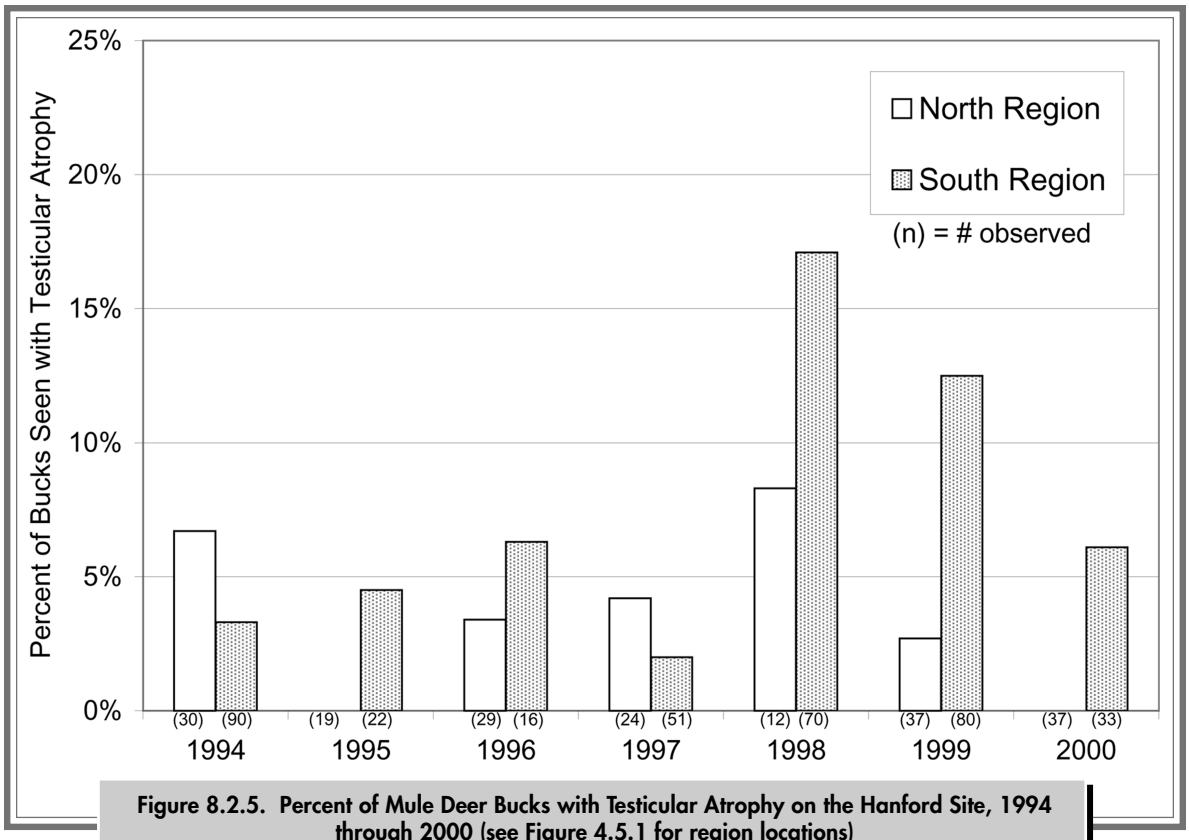

Figure 8.2.5. Percent of Mule Deer Bucks with Testicular Atrophy on the Hanford Site, 1994 through 2000 (see Figure 4.5.1 for region locations)

testicles during the post-hunting roadside surveys from 1994 through 2000. In 1993, an estimated 15% of the males were affected on the Hanford Site (Tiller et al. 1997). Ten affected animals were euthanized in 1994 and 1995 to obtain a variety of tissue samples for chemical and histologic examination. Between 1994 and 1997, the percentage of affected males decreased to around 5% and remained relatively constant; however, survey results in 1998 and 1999, indicated the frequency of the anomaly returned to 1993 levels (15%). Also, more animals in the south region appeared to be affected (see Figure 8.2.5). Survey results obtained in 2000 indicate the frequency of bucks with testicular atrophy is down (~6% [2 of 33] in south region deer herds and 0% [0 of 37] in the north region deer herds).

The changes in proportion affected may be related to changes in the proportion of older age class males (greater than 5 years of age) alive in the resident deer herd. In 1994 and 1995, ten older, affected animals were removed for histological and chemical analyses, while in 2000, many deer in the north region herd were illegally harvested along the Columbia River shoreline. Continued deer monitoring will help determine if age is indeed the only mechanism responsible for the observed change.

The number of fawns surviving the first year after birth is used to document population-level changes in the deer herds. Figure 8.2.6 illustrates trends in fawn:doe ratios from 1994 through 2000 in the north and south region deer herds. In both regions, fawn survival declined substantially from over 20 fawns per 100 does in 1994 to less than 10 fawns per 100 does in 1997. Since 1997, fawn survival has recovered to over 45 fawns per 100 does in 2000, which is similar to other deer populations in the shrub-steppe ecosystem. The observed trends in the rates fawns survive the first year suggest a cyclic

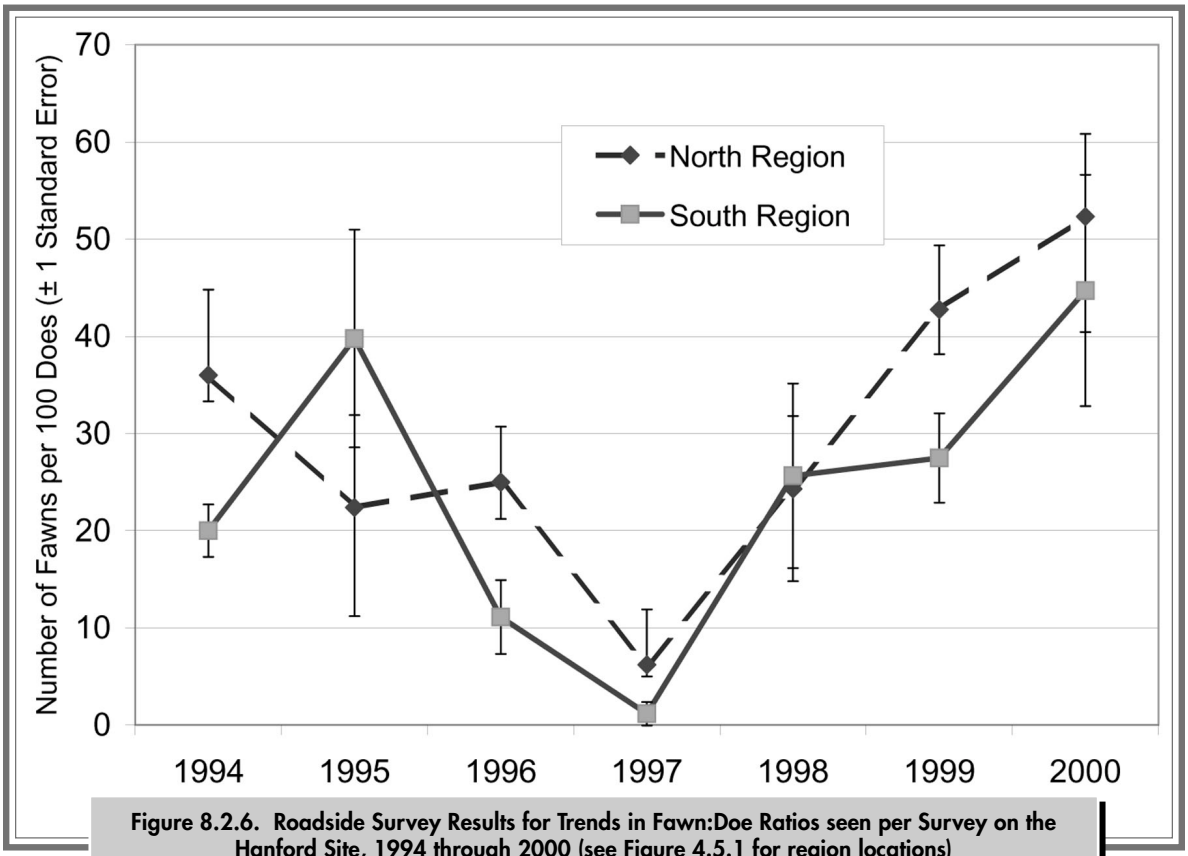

Figure 8.2.6. Roadside Survey Results for Trends in Fawn:Doe Ratios seen per Survey on the Hanford Site, 1994 through 2000 (see Figure 4.5.1 for region locations)

pattern. It is unknown whether the observed cycle is the result of natural processes or man-induced change.

Continued roadside surveys to monitor both the frequency of testicular atrophy and to document the demographic trends of mule deer on the Hanford Site will allow project scientists to evaluate the health of the deer population and attempt to isolate factors contributing to any observed changes.

8.2.6 Plant Biodiversity Inventories

The Hanford Site contains biologically diverse shrub-steppe plant communities that have been protected from disturbance, except for fire, over the past 55 years. This protection has allowed plant species and communities that have been displaced by agriculture and development in other parts of the Columbia Basin to thrive at Hanford. Surveys and mapping efforts have documented the occurrence and extent of rare plant populations and plant community types on the Hanford Site (Nature Conservancy 1999). Populations of rare plants include taxa listed by Washington State as endangered, threatened, or sensitive (see Appendix G) and the locations of species that are listed as review group 1 (i.e., taxa in need of additional field work before status can be determined) (Washington Natural Heritage Program 1997). Data are collected for plant populations and plant communities to develop baseline information and to monitor any changes resulting from Hanford operations. The data provide information that is critical to site planning processes and land-use policy development.

More than 100 rare plant populations of 31 different taxa are found at the Hanford Site (Figure 8.2.7). The U.S. Fish and Wildlife Service has designated five of these 31 taxa (including the two new species, *Eriogonum codium* and *Lesquerella tuplashensis* [Umtanum buckwheat and White Bluffs bladderpod]) as species of concern in the Columbia River Basin Ecoregion. These two new species are proposed as candidates for federal listing. 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 could support populations of rare annual forbs that have been documented in adjacent habitat.

Surveys in 2000 continued to indicate increases in the numbers of *Erigeron piperianus* (Piper's daisy), a species of concern occurring in the 200 Areas. Populations of another species of concern in the Columbia River Basin Ecoregion, *Rorippa columbiae* (persistent sepal yellowcress), do not appear to have experienced significant recovery after declining as a result of the high river flow levels over the past 4 years. *Rorippa columbiae* is a rhizomatous perennial found in moist soils along the Columbia River within the Hanford Site. This species is often inundated by river flows, but little is known concerning long-term survival under continuous inundation. Surveys in 2000 continued to show low numbers of stems at a cobble beach adjacent to the 100-F Area on the Hanford Reach and on Island 18 across from the 300 Area (Table 8.2.1), and no stems were observed in flower between 1997 and 1999. Number of stems found in 2000 on Locke Island did increase from previous years with ~4% of the plants exhibiting flowers.

Maps showing the extent and distribution of types of vegetation cover found on the Hanford Site have been updated to include recent work delineating the plant communities in central Hanford (Salstrom and Easterly 1997; Nature Conservancy 1999). The updated maps were merged with existing maps for the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit, the Wahluke Wildlife Unit, and the Saddle Mountain Unit of the Hanford Reach National Monument. The plant community map will be updated in 2001 to reflect the changes in plant community composition resulting from the wildfire in June 2000 (see Section 5.0). These maps are documented in the draft of the Hanford Site Biological Resource Management Plan (DOE/RL-96-32) and can be viewed on the Ecosystem Monitoring Project web page (www.pnl.gov/ecology/ecosystem).

8.2.7 Sagebrush Die-Off

Big sagebrush (*Artemisia tridentata* subspecies *wyomingensis*) is the most common shrub component of shrub-steppe vegetation on the Hanford Site. Sagebrush stands represent an important resource for wildlife that are dependent on sagebrush habitat to survive and successfully reproduce, such as black-tailed jackrabbits, sage sparrows, sage grouse, and loggerhead shrikes. Since 1993, areas of sagebrush die-off have been documented in stands near the 100-D Area, the cause of which is not known. Shrub die-off is not uncommon in the intermountain west and such episodes have been reported from British Columbia, Idaho, Nevada, Utah, and Wyoming (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). To date, no evidence exists suggesting any relationship between Hanford Site operations and the distribution and extent of the die-off of sagebrush. Big sagebrush is the only vascular plant species that has declined in the areas monitored. Other shrubs, such as hopsage (*Grayia spinosa*) and bitterbrush (*Purshia tridentata*), with similar deep root systems appear unaffected. In the monitored areas, herbaceous plant

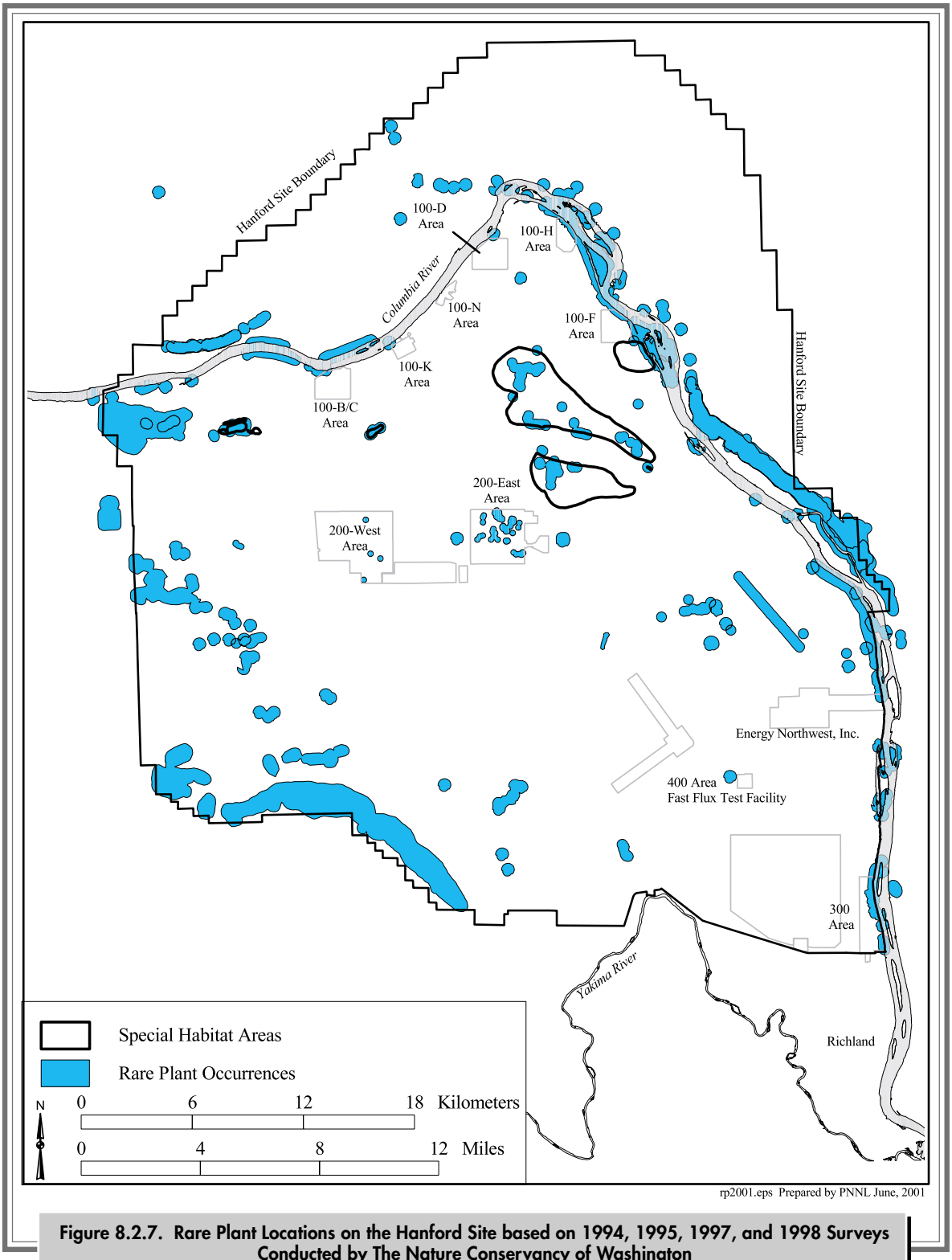

Figure 8.2.7. Rare Plant Locations on the Hanford Site based on 1994, 1995, 1997, and 1998 Surveys Conducted by The Nature Conservancy of Washington

Table 8.2.1. Numbers of *Rorippa columbiae*[a] Stems Counted along the Hanford Reach of the Columbia River, 1994, 1998, 1999, and 2000

Survey Location	1994 Counts	1998 Counts	1999 Counts	2000 Counts
100-F beach	>15,000	70	94	196
Locke Island	>10,000	117	Not surveyed[b]	1,038
Island 18[c]	>10,000	0	Not surveyed	19

(a) Persistent sepal yellowcress.
(b) High water levels prevented access to populations.
(c) Located in the Columbia River at the 300 Area.

species, such as native bunchgrasses, also appear to remain relatively healthy and vigorous.

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). The resulting report indicated that a total area of 1,776 hectares (4,388 acres) showed evidence of sagebrush decline, with a central portion of 280 hectares (692 acres) where shrub death was estimated to be ~80% or greater. Observations of shrub vigor (percent canopy defoliation) show continuing declines in shrub health in the die-off areas and along the boundary of the die-off areas.

Annual surveys from 1997 through 1999 of shrubs within the die-off areas indicate that sagebrush plants continue to decline. Shrubs along transects were classified by amount of live canopy in the following manner: dead, less than 50% live canopy, 50 to 90% live canopy, and more than 90% live canopy. These measurements indicated that though few shrubs actually died along each measured transect, 10% to 35% of shrubs measured declined by at least one category between 1997 and 2000. Surveys in 2000 indicate no further decline of the sagebrush (Table 8.2.2). However, the data also indicate a lack of establishment of new shrub seedlings that would be necessary for recovery of the population.

Table 8.2.2. Decline of Sagebrush Conditions Measured along Six Transects within and along the Boundaries of the Sagebrush Die-Off Area on the Hanford Site

Transect	% Dead 1997	% Dead 1999	% Dead 2000	% >90% Live Canopy 1997	% >90% Live Canopy 1999	% >90% Live Canopy 2000
1 (n=27)	95	95	95	5	5	5
2 (n=34)	18	18	18	41	35	22
3 (n=31)	81	84	84	10	0	0
4 (n=50)	48	48	48	14	4	6
5 (n=61)	15	16	20	43	15	24
6 (n=51)	18	18	18	54	27	27

n = Number of shrubs.

8.2.8. Ecological Compliance

DOE Richland Operations Office policies require that all projects having the potential to adversely affect biological resources have an ecological compliance review performed prior to initiation of the project. This review ensures that the DOE is in compliance with the *Endangered Species Act* and the *Migratory Bird Treaty Act*. It also ensures that other significant resources such as Washington State listed species of concern, wetlands, and native shrub steppe habitats are adequately considered during the project planning process. Where effects are identified, mitigation action is prescribed. Mitigation actions can include avoidance, minimization, rectification, or compensation.

Since many projects occur during periods of the year when the plants are not growing and plants are difficult to identify or evaluate, each of the operational areas (200-East and 200-West, all of the 100 Areas, and the 300 Area) are surveyed each spring. These baseline surveys provide information about the habitat types, and species inventories and abundance, which can then be used throughout the rest of the year to assess potential project impacts. Examples of the baseline survey maps are available at http://www.pnl.gov/ecology/ecosystem/Compliance/comp.html.

A total of 98 ecological compliance reviews were performed during 2000 in support of general Hanford Site activities. An additional 63 reviews were performed in support of environmental restoration activities. The total number of reviews prepared in 2000 (161) was slightly less than in previous years (Table 8.2.3).

Table 8.2.3. Ecological Reviews Performed by Pacific Northwest National Laboratory, 1997 through 2000

Calendar Year	100 Areas	200 Areas	300 Area	Other[a]	Total
1997	8	79	44	33	164
1998	42	91	28	47	208
1999	36	72	36	52	196
2000	36	52	27	47	161
Totals	121	294	135	179	729

(a) Includes the 400, 600, 700, Richland North, and former 1100 Areas.

8.3 Cultural Resources

L. L. Hale and D. W. Harvey

The U.S. Department of Energy (DOE), Richland Operations Office, established a cultural resources program in 1987 that is 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 for the cultural resources program on the Hanford Site throughout 2000. The U.S. Fish and Wildlife Service and DOE Richland Operations Office have managed cultural resources on the Fitzner/Eberhardt Arid Land Ecology Reserve Unit and North Slope Unit of the Hanford Site since October 1999. Thus, management of archaeological, historical, and traditional cultural resources at the Hanford Site was provided in compliance with the *American Indian Religious Freedom Act; Antiquities Act*; *Archaeological and Historic Preservation Act*; *Archaeological Resources Protection Act*; Executive Order 11593, *Protection and Enhancement of the Cultural Environment* (36 FR 8921); *Historic Sites, Buildings, and Antiquities Act*; *National Historic Preservation Act*, as amended; and *Native American Graves Protection and Repatriation Act*.

8.3.1 Monitoring Cultural Resources

The DOE Richland Operations Office provides the stewardship of all onsite archaeological resources, traditional-use areas, cultural landscapes, Native American cemeteries and places with human remains, paleontological deposits, and historic period properties as manager of the Hanford Site. The DOE Richland Operations Office, therefore, has the responsibility for determining whether management and protection policies for the Hanford Site are effective and when they are inadequate. The Hanford Cultural Resources Laboratory has maintained a monitoring program since 1987 to determine the impact of DOE Richland Operations Office policies and to safeguard cultural resources from adverse effects associated with natural processes or unauthorized excavation and collection that violate the *Archaeological Resources Protection Act* or the *Native American Graves Protection and Repatriation Act*.

Monitoring conducted during 2000 focused on four site or place categories: Locke Island's erosion transects, archaeological sites with natural and visitor impacts, historic buildings, and places with Native American burials.

Monitoring erosion at Locke Island has been ongoing since 1994. Locke Island, located 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. The island has sustained loss due to erosion along its eastern shoreline that has affected archaeological materials. Recent studies have shown that this is due to movement of a large landslide on the eastern side of the Columbia River.

In the 1960s and 1970s, intensive irrigation development began to occur east of Locke Island, above the White Bluffs, which form the eastern boundary of the Columbia River channel in this area. As a result, the White Bluffs began to show geological failures as excess irrigation water seeped

out along the bluffs. One of the largest such failures, known as the "Locke Island Landslide," is located just east of Locke Island. By the early 1980s, this landslide had moved westward into the river channel toward the island and was diverting the current at the island's eastern perimeter. Erosion of the eastern bank of the island accelerated, threatening the cultural resources. By the early 1990s, the erosion had exposed cultural features and artifacts along the bank, leading to the beginning of intermittent monitoring of the cutbank. In 1994, DOE initiated more scheduled, systematic monitoring of island erosion to better understand the physical processes involved as well as mitigate ongoing loss of the archaeological record (PNNL-11970).

Erosion monitoring continued at the Locke Island's erosion transects during 2000. The greatest loss recorded at any one monitoring transect was a total of 2.1 meters (6.9 feet), as measured perpendicularly from the Columbia River (Figure 8.3.1). This amount of erosion was less than the 19.6 meters (64.3 feet) of horizontal cut bank lost to the river at a single transect in 1997 during a period of high water flow (PNNL-11970). The overall reduction in erosion observed from 1997 to 2000 was likely attributable to several factors including a slow and steady snowmelt following the 1998-1999 winter season, less dramatic river fluctuations during periods of high water, and a wider channel on the east side of Locke Island (Figure 8.3.2).

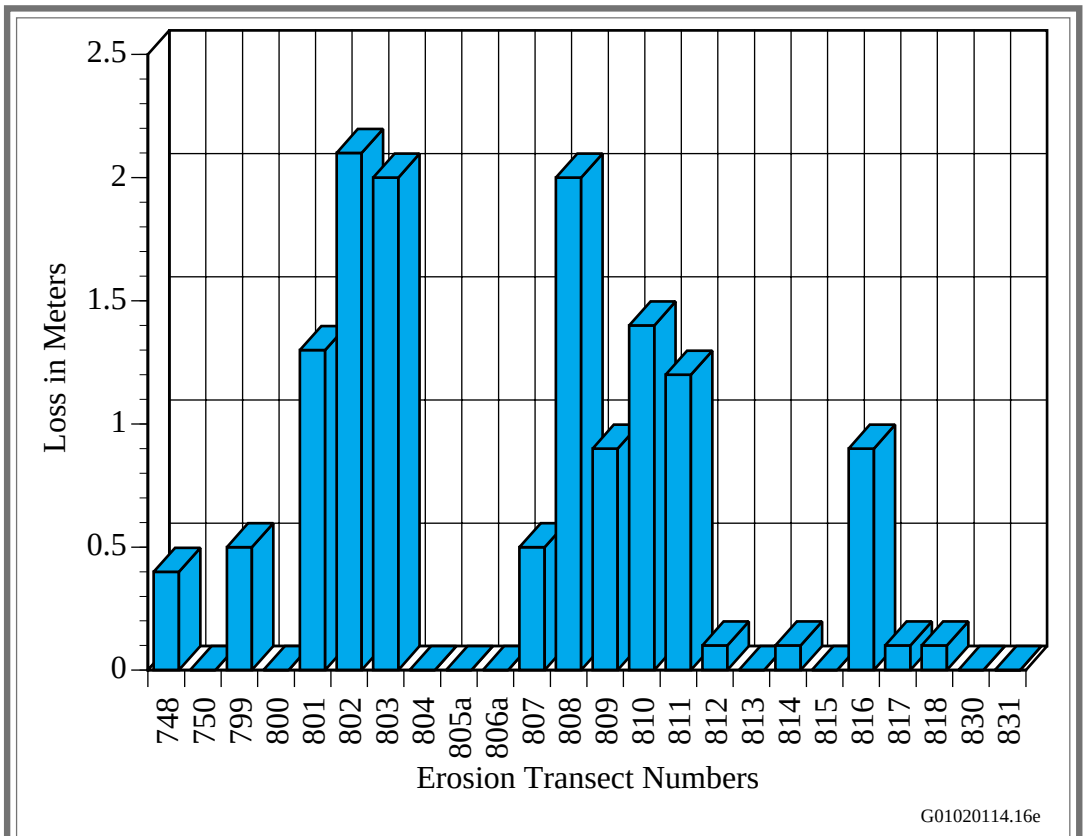

Figure 8.3.1. Measured Loss at Locke Island's Erosion Transects during Calendar Year 2000. Transects are spaced at eroding cutbanks along the full length of the island's eastern shoreline.

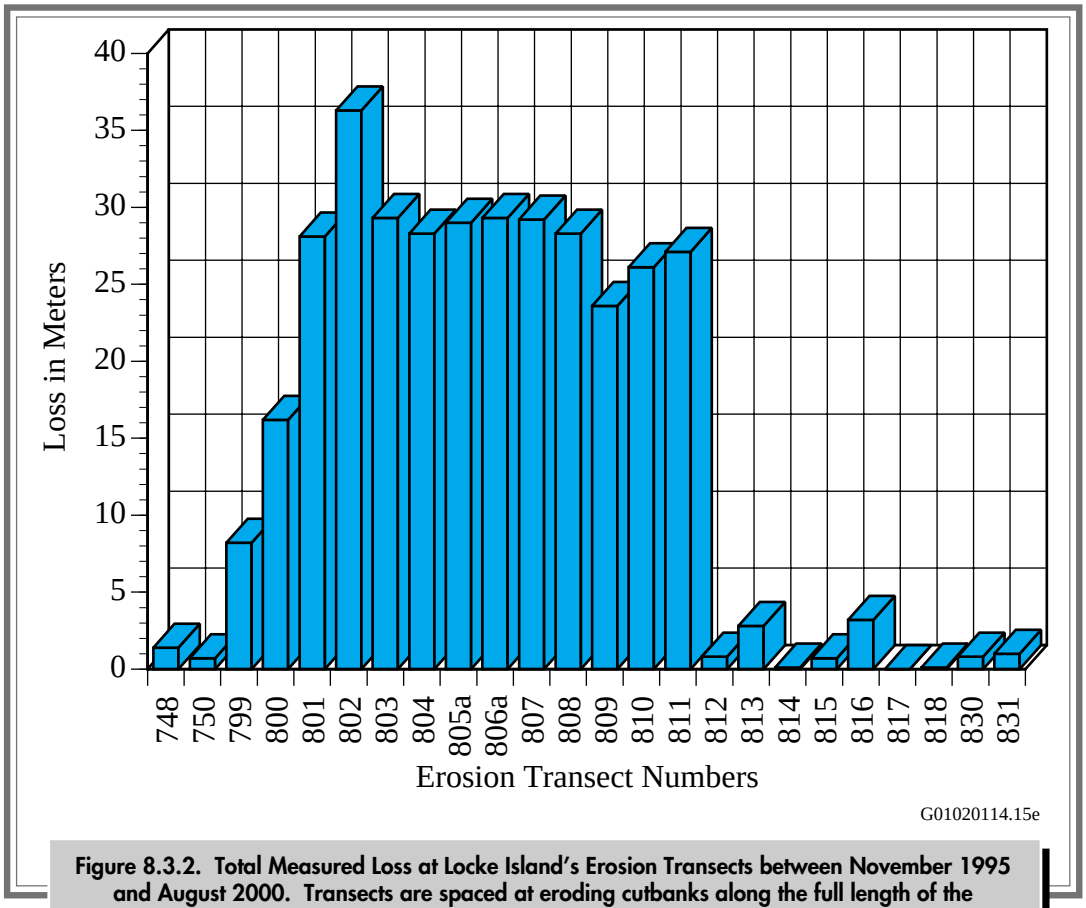

Figure 8.3.2. Total Measured Loss at Locke Island's Erosion Transects between November 1995 and August 2000. Transects are spaced at eroding cutbanks along the full length of the island's eastern shoreline.

Monitoring associated with the second category, archaeological sites with natural and visitor impacts, was initiated in 1998 and continued in 2000. Ninety-six archaeological sites were monitored to gather empirical data about

- the natural characteristics of each site (i.e., landform, stratigraphy)
- the processes adversely impacting the site (such as riverbank erosion, wind erosion, or human visitation)
- the trends in change at the site (e.g., likelihood of increasing erosion or eventual stability).

Monitoring stations established at each archaeological site in this category facilitated the collection of standardized data unique to each site. In 2000, effects observed and measured at these sites were due to recreational use, visitor impact, and/or natural weathering processes. The data collected at these archaeological sites will be used to monitor changes that may impact the site, predict outcomes, and proactively manage other similar archaeological sites across the Hanford Site.

The third category, monitoring of historic buildings, focused on Bruggemann's Warehouse, the only cobblestone structure remaining on the Hanford Site, and the White Bluffs Bank. Both buildings' structural integrity was photographed and locations of potential failure were identified. Future monitoring inspections will continue to gather data about any crack widening and structural leaning that may occur.

The final category, places with cemeteries or known human remains, are sacred to the Wanapum People, Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe. These places were monitored to document baseline conditions, determine whether wind or water erosion had caused exposures of human remains, and ensure that violations of the *Native American Graves Protection and Repatriation Act* and/or *Archaeological Resources Protection Act* were not present or ongoing at these important places. During 2000, all of the places were monitored. Overall, places with human remains were found to be stable in 2000. However, one *Archaeological Resources Protection Act* violation (collector digging) was noted at one cemetery or place with human remains.

A total of 96 archaeological sites, a building, and cemetery or burial locations were monitored during 2000. Of the incidents recorded at these monitored places, 31 of 119 were related to natural causes such as animal trailing and digging, wind-caused deflation or aggradation, and water erosion. Sixteen percent of the incidents were determined to be human-related causes such as vehicle traffic where sites were exposed in roads, or recreational activities such as fishing or duck hunting. Two percent of the incidents were found to be associated with recent collector digging within archaeological site boundaries and/or surface collection of artifacts. Such collector digging and artifact collection on Federal lands is in violation of the *Archaeological Resources Protection Act*.

8.3.2 Native American Involvement

Members of the Confederated Tribes of the Umatilla Indian Reservation, Yakama Nation, Nez Perce Tribe, and Wanapum People were actively involved in the cultural resources program during 2000. Each tribe was involved in deciding DOE's cultural resource program work scope, budget, and schedule. Monthly meetings on cultural resource issues provided a venue for the exchange of information between DOE, tribal staff members, and site contractors about projects and work on the Hanford Site. These meetings included discussions of sitewide projects dealing with a wide range of topics: the groundwater/vadose zone, sagebrush mitigation, survey of Hanford's large dune fields, elk relocation and trapping efforts, and Hanford's native plants. Tribal staff and site contractors worked together during the completion of several field surveys to identify and record cultural features, sites, and landscapes in advance of new construction and archaeological test excavations and to monitor numerous projects requiring excavation during the year.

Two Wanapum People members continued assisting with cultural resource surveys, site form preparation, records management, and equipment use in 2000. In addition, interviews were conducted with Wanapum elders concerning traditional cultural properties on the Hanford Site.

8.3.3 Public Involvement

Public involvement is an important component of a cultural resources management program. To accomplish this, DOE developed mechanisms that allow the public access to cultural resources information and the ability to comment and make recommendations concerning the management of cultural resources on the Hanford Site. These mechanisms were woven into a draft involvement plan that includes input provided by the public and Hanford Site staff over the past several years.

Workshops were organized and conducted to seek public comment on a variety of cultural resource initiatives and projects undertaken by DOE. Comments were sought on an update on the draft Hanford Cultural Resources Management Plan and a review of the draft Public Involvement Plan. The purpose of the Public Involvement Plan was to determine the process that the Hanford Cultural Resources Program will follow to interact with interested groups. Major interest groups involved in assisting DOE with cultural resource initiatives included the B Reactor Museum Association, White Bluffs - Hanford Pioneer Association the Washington State Railroad Historical Society, and local historical societies and museums.

At public issues exchange workshops, there were discussions pertaining to a White Bluffs Memorial on the Hanford Site. The memorial is planned to commemorate the veterans of World War II from the Priest Rapids Valley and the former Euro-American and Native American residents who were resettled following government acquisition of the Hanford Site in 1943. There was also a presentation on studies conducted for the Bruggemann Warehouse and the White Bluffs Bank.

Additional discussions at the workshop focused on the ongoing curation of Manhattan Project and Cold War era artifacts into the Hanford collection, and an update on the draft *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990*, which was completed and distributed for public review. Comments were sought on mitigation plans for the Hanford Generating Plant (Building 185-N) Project.

These workshop discussions indicated strong support for the use of B Reactor as a publicly accessible museum. A millennium grant proposal to fund renovation of B Reactor was discussed as were the preservation of B Reactor artifacts and a proposal for a boat dock on the Columbia River at 100-B to serve the B Reactor museum.

Discussions also centered on the ongoing effort to document the oral histories of early residents of the Hanford Site. In 2000, an Oral History Pilot Project was completed. The purpose of the pilot project was to identify pre-1943 Euro-American settlement themes for oral history interviews of former residents of areas now part of the Hanford Site. An initial outcome of the pilot project was the oral history interview of Judge Lloyd Wiehl, former resident of East White Bluffs and the Wiehl Ranch.

Updates were given in July on the effects of the 2000 Hanford Site wildfire on the site's cultural resources. Discussions focused on the damage to the anti-aircraft artillery sites and the former Nike installation on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit (see Section 5.0).

8.3.4 Section 106 Activities

Pursuant to Section 106 of the *National Historic Preservation Act*, cultural resources reviews must be conducted before each proposed ground disturbance or building alteration/demolition project can take place. Although cultural resource reviews are required to identify properties within the proposed project area that may be eligible for, or listed in, the National Register of Historic Places and evaluate the project's potential to effect any such property, the recently modified cultural resource review process includes two review options. The first option allows DOE to determine that proposed projects have no potential to effect historic properties and the review process is considered complete. A second option is used if a project has potential to effect a historic property. The latter involves notification of the State Historic Preservation Officer, tribes, and interested parties.

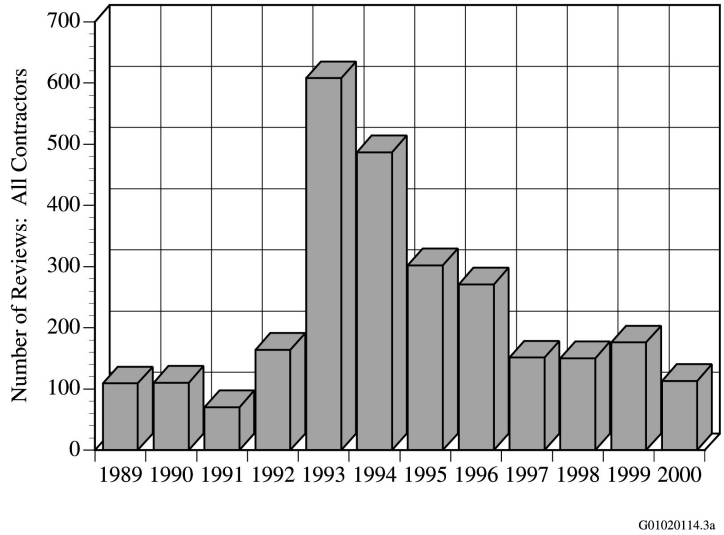

Figure 8.3.3. Cultural Resources Reviews Requested each Calendar Year

During 2000, 113 cultural resource reviews were requested (Figure 8.3.3). A majority of the reviews involved project areas that had been previously surveyed or were located in previously disturbed ground. Of the projects reviewed, 13 were also monitored during the construction phase, 5 required archaeological surveys, and 37 involved proposed building modifications, demolitions, and programmatic agreement exemptions. The surveys covered a total of 185 hectares (456 acres) and resulted in the discovery of two isolated finds and three archaeological sites (Figure 8.3.4).

Figure 8.3.4. Historic Sites are Commonly found during Surveys Conducted at the Hanford Site

The largest survey conducted for Section 106 activities during 2000 was for the Export Waterline Replacement in the Atmospheric Dispersion Test Facility near the 200-West Area. Covering 117 hectares (290 acres), the survey recorded the dispersion grids, a Cold War era atmospheric monitoring facility.

8.3.5 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 buildings or structures. Agencies are further required to maintain and manage historic properties in a way that considers preservation of their value and ensures that preservation-related activities are completed in consultation with other agencies, the tribes, and the general public.

During 2000, DOE was in the process of evaluating the feasibility of retaining various historic structures on the Hanford Site, including the Bruggemann Warehouse and White Bluffs Bank, two pre-Manhattan Project era buildings. An assessment of the structural condition of both

buildings was completed. The studies detailed existing conditions, interim actions, conservation needs, and immediate stabilization requirements. Both studies developed cost estimates for stabilization. A follow-up study was conducted of the White Bluffs Bank that outlined emergency stabilization options and costs, and the design and installation of a fabric roof structure to protect the White Bluffs Bank from further weather infiltration. A committee comprised of members of the interested public and staff of DOE, Bechtel Hanford, Inc., and Pacific Northwest National Laboratory has been established to explore stabilization and restoration alternatives. The Bruggemann Warehouse study made recommendations concerning the feasibility of converting the former fruit warehouse into a visitor's center.

In 2000, management activities conducted to fulfill Section 110 requirements included continual implementation of the programmatic agreement for the built environment (DOE/RL-96-77) and application of the Hanford Site curation strategy to identify, evaluate, and preserve Manhattan Project and Cold War era artifacts (DOE/RL-97-71). Since Section 110 activities began on the Hanford Site, 531 buildings/structures have been documented on historic property inventory forms and are on file at the Hanford Cultural Resources Laboratory (Figure 8.3.5).

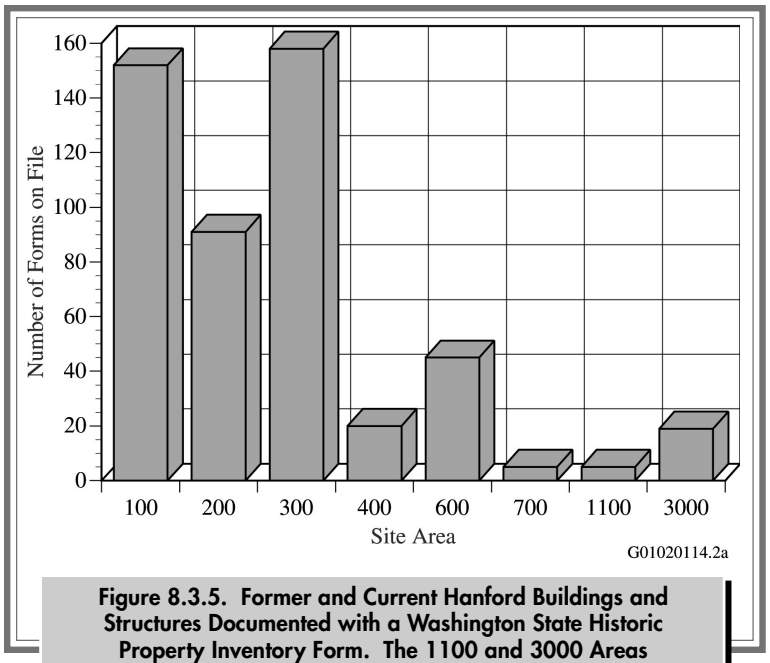

Figure 8.3.5. Former and Current Hanford Buildings and Structures Documented with a Washington State Historic Property Inventory Form. The 1100 and 3000 Areas are former site areas.

Four surveys comprised the 2000 Section 110 effort: the Gable Mountain Block Survey, the West Vernita Bridge Cultural Resources and Current Impacts Survey, the White Bluffs Road Archaeological Block Survey, and the Bruggemann Agricultural Complex/Riverlands Ranch survey.

The Gable Mountain Block Survey was conducted by the Hanford Cultural Resources Laboratory and the Confederated Tribes of the Umatilla Indian Reservation during April and May 2000. The survey covered 4.63 square kilometers or 463 hectares (1.67 square miles or 1,144 acres). Eighteen archaeological sites and four isolated finds were recorded; almost all of the sites were Native American rock cairns or rock alignments, with few prehistoric artifacts. Historic artifacts were limited to two isolated finds and one ranch site. Impacts noted to sites included use of Gable Mountain as a recreational walking area and non-recent dismantling of Native American cairns.

The West Vernita Cultural Resources and Current Impacts Survey was conducted in March 2000 by Hanford Cultural Resources Laboratory personnel; members of the Wanapum People, Yakama and Nez Perce tribes; and Central Washington University students. The 269-hectare (665-acre) survey area yielded four previously recorded archaeological sites, four new prehistoric sites, three new historic sites, and two sites combining both prehistoric and historic artifacts. Recreational impacts identified

include vehicle traffic, refuse, riverbank erosion, and possible damage to recorded cultural resources including rock cairns.

The White Bluffs Road Archaeological Block Survey was conducted in May 2000 and covered 3.56 square kilometers or 356 hectares (1.37 square miles or 880.5 acres) in a 200-meter (656-foot) wide strip along the historic White Bluffs Road from State Highway 240 to a point north of Gable Mountain. During the survey, 6 artifact concentrations and 56 isolated finds were recorded as part of the White Bluffs Road. Almost all of the artifact concentrations were historic trash dumps and the isolated finds were generally cans. Prehistoric artifacts were limited to one cryptocrystalline silica flake and one projectile point. All other artifacts recorded were historic. Later impacts noted to the road included wind erosion exacerbated by loss of vegetation caused by the Hanford Site wildfire in late June 2000 (see Section 5.0).

The Bruggemann Agricultural Complex/ Riverlands Ranch Survey was conducted in January and February 2000 to provide data necessary for a Determination of Eligibility for listing in the National Register of Historic Places. On the 227-hectare (562-acre) site, Hanford Cultural Resources Laboratory personnel located and recorded ten foundation features, one domestic dump, one equipment debris scatter near the main building complex, three large rock piles, and over 23,000 linear feet of irrigation line consisting of tile pipe, wire-wrapped wood pipe, and wire-wrapped wood pipe lined with tile and tin. The State Historic Preservation Officer concurred with DOE that the site was eligible for listing in the National Register of Historic Places.

One archaeological site was determined eligible for listing in the National Register during 2000. Test excavations were conducted at 45 BN 606, which documented that this site held the potential to contribute information important to understanding the prehistory of the Hanford Reach.

8.3.5.1 Historic District

During 2000, implementation of the building mitigation project continued to carry out the programmatic agreement (DOE/RL-96-77) and the sitewide treatment plan (DOE/RL-97-56). The treatment plan is stipulated in the programmatic agreement and directs a mitigation document be provided that chronicles the history of the Hanford Site during the Manhattan Project and Cold War periods. The draft, *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990*, has been completed and distributed for public review, regulatory review by the State Historic Preservation Officer and the Federal Advisory Council on Historic Preservation, and peer review by Cold War scholars and technical experts.

The Hanford Site Manhattan Project and Cold War Era Historic District was established in 1996, and 185 buildings, structures, and complexes were recommended for mitigation. Subsequent public meetings and staff evaluations identified additional properties in the 600, 700, and former 1100 Areas, including the Hanford Site railroad and the Hanford Atmospheric Dispersion Test Facility, as contributing properties within the historic district and recommended for mitigation, bringing the total to 190 (Figure 8.3.6). All of the buildings, structures, and complexes recommended for mitigation have been documented according to mitigation standards identified in the sitewide treatment plan (DOE/RL-97-56). Six historic properties, including B Reactor, have been documented at the Historic American Engineering Record level, 46 have been documented with Expanded Historic Property Inventory Forms, while standard Historic Property Inventory Forms have been prepared for the remaining 138 buildings and structures.

Approximately 900 buildings and structures have been identified as either contributing properties with no individual documentation requirement (not selected for mitigation) or as non-contributing/ exempt buildings and structures. These buildings

Figure 8.3.6. KW Reactor, a Contributing Property Recommended for Mitigation within the Hanford Site Manhattan Project and Cold War Era Historic District

will be documented in a database maintained by DOE. According to the programmatic agreement (DOE/RL-96-77), certain property types such as mobile trailers, modular buildings, storage tanks, towers, wells, and structures with minimal or no visible surface manifestations are exempt from the identification and evaluation requirement.

8.3.5.2 Hanford Curation Strategy

The application of the curation strategy for artifacts and records associated with the Hanford Site Manhattan Project and Cold War Era Historic District continued in 2000. The strategy is stipulated in the programmatic agreement (DOE/RL-96-77), which directs DOE to assess the contents of Hanford's historic buildings and structures prior to the commencement of deactivation, decontamination, or decommissioning activities. The purpose of these assessments is to identify and preserve any artifacts (e.g., control panels, signs, scale models, machinery) that may have interpretive or educational value as exhibits within national, state, or local museums. The assessments are accomplished by conducting walkthroughs of the contributing properties within the historic district by teams of cultural resources specialists, historians, archivists/curators, and facility experts. Ten assessments/walkthroughs were conducted in 2000, including one facility in the 300 Area, one in the 600 Area, one in the 400 Area, and seven in the 100 Areas, including the 105-KE, 105-KW, 105-D, 105-H, and 105-B reactors. Industrial artifacts associated with the Manhattan Project and Cold War are curated with the Columbia River Exhibition of History, Science and Technology museum.

DOE's archaeological collections and associated records continued to be housed in Pacific Northwest National Laboratory's repositories during 2000. A draft management plan that deals specifically with archaeological collections, developed in 1998, was used during 2000 to guide access to, and uses of, the

collections and to provide guidelines for acquisition and deaccessioning processes. A pest management and monitoring effort for archaeological collections conducted during 2000 resulted in no indications of pest infestations.

8.3.6 Education and Research

Educational activities associated with the cultural resources program in 2000 included lectures on a variety of topics including preservation and protection legislation 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's cultural resources management techniques to professional groups and societies. Washington's Archaeology Month provided educational opportunities in the form of lectures and social gatherings for residents of the Tri-Cities' area through the efforts of staff and professionals from Washington State University, DOE, and Pacific Northwest National Laboratory.

Several cultural resources newsletters were written by Pacific Northwest National Laboratory, DOE, and Bechtel Hanford, Inc. staff that focused on the Section 106 process, B Reactor history, White Bluffs townsites, how to identify archeological sites, and a summary of the history of the Manhattan Project and Cold War era at Hanford.

Pacific Northwest National Laboratory participated in the Associated Western Universities, Inc., program by hosting several student interns 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 and documentation of the built environment of the Manhattan Project and Cold War periods.

8.4 Community-Operated Environmental Surveillance Project

R. W. Hanf

Since 1991, citizens living near the Hanford Site have actively participated in site environmental surveillance activities through the Community-Operated Environmental Surveillance Program. During 2000, nine radiological air sampling stations were operated by local teachers at selected locations around the site perimeter. These stations were located in Basin City, Richland, Pasco, Kennewick, north Franklin County, Othello, Mattawa, Toppenish, and Benton City, Washington (see Figure 4.1.1). Each station consisted of equipment to collect air samples and to monitor ambient radiation levels. Four of the nine stations also included large, lighted, informational displays that provided real-time meteorological and radiological information as well as general information on station equipment, sample types, and analyses (Figure 8.4.1). The station managers' names and telephone numbers were provided on the four displays for anyone desiring additional information about the purpose of the station, station equipment, or analytical results.

Figure 8.4.1. 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. The teachers were responsible for collecting a variety of air samples, preparing the samples and collection records for submission to the analytical laboratory, monitoring the performance of station equipment, performing minor station maintenance, and participating in scheduled training. They also served as 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 Site environmental surveillance. Analytical results for samples collected at these stations in 2000 are discussed in Section 4.1. Results of gamma radiation measurements obtained at selected stations are discussed briefly in Section 4.6.

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9.0 Quality Assurance

B. M. Gillespie, L. P. Diediker, and D. L. Dyekman

Quality assurance and quality control practices encompassed all aspects of Hanford Site environmental monitoring and surveillance programs. This section discusses specific measures taken to ensure quality in project management, sample collection, and analytical results.

Samples were collected and analyzed according to documented standard analytical procedures. Analytical data quality was 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 environmental monitoring and surveillance programs also include procedures and protocols to

- document instrument calibrations
- conduct program-specific activities in the field
- maintain groundwater wells to ensure representative samples were collected
- avoid cross-contamination by using dedicated well sampling pumps.

9.1 Environmental Surveillance and Groundwater Monitoring

During 2000, comprehensive quality assurance programs, including various quality control practices, were maintained to ensure the quality of data collected through the Surface Environmental Surveillance Project and the Hanford Groundwater Monitoring Project. Quality assurance plans were maintained for all program activities and defined the appropriate controls and documentation required by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) for the project-specific requirements.

9.1.1 Project Management Quality Assurance

Site environmental surveillance, groundwater monitoring, and related programs such as processing of thermoluminescent dosimeters and performing dose calculations were subject to an overall quality assurance program. This program implemented the requirements of DOE Order 414.1A.

The site surveillance and groundwater monitoring projects maintained quality assurance plans that described the specific quality assurance elements that applied to each project. These plans were approved by a quality assurance organization that conducted 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 service suppliers were audited before service contracts or material purchases that could have had a significant impact on quality within the project were approved and awarded.

9.1.2 Sample Collection Quality Assurance/Quality Control

Surface Environmental Surveillance Project samples were collected by staff trained to conduct sampling according to approved and documented procedures (PNL-MA-580). Continuity of all sampling location identities was maintained through careful documentation. Field replicates were collected for specific media and a summary of the 2000 results is provided in Table 9.1. Eighty-eight percent of the field replicate results for 2000 were acceptable. The results were within the control limits of ±30% for the sample and duplicate results.

Samples for the Hanford Groundwater Monitoring Project were collected by trained staff according to approved and documented procedures (PNNL-13404, Appendix B). Chain-of-custody procedures were followed (SW-846) that provided for the use of evidence tape in sealing sample bottles to maintain the integrity of the samples during shipping. Full trip blanks and field replicates were obtained during field operations. Summaries of the 2000 groundwater field quality control sample results are provided in Appendix B of PNNL-13404 or at the web address http://hanford-site.pnl.gov/groundwater/reports/gwrep00/html/start1.htm. The percentage of acceptable field blank and replicate results in fiscal year 2000 were very high – 96% for field blanks and 99% for field replicates.

9.1.3 Analytical Results Quality Assurance/Quality Control

Routine chemical analyses of water samples were performed under contract primarily by Severn Trent Laboratories, Incorporated, St. Louis, Missouri, for environmental surveillance and groundwater monitoring. Some routine analyses of hazardous and nonhazardous chemicals for the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) groundwater program were also performed under contract by Recra Environmental, Inc., Lionsville, Pennsylvania. Each laboratory participated in the EPA Water Pollution and Water Supply Performance Evaluation Studies. Each

Table 9.1. Summary of Surface Environmental Surveillance Project Field Replicate Results, 2000

Medium	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air filters	Gross alpha	27	16
	Gross beta	27	24
	^{3}H	12	6
	^{7}Be, ^{40}K, ^{60}Co, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{154}Eu, ^{155}Eu	36	36
Water	Gross alpha	1	1
	Gross beta	1	1
	^{3}H	4	4
	^{7}Be, ^{40}K, ^{60}Co, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{154}Eu, ^{155}Eu	9	9
	^{90}Sr	3	2
	^{234}U, ^{235}U, ^{238}U	9	9
Milk	^{7}Be, ^{40}K, ^{60}Co, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{154}Eu, ^{155}Eu	36	36
	^{90}Sr	4	4
	^{3}H	1	1

(a) The sample and duplicate results are acceptable if they fall within the control limit of ±30% for the sample and duplicate results above the detection limit or minimum detectable concentration.

laboratory maintained 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 submitted additional quality control double-blind spiked samples for analysis.

Routine radiochemical analyses of samples for the Surface Environmental Surveillance and Hanford Groundwater Monitoring Projects were performed primarily by Severn Trent Laboratories, Incorporated, Richland, Washington. Data from Thermo-Retec, Richmond, California, were also used in the fiscal year 2000 groundwater evaluations. Each laboratory participated in DOE's Quality Assessment Program at the Environmental Measurements Laboratory in New York, and the Proficiency Testing Program at Environmental Resource Associates in Arvada, Colorado. The Environmental Resource Associates program replaced the EPA's Laboratory Intercomparison Studies Program, which terminated in December 1998. Environmental Resource Associates prepared and distributed proficiency standard samples according to EPA requirements. An additional quality control blind spiked sample program was conducted for each project. Each laboratory also maintained an internal quality control program, which was audited and reviewed internally and by Pacific Northwest National Laboratory. Additional information on these quality control efforts is provided in the following sections.

9.1.4 DOE and EPA Comparison Studies

Standard water samples were distributed blind to participating laboratories as part of the EPA performance evaluation program. These samples contained specific organic and inorganic analytes that had concentrations unknown to the analyzing laboratories. After analysis, the results were submitted to Environmental Resource Associates, the EPA performance evaluation program sponsor, for comparison with known values and results from other participating laboratories. Summaries of the results for 2000 are provided in PNNL-13404, Appendix B, for the primary laboratory, Severn Trent Laboratories, Incorporated, St. Louis, Missouri.

The DOE Quality Assessment Program and Environmental Resource Associates' Proficiency Testing Program provided standard samples of environmental media (e.g., water, air filters, soil, vegetation) that contained specific amounts of one or more radionuclides that were unknown by the participating laboratory. After analysis, the results were forwarded to DOE or Environmental Resource Associates for comparison with known values and results from other laboratories. Both DOE and Environmental Resource Associates had established criteria for evaluating the accuracy of results (NERL-Ci-0045; EML-608; EML-611). Summaries of the 2000 results are provided in Tables 9.2 and 9.3. Eighty-one percent of the DOE quality assessment sample results fell within the acceptable control limits. Ninety-four percent of the Environmental Resource Associates samples fell within the acceptable control limit range.

9.1.5 Pacific Northwest National Laboratory Evaluations

In addition to DOE and EPA interlaboratory quality control programs, Pacific Northwest National Laboratory maintained a quality control program to evaluate analytical contractor precision and accuracy and to conduct special intercomparisons. This program included 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 Severn Trent Laboratories, Incorporated. In 2000, blind spiked samples were submitted for groundwater (PNNL-13404, Appendix B) and for air filters, vegetation, soil, and surface water (Table 9.4). For results of all water sample non-radiochemistry blind spiked determinations, see discussion of results in Appendix B of PNNL-13404.

Table 9.2. Summary of Laboratory Performance on DOE Quality Assessment Program Samples, 2000

Medium	Radionuclides	Number of Results Reported for Each Analyte	Number Within Acceptable Control Limits[a]
Severn Trent Laboratories, Richland, Washington			
Air filter particulate	^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{238}U, ^{239}Pu, ^{241}Am, total uranium	2	2
	Gross alpha, gross beta, ^{234}U	2	1
	^{106}Ru, ^{134}Cs	1	1
Soil	^{40}K, ^{90}Sr, ^{214}Bi, ^{214}Pb, ^{228}Ac, ^{234}U, ^{238}U, ^{239}Pu, ^{241}Am, total uranium	2	2
	^{137}Cs, ^{212}Pb	2	1
	^{238}Pu	1	1
	^{234}Th	1	0
Vegetation	^{40}K, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{239}Pu, ^{241}Am, ^{244}Cm	2	2
Water	Gross alpha, gross beta, ^{3}H, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}Pu, ^{238}U, ^{239}Pu, ^{241}Am, total uranium	2	2
	^{55}Fe, ^{60}Co, ^{63}Ni	1	1

(a) Control limits are from EML-608 and EML-611.

Table 9.3. Summary of Laboratory Performance on Environmental Resource Associates Proficiency Testing Program, 2000

Medium	Radionuclides	Number of Results Reported for Each Analyte	Number Within Control Limits for Each Analyte[a]
Severn Trent Laboratories, Richland, Washington			
Water	Gross alpha	7	7
	Gross beta	7	6
	^{60}Co, ^{137}Cs, ^{226}Ra, ^{228}Ra total uranium	6	6
	^{134}Cs	6	5
	^{89}Sr, ^{90}Sr	5	5
	^{65}Zn, ^{131}I, ^{133}Ba	3	3
	^{3}H	1	1

(a) Control limits are from NERL-Ci-0045.

Table 9.4. Summary of Surface Environmental Surveillance Project Blind Spiked Determinations, 2000

Medium	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air filters	Gross alpha, gross beta, ^{60}Co, ^{90}Sr, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu	11	11
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu	10	10
Water	^{3}H, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu	12	12
Vegetation	^{40}K, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{239}Pu	9	9

(a) Control limit of ±30%.

For all media, 100% of Severn Trent Laboratories, Incorporated, Richland, radiochemistry blind spiked determinations were within control limits, which indicated acceptable results.

9.1.6 Quality Assurance Task Force Results

Pacific Northwest National Laboratory also participated in a Quality Assurance Task Force, a program coordinated by the Washington State Department of Health. Public and private organizations from Idaho, Oregon, Washington, and Georgia participated in analyzing the intercomparison samples in 1999 and 2000. For the 1999 intercomparison sample exchange, samples from a Hanford Site well were collected; in 2000, soil was collected on the site from the 100 and 300 Areas and composited for analysis. Summary results from both studies are presented in Tables 9.5 and 9.6.

9.1.7 Laboratory Internal Quality Assurance Programs

The analytical laboratories were required to maintain an internal quality assurance and control program. Periodically, the laboratories were audited internally for compliance to the quality assurance and control programs. At Severn Trent Laboratories, Incorporated, St. Louis, the quality control programs met the quality assurance and control criteria in SW-846. The laboratories were also required to maintain a system to review and analyze the results of the quality control samples to detect problems that may have arisen from contamination, inadequate calibrations, calculation errors, or improper procedure performance. Method detection levels were determined at least annually for each analytical method.

Table 9.5. Comparison[a] of the Quality Assurance Task Force Intercomparison Well Water Analytical Results, 1999

Radionuclide	Number of Results	Intercomparison Sample Concentrations, pCi/L
Gross Beta		
Grand Mean	26	3,153 ± 774
PNNL	3	3,607 ± 248
Strontium-90		
Grand Mean	20	1,634 ± 306
PNNL	3	1,857 ± 24
Tritium		
Grand Mean	23	24,503 ± 3,456
PNNL	3	23,200 ± 980

(a) Pacific Northwest National Laboratory (PNNL) analyses by Severn Trent Laboratories, Incorporated, Richland, Washington, are compared against grand mean (±2 standard deviation) of participating laboratories.

Table 9.6. Comparison[a] of the Quality Assurance Task Force Intercomparison Soil Analytical Results, 2000

Radionuclide	Number of Results	Intercomparison Sample Concentrations, pCi/L
Cobalt-60		
Grand Mean	25	1.85 ± 0.60
PNNL	3	1.57 ± 0.04
Cesium-134		
Grand Mean	14	0.046 ± 0.208
PNNL	3	0.008 ± 0.028
Cesium-137		
Grand Mean	25	43.8 ± 9.2
PNNL	3	39.2 ± 1.0
Europium-154		
Grand Mean	23	6.7 ± 7.5
PNNL	3	4.83 ± 0.24
Europium-155		
Grand Mean	22	1.0 ± 2.6
PNNL	3	0.83 ± 0.56
Potassium-40		
Grand Mean	21	12.6 ± 4.1
PNNL	3	9.8 ± 2.0
Strontium-90		
Grand Mean	9	1.22 ± 0.42
PNNL	3	1.15 ± 0.08
Uranium-234		
Grand Mean	14	312 ± 146
PNNL	3	309 ± 64
Uranium-235		
Grand Mean	22	15.2 ± 6.6
PNNL	3	12.3 ± 3.4
Uranium-238		
Grand Mean	14	311 ± 142
PNNL	3	310 ± 60

(a) Pacific Northwest National Laboratory (PNNL) analyses by Severn Trent Laboratories, Incorporated, Richland, Washington, are compared against grand mean (±2 deviation) of participating laboratories.

The internal quality control program at Severn Trent Laboratories, Incorporated, Richland involved routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation check sources and background counts, replicate and spiked sample analyses, matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Available calibration standards traceable to the National Institute of Standards and Technology were used for radiochemical calibrations. Calculation of minimum detectable concentrations involved 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 pre-designated uncertainty multiplier (EPA 520/1-80-012).

Periodically, inspections of services were performed that documented conformance with contractual requirements of the analytical facility and provided the framework to identify and resolve potential performance problems. Responses to assessment and inspection findings were documented by written communication, and corrective actions were verified by follow-up audits and inspections. In 2000, 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., conducted assessments of Severn Trent Laboratories, Incorporated, St. Louis and Severn Trent Laboratories, Incorporated, Richland. The purpose of the assessment 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 were reported with the analytical results. Scientists at Pacific Northwest National Laboratory summarized the results quarterly. The results of the quality control sample summary reports indicated an acceptable performance for the internal quality control program.

9.1.8 Media Audits and Comparisons

Additional audits and comparisons were conducted on several specific types of samples. The Washington State Department of Health routinely cosampled various environmental media and measured external radiation levels at multiple locations during 2000. Media that were cosampled and analyzed for radionuclides included groundwater, water from 10 locations along and across the Columbia River, water from six riverbank springs, water from one onsite drinking water location, sediment from nine Columbia River sites, samples from four air monitoring stations, thermoluminescent dosimeters from 12 sites, hops, carp, and mule deer. Also cosampled and analyzed for radionuclides were upwind and downwind samples of leafy vegetables, fruit, potatoes, and wine. The Washington State Department of Health and Pacific Northwest National Laboratory cosampled data may be found in PNNL-13487, APP. 1. The air particulate gross beta data for three sampling locations are compared graphically in Figures 9.1, 9.2, and 9.3. For these three locations, gross beta data from the two organizations compare favorably.

The U.S. Food and Drug Administration also cosampled from upwind and downwind sampling locations and analyzed apples, leafy vegetables (cabbage and beet leaves), and potatoes for radionuclides. The data are presented in Table 9.7. There is good agreement between the U.S. Food and Drug Administration and Pacific Northwest National Laboratory data.

Quality control for environmental thermoluminescent dosimeters included the audit exposure of three environmental thermoluminescent dosimeters per quarter to known values of radiation (between 17 and 28 mR). A summary of 2000 results is shown in

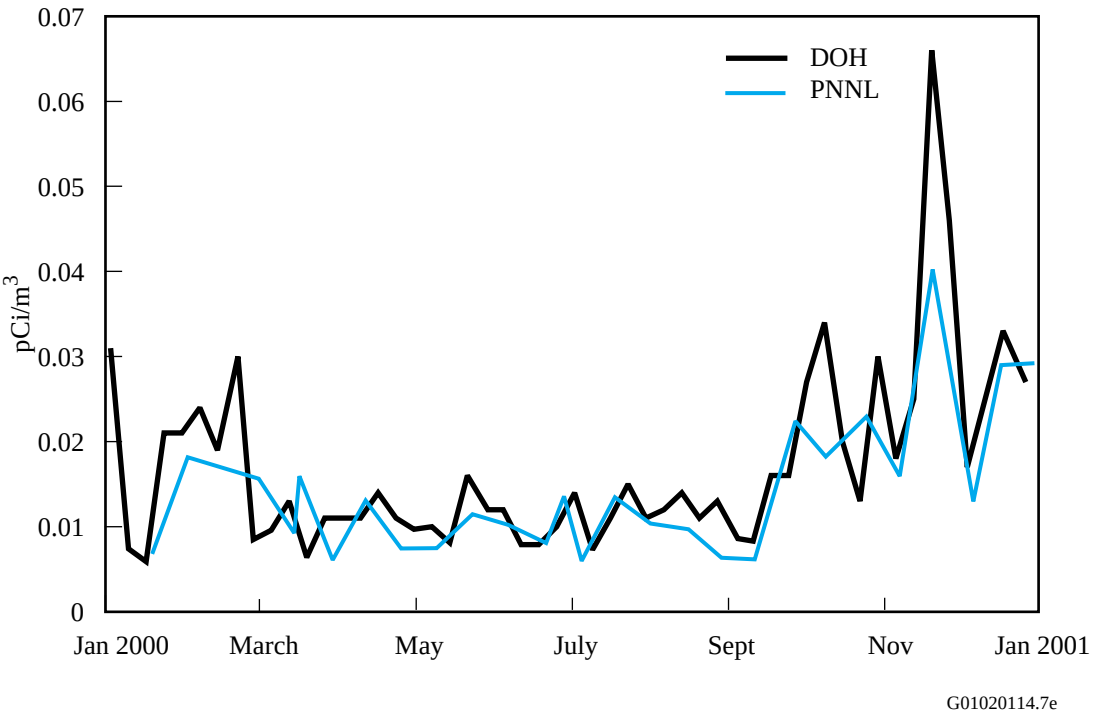

Figure 9.1. Gross Beta Concentrations (pCi/m³) in Air Particulate Samples Cosampled by the Pacific Northwest National Laboratory and the Washington State Department of Health at the West End of Fir Road (see Figure 4.1.1 for location of sampling station)

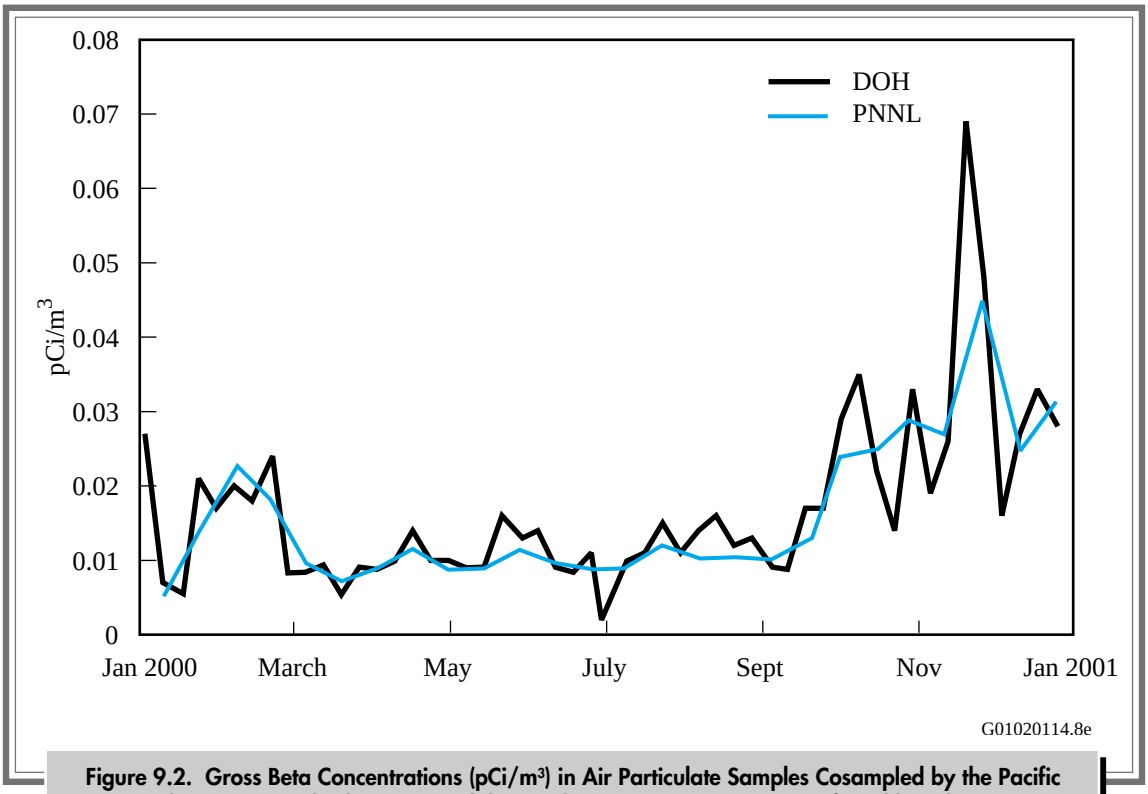

Figure 9.2. Gross Beta Concentrations (pCi/m³) in Air Particulate Samples Cosampled by the Pacific Northwest National Laboratory and the Washington State Department of Health at the Wye Barricade (see Figure 4.1.1 for location of sampling station)

Table 9.8. On average, the thermoluminescent dosimeter measurements were unbiased. For 12 measurements, the lowest measurement of measured/known was 95% and the highest measured/known was 110%, with an average of 100 ± 4.

9.2 Effluent Monitoring and Near-Facility Environmental Monitoring

The Effluent Monitoring and Near-Facility Environmental Monitoring Programs were subject to the quality assurance requirements specified in the Hanford Analytical Services Quality Assurance Requirements Document (DOE/RL-96-68). These quality assurance programs complied with DOE Order 414.1A, using standards from the American Society of Mechanical Engineers (ASME NQA-1-1997 Edition) as their basis. The programs also adhered to the guidelines and objectives in EPA/005/80 and EPA QA/R-5.

The monitoring programs each had a quality assurance project plan describing applicable quality assurance elements. These plans were approved by contractor quality assurance groups, who conducted surveillances and audits to verify compliance with the plans. Work such as sample analysis performed through contracts had to meet the requirements of these plans. Suppliers were audited before the contract selection was made for equipment and services that may have significantly affected the quality of a project.

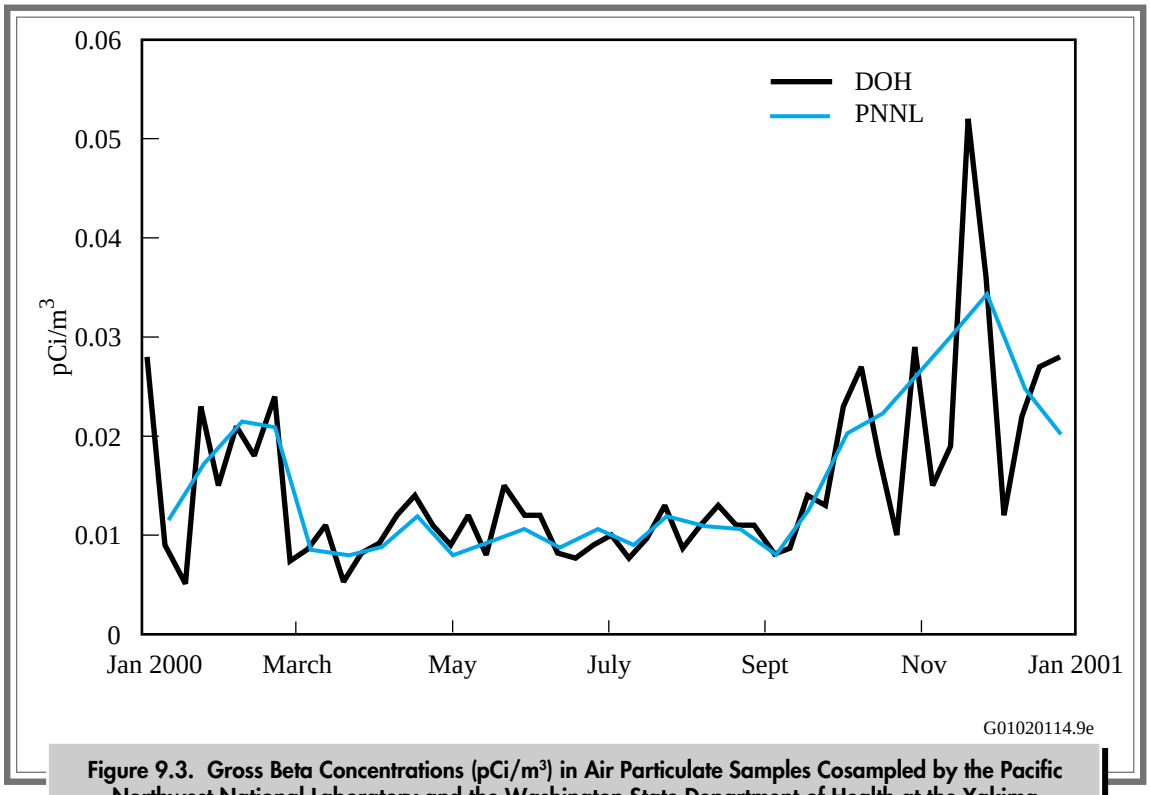

Figure 9.3. Gross Beta Concentrations (pCi/m³) in Air Particulate Samples Cosampled by the Pacific Northwest National Laboratory and the Washington State Department of Health at the Yakima Barricade (see Figure 4.1.1 for location of sampling station)

9.2.1 Sample Collection Quality Assurance

Samples for the Effluent Monitoring and Near-Facility Environmental Monitoring Programs were collected by staff trained for the task in accordance with approved procedures. Established sampling locations were accurately identified and documented to ensure continuity of data for those sites and are described in DOE/RL-91-50.

9.2.2 Analytical Results Quality Assurance

Samples for the Effluent Monitoring and Near-Facility Environmental Monitoring Programs were analyzed by up to three different analytical laboratories. The use of these laboratories was dependent on the Hanford contractor collecting the samples and contract(s) established between the contractor and the analytical laboratory(s). Table 9.9 provides a summary of the Hanford Site's analytical laboratories used for effluent monitoring and near-facility monitoring samples.

The quality of the analytical data was ensured by several means. Counting room instruments, for instance, were kept within calibration limits through daily checks, the results of which were stored in computer databases. Radiochemical standards used in analyses were regularly measured and the results were reported and tracked. Formal, written laboratory procedures were used to analyze samples. Analytical procedural control was ensured through administrative procedures. Chemical technologists at the laboratory qualified to perform analyses through formal classroom and on-the-job training.

Table 9.7. Comparison of U.S. Food and Drug Administration Cosampling, 2000

Medium	Sampling Area[a]	Organization[b]	Strontium-90, pCi/g[c]	Cesium-137, pCi/g[c]	Ruthenium-106, pCi/g[c]
Leafy vegetables	Riverview	FDA[d]	<0.002	<0.045	<0.10
		FDA	<0.002	<0.045	<0.10
		PNNL[e]	<0.0020	<0.0089	<0.078
	Sunnyside	FDA	0.0041 ± 0.0007[f]	<0.045	<0.10
		FDA	0.0097 ± 0.0007[f]	<0.045	<0.10
		PNNL	0.012 ± 0.0044[f]	<0.012	<0.10
Potatoes	Sunnyside	FDA	<0.002	<0.045	<0.10
		FDA	<0.002	<0.045	<0.10
		PNNL	<0.030	<0.0060	<0.050
	Sagemoor	FDA	<0.002	<0.045	<0.10
		FDA	<0.002	<0.045	<0.10
		PNNL	<0.0023	<0.0058	<0.052
Apples	Sagemoor	FDA	<0.002	<0.045	<0.10
		FDA	<0.002	<0.045	<0.10
		PNNL	<0.0017	<0.0094	<0.076
	Riverview	FDA	<0.002	<0.045	<0.10
		FDA	<0.002	<0.045	<0.10
		PNNL	<0.0020	<0.0091	<0.080

(a) Locations are identified in Figure 4.4.1.
(b) Two samples of each medium were collected for FDA, one for PNNL.
(c) Less than (<) values are the 2 sigma total propagated analytical uncertainties.
(d) FDA = U.S. Food and Drug Administration.
(e) PNNL = Pacific Northwest National Laboratory.
(f) ±2 sigma total propagated analytical uncertainty.

Table 9.8. Comparison of Thermoluminescent Dosimeter Results with Known Exposure, 2000

Quarter	Exposure Date	Known Exposure, mR[a]	Determined Exposure, mR[b]	% of Known Exposure
1st	February 23, 2000	17 ± 0.63	17.23 ± 0.81	101
	February 23, 2000	25 ± 0.93	25.07 ± 1.20	100
	February 23, 2000	28 ± 1.04	27.71 ± 0.98	99
2nd	May 19, 2000	18 ± 0.67	17.43 ± 0.01	97
	May 19, 2000	21 ± 0.78	20.29 ± 0.14	97
	May 19, 2000	27 ± 1.00	26.70 ± 0.52	99
3rd	August 15, 2000	19 ± 0.70	20.96 ± 1.29	110
	August 15, 2000	24 ± 0.89	24.33 ± 0.70	101
	August 15, 2000	26 ± 0.96	25.61 ± 0.43	99
4th	November 20, 2000	18 ± 0.67	17.01 ± 0.00	95
	November 20, 2000	22 ± 0.81	23.02 ± 0.55	105
	November 20, 2000	25 ± 0.93	24.73 ± 0.62	99

(a) ±2 sigma total propagated analytical uncertainty.
(b) ±2 times the standard deviation.

Table 9.9. Hanford Site Laboratories used by Contractor and Sample Type, 2000

Analytical Laboratory	Effluent Monitoring Samples					Near-Facility Environmental Monitoring Samples		
	Fluor Hanford, Inc.		Pacific Northwest National Laboratory	Bechtel Hanford, Inc.		Fluor Hanford, Inc.		
	Air	Water	Air	Air	Water	Air	Water	Other
Waste Sampling and Characterization Facility[a]	X	X		X	X	X	X	X
222-S Analytical Laboratory[a]								X
Severn Trent Laboratories, Inc., Richland	X	X	X	X	X			
Analytical Chemistry Laboratory[b]	X	X	X					

(a) Operated by Fluor Hanford, Inc.
(b) Operated by Pacific Northwest National Laboratory.

The participation of the Hanford Site analytical laboratories in EPA and DOE laboratory performance programs also served to ensure the quality of the data produced. Laboratory performance program results for calendar year 2000 for the Waste Sampling and Characterization Facility were evaluated in two different studies. In the EPA Water Pollution Study # 66 and a Quick Response Study, 196 different parameters, analytes, and compounds were submitted to the Waste Sampling

Table 9.10. Waste Sampling and Characterization Facility[a] Performance on DOE Quality Assessment Program Samples, 2000

Medium	Radionuclide	Number of Results Reported	Number Within Control Limits
Air filters	^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}Pu, ^{238}U, ^{239}Pu, ^{241}Am, gross alpha, gross beta	24	23 (^{90}Sr failed once)
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U, ^{239}Pu, ^{241}Am	14	13 (^{90}Sr failed once)
Vegetation	^{40}K, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{239}Pu, ^{241}Am, ^{244}Cm	13	12 (^{60}Co failed once)
Water	^{3}H, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}Pu, ^{238}U, ^{239}Pu, ^{241}Am, gross alpha, gross beta	22	22

(a) Onsite laboratory operated by Fluor Hanford, Inc.

Table 9.11. 222-S Analytical Laboratory[a] Performance on DOE Quality Assessment Program Samples, 2000

Medium	Radionuclide	Number of Results Reported	Number Within Control Limits
Air filters	^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am	16	16
Soil	^{90}Sr, ^{137}Cs, ^{212}Pb, ^{214}Bi, ^{214}Pb, ^{228}Ac, ^{239}Pu, total uranium	14	12
Vegetation	^{60}Co, ^{90}Sr, ^{137}Cs, ^{239}Pu, ^{241}Am, ^{244}Cm	12	11
Water	^{3}H, ^{60}Co, ^{63}Ni, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, gross alpha, gross beta, total uranium	21	20

(a) Onsite "high-level" radiological laboratory operated by Fluor Hanford, Inc. (Note: These samples are "low-level" environmental activity samples.)

Table 9.12. 222-S Analytical Laboratory[a] Performance on Environmental Resource Associates Laboratory Water Pollution Inorganic Studies, 2000

Laboratory	Water Pollution Study April 2000 % Acceptable	Water Pollution Study October 2000 % Acceptable
222-S Analytical Laboratory	97[b]	95[c]

(a) Onsite "high-level" radiological laboratory operated by Fluor Hanford, Inc.
(b) Thirty-seven of 38 analytes scored as acceptable. Acceptable with warning result for conductivity scored as unacceptable.
(c) Thirty-eight of 40 analytes scored as acceptable. Unacceptable result for conductivity and acceptable with warning result for total suspended solids both scored as unacceptable.

Characterization Facility for analysis. Fourteen analytes were unacceptable for a total of 93% acceptable analysis results. In the DOE Mixed Analyte Performance Evaluation Program studies (MAPEP-00-W7 and MAPEP-00-S7), 66 analytes and/or compounds were submitted to the Waste Sampling Characterization Facility for analysis. Six analytes were unacceptable for a total of 91% acceptable analysis results. Other performance results are presented in Tables 9.10 through 9.12.

9.3 References

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Appendix A
Helpful Information

The following information is provided to assist the reader in understanding this report. Definitions of technical terms can be found in Appendix C. A public information summary document is available and may be obtained by following the 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 or "E" notation, written as 1 x 10^9 or 1.0E+09. 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 x 10^3 (or 2.0E+03), 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 x 10^{-5} (or 2.0E-05), the decimal point should be moved five places to the **left** so that the result would be 0.00002.

Units of Measure

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

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

Symbol	Name
Temperature	
°C	degree Celsius
°F	degree Fahrenheit
Time	
d	day
h	hour
min	minute
s	second
yr	year
Rate	
cfs (or ft^3/s)	cubic foot per second
gpm	gallon per minute
mph	mile per hour
Volume	
cm^3	cubic centimeter
ft^3	cubic foot
gal	gallon
L	liter
m^3	cubic meter
mL	milliliter (1 x 10^{-3} L)
yd^3	cubic yard
Concentration	
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume

Symbol	Name
Length	
cm	centimeter (1 x 10^{-2} m)
ft	foot
in.	inch
km	kilometer (1 x 10^3 m)
m	meter
mi	mile
mm	millimeter (1 x 10^{-3} m)
µm	micrometer (1 x 10^{-6} m)
Area	
ha	hectare (1 x 10^4 m^2)
km^2	square kilometer
mi^2	square mile
ft^2	square foot
Mass	
g	gram
kg	kilogram (1 x 10^3 g)
mg	milligram (1 x 10^{-3} g)
µg	microgram (1 x 10^{-6} g)
ng	nanogram (1 x 10^{-9} g)
lb	pound
wt%	weight percent

Table A.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
Bq	2.7×10^{-11}	Ci	Ci	3.7×10^{10}	Bq
Bq	27	pCi	pCi	0.03704	Bq
Gy	100	rad	rad	0.01	Gy
Sv	100	rem	rem	0.01	Sv
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 (Table A.3). The curie is the basic unit used to describe the amount of radioactivity present, and activities 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 most 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 the U.S. Department of Energy. 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, by multiplying the number of curies by 37 billion. The becquerel is defined as one nuclear disintegration per second.

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

Symbol	Name
Ci	curie
cpm	counts per minute
mCi	millicurie (1×10^{-3} Ci)
µCi	microcurie (1×10^{-6} Ci)
nCi	nanocurie (1×10^{-9} Ci)
pCi	picocurie (1×10^{-12} Ci)
aCi	attocurie (1×10^{-18} Ci)
Bq	becquerel (2.7×10^{-11} Ci)

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 or in the SI unit millisievert (Table A.4). Millirem (millisievert) is a term that relates ionizing radiation and biological effect or risk (to humans). A dose of 1 millirem (0.01 millisievert) 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 millirems (1,000 to 4,000 millisieverts) can cause radiation sickness in humans. An acute dose of 400,000 to 500,000 millirems (4,000 to 5,000 millisieverts), if left untreated, results in death approximately 50% of the time. Exposure to lower amounts of radiation (1,000 millirems [10 millisieverts] or less) produces no immediate 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 millirems (3 millisieverts). Medical and dental x-rays and air travel add to this total. (See Section 6.7 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, 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 is a measure of radiation exposure with no SI equivalent. Generally speaking, 1 roentgen of exposure will result in an effective dose equivalent of 1 rem (10 millisieverts).

Table A.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 (100 rem)
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 (100 rad)

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

Chemical and Elemental Nomenclature

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

Table A.5. Radionuclides and Their Half-Lives[a]

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
^{3}H	tritium	12.35 yr	^{137m}Ba	barium-137m	2.552 min
^{7}Be	beryllium-7	53.44 d	^{152}Eu	europium-152	13.3 yr
^{14}C	carbon-14	5,730 yr	^{154}Eu	europium-154	8.8 yr
^{40}K	potassium-40	1.3×10^{8} yr	^{155}Eu	europium-155	5 yr
^{51}Cr	chromium-51	27.7 d	^{212}Pb	lead-212	10.6 h
^{54}Mn	manganese-54	312.7 d	^{220}Rn	radon-220	56 s
^{55}Fe	iron-55	2.7 yr	^{222}Rn	radon-222	3.8 d
^{59}Fe	iron-59	44.63 d	^{232}Th	thorium-232	1.4×10^{10} yr
^{59}Ni	nickel-59	75,000 yr	U or uranium[b]	uranium total	--[c]
^{60}Co	cobalt-60	5.3 yr	^{233}U	uranium-233	1.59×10^{5} yr
^{63}Ni	nickel-63	100.1 yr	^{234}U	uranium-234	2.4×10^{5} yr
^{65}Zn	zinc-65	243.9 d	^{235}U	uranium-235	7×10^{8} yr
^{85}Kr	krypton-85	10.7 yr	^{237}Np	neptunium-237	2.14×10^{6} yr
^{90}Sr	strontium-90	29.1 yr	^{238}U	uranium-238	4.5×10^{9} yr
^{90}Y	yttrium-90	64.1 h	^{238}Pu	plutonium-238	87.7 yr
^{95}Zr	zirconium-95	63.98 d	^{239}Pu	plutonium-239	2.4×10^{4} yr
^{99}Tc	technetium-99	2.1×10^{5} yr	^{240}Pu	plutonium-240	6.5×10^{3} yr
^{103}Ru	ruthenium-103	39.3 d	^{241}Pu	plutonium-241	14.4 yr
^{106}Ru	ruthenium-106	368.2 d	^{242}Pu	plutonium-242	3.76×10^{5} yr
^{113}Sn	tin-113	115 d	^{241}Am	americium-241	432.2 yr
^{125}Sb	antimony-125	2.8 yr	^{243}Am	americium-243	7,380 yr
^{129}I	iodine-129	1.6×10^{7} yr	^{243}Cm	curium-243	28.5 yr
^{131}I	iodine-131	8 d	^{244}Cm	curium-244	18.11 yr
^{134}Cs	cesium-134	2.1 yr	^{245}Cm	curium-245	8,500 yr
^{137}Cs	cesium-137	30 yr			

(a) From Shleien 1992.
(b) Total uranium may also be indicated by U-natural (U-nat) or U-mass.
(c) Natural uranium is a mixture dominated by ^{238}U, thus the half-life is approximately 4.5×10^{9} years.

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

Table A.6. Elemental and Chemical Constituent Nomenclature

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

sample. The uncertainty associated with samples that are analyzed but not counted includes only the analytical process uncertainty.

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 ~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 than 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. In this situation, the total propagated analytical uncertainty is assumed to be the nominal detection limit.

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 ~95% of the time the next calculated mean will fall somewhere between the reported value minus the standard error and the reported value plus the standard error.

Median, Maximum, and Minimum Values

Median, maximum, and minimum values are reported in some sections of this report. A median value is the middle value when all the values are arranged in order of increasing or decreasing magnitude. For example, the median value in the series of numbers – 1, 2, 3, 3, 4, 5, 5, 5, 6 is 4. The maximum value would be 6 and the minimum value would be 1. Median, maximum, and minimum values are reported when there are too few analytical results to accurately determine the mean with a ± statistical uncertainty or when the data do not follow a bell-shape (i.e., normal) distribution.

Negative Concentrations

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 activities 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 also may 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 would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 grams per liter (Figure A.1). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure A.2).

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)

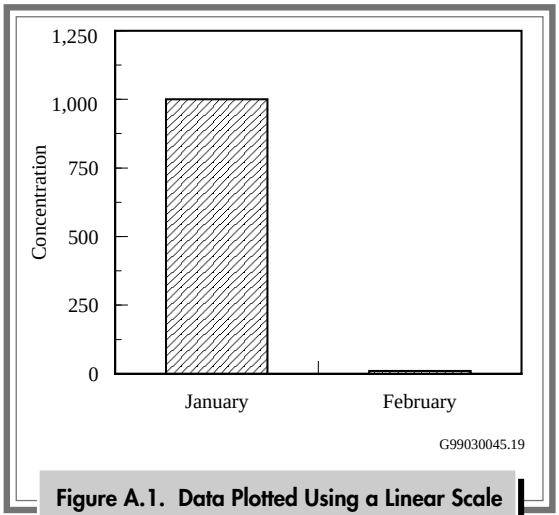

Figure A.1. Data Plotted Using a Linear Scale

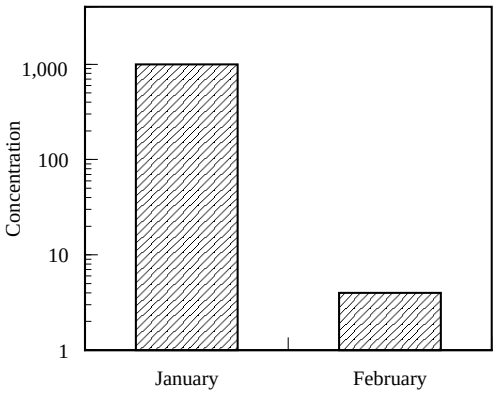

Figure A.2. Data Plotted Using a Logarithmic Scale

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 A.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 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.

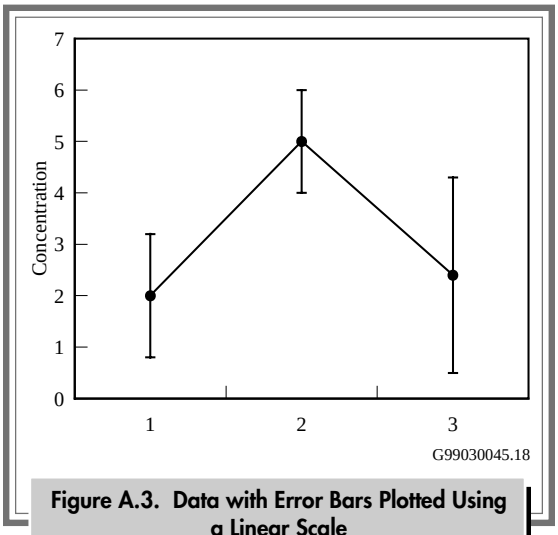

Figure A.3. Data with Error Bars Plotted Using a Linear Scale

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.

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

Reference

Shleien, B. 1992. *The Health Physics and Radiological Health Handbook, Revised Edition*. Scinta, Inc., Silver Spring, Maryland.

Appendix B
Additional Monitoring Results for 2000

G. W. Patton

This appendix contains additional information on 2000 monitoring results, supplementing the data summarized in the main body of the report. More detailed information is available in PNNL-13487, APP. 1.

Table B.1. Radionuclide Concentrations in Columbia River Water at Priest Rapids Dam, 2000 Compared to Previous 5 Years

Radionuclide[a]		2000 No. of Samples	2000 Concentration,[b] pCi/L Maximum	2000 Concentration,[b] pCi/L Average	1995-1999 No. of Samples	1995-1999 Concentration,[b] pCi/L Maximum	1995-1999 Concentration,[b] pCi/L Average	Ambient Surface Water Quality Standard, pCi/L
Composite System								
Tritium		11	53 ± 6.9	35 ± 5.6	57[c]	62 ± 12	33 ± 2.1	20,000[d]
Alpha (gross)		12	1.2 ± 1.0	0.63 ± 0.22	60	5.6 ± 3.1	0.50 ± 0.19	15[e,f]
Beta (gross)		12	3.5 ± 1.7	1.1 ± 0.69	60	7.7 ± 2.2	0.98 ± 0.44	50[e,f]
Strontium-90		12	0.082 ± 0.034	0.072 ± 0.0051	60	0.13 ± 0.062	0.079 ± 0.0050	8[e,f]
Technetium-99		12	0.16 ± 0.28	-0.019 ± 0.0072	60	1.6 ± 0.69	0.022 ± 0.066	900[d]
Iodine-129[h]		4	0.000014 ± 0.0000012	0.0000082 ± 0.0000050	16	0.000022 ± 0.0000021	0.000010 ± 0.0000033	1[d]
Uranium-234		12	0.26 ± 0.060	0.22 ± 0.013	60	0.42 ± 0.087	0.24 ± 0.013	--[g]
Uranium-235		12	0.0079 ± 0.013	0.0027 ± 0.0017	60	0.029 ± 0.016	0.0079 ± 0.0018	--
Uranium-238		12	0.19 ± 0.058	0.17 ± 0.0098	60	0.38 ± 0.080	0.20 ± 0.012	--
Uranium (total)		12	0.44 ± 0.11	0.40 ± 0.016	60	0.81 ± 0.18	0.45 ± 0.025	--
Continuous System								
Cobalt-60[i]	P	12	0.00088 ± 0.00069	0.00026 ± 0.00022	36	0.0015 ± 0.00097	0.00018 ± 0.00019	100[d]
	D	12	0.0016 ± 0.0022	-0.000064 ± 0.00074	36	0.0065 ± 0.0057	0.00042 ± 0.00099	
Cesium-137[i]	P	12	0.0012 ± 0.00072	0.00044 ± 0.00025	36	0.0031 ± 0.0016	0.0011 ± 0.00027	200[d]
	D	12	0.0030 ± 0.0019	0.0011 ± 0.00061	36	0.24 ± 0.0016	0.0072 ± 0.013	
Europium-155[i]	P	12	0.0012 ± 0.0017	0.000070 ± 0.00044	36	0.0032 ± 0.0044	0.00051 ± 0.00037	600[d]
	D	12	0.0060 ± 0.0056	0.00087 ± 0.0016	36	0.012 ± 0.014	0.0019 ± 0.0015	
Plutonium-239/240	P	4	0.000026 ± 0.000011	0.000020 ± 0.0000067	20	0.00028 ± 0.00010	0.000052 ± 0.000028	--
	D	4	0.000048 ± 0.000079	0.000023 ± 0.000022	20	0.000072 ± 0.000082	0.000018 ± 0.000010	

(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).
(b) Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard error of the calculated mean.
(c) Excludes one result of 200 ± 22 pCi/L.
(d) WAC 173-201A-050 and EPA-570/9-76-003.
(e) WAC 246-290.
(f) 40 CFR 141.
(g) Dashes indicate no concentration guides available.
(h) From 1994 through 1995, iodine-129 activities were obtained from the dissolved fraction of the continuous system. Table shows composite system results for 1996 through 2000.
(i) All 2000 results were less than the detection limit.

Table B.2. Radionuclide Concentrations in Columbia River Water at the Richland Pumphouse, 2000 Compared to Previous 5 Years

Radionuclide[a]		2000 No. of Samples	2000 Concentration,[b] pCi/L Maximum	2000 Concentration,[b] pCi/L Average	1995-1999 No. of Samples	1995-1999 Concentration,[b] pCi/L Maximum	1995-1999 Concentration,[b] pCi/L Average	Ambient Surface Water Quality Standard, pCi/L
Composite System								
Tritium		11	98 ± 11	77 ± 11	58	150 ± 11	70 ± 6.8	20,000[c]
Alpha (gross)		12	1.5 ± 1.1	0.60 ± 0.23	60	2.2 ± 1.1	0.55 ± 0.11	15[c,d]
Beta (gross)		12	2.3 ± 1.6	0.76 ± 0.41	60	6.6 ± 2.5	0.98 ± 0.38	50[c,d]
Strontium-90		12	0.10 ± 0.037	0.065 ± 0.0085	60	0.30 ± 0.081	0.083 ± 0.0091	8[c,d]
Technetium-99		12	0.30 ± 0.26	0.0034 ± 0.066	60	0.53 ± 0.52	0.034 ± 0.042	900[e]
Iodine-129[g]		4	0.00012 ± 0.0000057	0.000090 ± 0.000026	16	0.00016 ± 0.000013	0.00011 ± 0.000023	1[e]
Uranium-234		12	0.33 ± 0.078	0.25 ± 0.023	60	0.45 ± 0.081	0.27 ± 0.016	--[f]
Uranium-235		12	0.014 ± 0.013	0.0062 ± 0.0032	60	0.048 ± 0.022	0.0096 ± 0.0021	--
Uranium-238		12	0.23 ± 0.054	0.19 ± 0.014	60	0.30 ± 0.060	0.22 ± 0.010	--
Uranium (total)		12	0.56 ± 0.15	0.45 ± 0.034	60	0.78 ± 0.16	0.50 ± 0.024	--
Continuous System								
Cobalt-60[h]	P	12	0.00088 ± 0.00071	0.00028 ± 0.00021	27	0.0016 ± 0.0011	0.000063 ± 0.00026	100[e]
	D	12	0.0022 ± 0.0021	0.00056 ± 0.00049	27	0.0062 ± 0.0054	0.0010 ± 0.00085	
Cesium-137[h]	P	12	0.0012 ± 0.00074	0.00049 ± 0.00023	27	0.0037 ± 0.0015	0.0014 ± 0.00034	200[e]
	D	12	0.0023 ± 0.0014	0.00092 ± 0.00051	27	0.0071 ± 0.0052	0.0015 ± 0.00072	
Europium-155[h]	P	12	0.0022 ± 0.0017	0.00060 ± 0.00055	27	0.0029 ± 0.017	0.00022 ± 0.00054	600[e]
	D	12	0.0056 ± 0.0039	0.0014 ± 0.0012	27	0.0093 ± 0.012	0.0010 ± 0.0018	
Plutonium-239/240	P	4	0.000028 ± 0.000013	0.000014 ± 0.000011	17	0.00017 ± 0.000083	0.000051 ± 0.000022	--
	D	4	0.000063 ± 0.000090	0.000032 ± 0.000028	17	0.00016 ± 0.000091	0.000038 ± 0.000020	

(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).
(b) Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard error of the calculated mean.
(c) 40 CFR 141.
(d) WAC 246-290.
(e) WAC 173-201A-050 and EPA-570/9-76-003.
(f) Dashes indicate no concentration guides available.
(g) From 1994 through 1995, iodine-129 activities were obtained from the dissolved fraction of the continuous system. Table shows composite system results for 1996 through 2000.
(h) All 2000 results were less than the detection limit.

Table B.3. Radionuclide Concentrations Measured in Columbia River Water along Transects of the Hanford Reach, 2000

Transect/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Minimum	Mean
Vernita Bridge (HRM 0.3)[b]				
Tritium	16	46 ± 6.3	27 ± 4.8	35 ± 3.2
Strontium-90	16	0.085 ± 0.034	0.043 ± 0.025	0.067 ± 0.0056
Uranium (total)	16	0.51 ± 0.13	0.34 ± 0.12	0.38 ± 0.023
100-N Area (HRM 9.5)				
Tritium	9	150 ± 16	26 ± 4.8	56 ± 28
Strontium-90	7	0.17 ± 0.051	0.058 ± 0.031	0.087 ± 0.029
Uranium (total)	7	0.42 ± 0.13	0.32 ± 0.086	0.36 ± 0.032
100-F Area (HRM 19)				
Tritium	7	33 ± 6.3	24 ± 4.7	29 ± 2.3
Strontium-90	6	0.076 ± 0.037	0.062 ± 0.034	0.069 ± 0.0045
Uranium (total)	6	0.45 ± 0.12	0.31 ± 0.10	0.37 ± 0.041
Old Hanford Townsite (HRM 28.7)				
Tritium	8	500 ± 45	27 ± 5.8	150 ± 130
Strontium-90	6	0.081 ± 0.039	0.046 ± 0.024	0.060 ± 0.010
Uranium (total)	6	0.39 ± 0.11	0.34 ± 0.099	0.36 ± 0.012
300 Area (HRM 43.1)				
Tritium	8	58 ± 8.1	29 ± 6.0	41 ± 7.8
Strontium-90	6	0.074 ± 0.033	0.050 ± 0.032	0.062 ± 0.0072
Uranium (total)	6	0.54 ± 0.14	0.34 ± 0.097	0.41 ± 0.059
Richland Pumphouse (HRM 46.4)				
Tritium	28	150 ± 14	23 ± 5.8	59 ± 14
Strontium-90	26	0.13 ± 0.045	0.046 ± 0.029	0.067 ± 0.0074
Uranium (total)	26	0.94 ± 0.19	0.32 ± 0.088	0.45 ± 0.055

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2 sigma). Mean values are ±2 standard error of the mean.
(b) HRM = Hanford River Mile (e.g., Vernita Bridge crossing is Mile 0, the Richland Pumphouse is Mile 46.4).

Table B.4. Radionuclide Concentrations Measured in Columbia River Water at Nearshore Locations in the Hanford Reach, 2000

Nearshore/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Minimum	Mean
Vernita Bridge (HRM 0.3)[b]				
Tritium	4	41 ± 5.8	27 ± 6.0	34 ± 6.1
Strontium-90	4	0.079 ± 0.041	0.072 ± 0.034	0.076 ± 0.0033
Uranium (total)	4	0.40 ± 0.12	0.35 ± 0.089	0.38 ± 0.023
100-N Area (HRM 8.4 to 9.8)				
Tritium	11	150 ± 16	31 ± 5.2	60 ± 21
Strontium-90	6	0.27 ± 0.076	0.068 ± 0.031	0.12 ± 0.062
Uranium (total)	6	0.42 ± 0.11	0.33 ± 0.086	0.36 ± 0.026
100-F Area (HRM 18-23)				
Tritium	6	34 ± 6.2	30 ± 5.1	32 ± 1.3
Strontium-90	4	0.080 ± 0.036	0.050 ± 0.013	0.069 ± 0.013
Uranium (total)	4	0.40 ± 0.12	0.33 ± 0.096	0.37 ± 0.031
Old Hanford Townsite (HRM 26 to 30)				
Tritium	9	4,100 ± 360	24 ± 5.8	810 ± 920
Strontium-90	5	0.081 ± 0.039	0.046 ± 0.026	0.062 ± 0.012
Uranium (total)	5	0.43 ± 0.12	0.30 ± 0.091	0.35 ± 0.044
300 Area (HRM 41.5 to 43.1)				
Tritium	10	580 ± 52	37 ± 6.7	180 ± 130
Strontium-90	5	0.072 ± 0.033	0.048 ± 0.026	0.059 ± 0.0084
Uranium (total)	5	0.58 ± 0.13	0.18 ± 0.061	0.40 ± 0.13
Richland Pumphouse (HRM 43.5 to 46.4)				
Tritium	26	87 ± 8.2	33 ± 6.5	50 ± 6.8
Strontium-90	22	0.095 ± 0.043	0.042 ± 0.024	0.069 ± 0.0068
Uranium (total)	22	0.66 ± 0.16	0.20 ± 0.066	0.41 ± 0.065

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2 sigma). Mean values are ±2 standard error of the mean.
(b) HRM = Hanford River Mile (e.g., Vernita Bridge crossing is Mile 0, the Richland Pumphouse is Mile 46.4).

Table B.5. Selected U.S. Geological Survey Columbia River Water Quality Data,[a] 2000

Analysis	Units	Vernita Bridge (upstream) No. of Samples	Median	Maximum	Minimum	Richland Pumphouse (downstream) No. of Samples	Median	Maximum	Minimum	Washington Ambient Surface Water Quality Standard[b]
Temperature	°C	9	11	19	4.5	3	17	18	4.7	20 (maximum)
Dissolved oxygen	mg/L	9	12	14	9.2	3	11	13	8.8	8 (minimum)
Turbidity	NTU[c]	9	0.70	3.0	<0.1	3	0.70	0.80	0.50	5 + background
pH	pH units	9	8.0	8.2	7.9	3	8.1	8.2	8.0	6.5 - 8.5
Sulfate, dissolved	mg/L	9	7.7	9.3	6.1	3	8.1	10	6.7	--[d]
Dissolved solids, 180°C (356°F)	mg/L	9	78	85	67	3	81	90	68	--
Specific conductance	µS/cm	9	140	151	115	3	132	152	116	--
Total hardness, as $CaCO_3$	mg/L	1	61	61	61	3	56	64	50	--
Alkalinity	mg/L	9	57	62	46	3	52	60	42	
Phosphorus, total	mg/L	9	0.006	0.05	0.005	3	<0.05	<0.05	<0.05	--
Chromium, dissolved	µg/L	1	<0.8	<0.8	<0.8	4	<0.8	<0.8	0.5	--
Dissolved organic carbon	mg/L	9	1.5	1.9	1.1	3	1.8	7.8	1.1	--
Iron, dissolved	µg/L	9	<10	<10	6	3	<10	<10	<10	--
Ammonia, dissolved, as N	mg/L	9	<0.04	0.002	<0.002	3	<0.02	<0.02	<0.02	--
Nitrite + nitrate, dissolved, as N	mg/L	9	0.12	0.22	0.04	3	0.10	0.15	0.070	--

(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.

Table B.6. Concentrations (µg/L) of Dissolved Metals in Columbia River Transect and Nearshore Water Samples, 2000

Location	Metal	No. of Samples	Maximum	Minimum	Average	±2SEM[a]
Vernita Bridge	Antimony	20	0.20	0.17	0.18	0.0045
	Arsenic	20	0.63	0.43	0.53	0.0250
	Beryllium	20	0.048	0.012	0.021	0.0072
	Cadmium	20	0.027	0.014	0.018	0.0019
	Chromium	20	0.27	0.042	0.19	0.039
	Copper	20	0.72	0.50	0.58	0.037
	Lead	20	0.062	0.0035	0.015	0.0062
	Mercury	5	0.00064	0.00026	0.00044	0.00015
	Nickel	20	0.57	0.14	0.30	0.067
	Selenium	20	0.39	0.096	0.25	0.053
	Silver	20	0.050	0.00083	0.017	0.0094
	Thallium	20	0.038	0.020	0.029	0.0030
	Zinc	20	2.8	1.0	1.8	0.29
100-N Area	Antimony	10	0.21	0.17	0.19	0.0082
	Arsenic	10	0.58	0.44	0.51	0.023
	Beryllium	10	0.048	0.048	0.048	0
	Cadmium	10	0.058	0.015	0.029	0.0076
	Chromium	10	1.1	0.042	0.24	0.21
	Copper	10	0.56	0.36	0.44	0.041
	Lead	10	0.029	0.0023	0.012	0.0056
	Mercury	0				
	Nickel	10	0.54	0.38	0.44	0.035
	Selenium	10	0.39	0.39	0.39	0
	Silver	10	0.050	0.0043	0.014	0.012
	Thallium	10	0.027	0.023	0.025	0.00095
	Zinc	10	1.0	0.67	0.77	0.088
100-F Area	Antimony	10	0.20	0.15	0.18	0.0088
	Arsenic	10	0.60	0.45	0.55	0.028
	Beryllium	10	0.48	0.48	0.48	0
	Cadmium	10	0.045	0.015	0.020	0.0062
	Chromium	10	0.21	0.042	0.066	0.033
	Copper	10	0.50	0.40	0.45	0.020
	Lead	10	0.027	0.0046	0.011	0.0044
	Mercury	0				
	Nickel	10	0.48	0.36	0.42	0.024
	Selenium	10	0.39	0.39	0.39	0
	Silver	10	0.0096	0.0043	0.0061	0.0013
	Thallium	10	0.030	0.022	0.026	0.0015
	Zinc	10	1.7	0.54	0.92	0.23
Old Hanford Townsite	Antimony	10	0.20	0.17	0.18	0.0063
	Arsenic	10	0.74	0.46	0.55	0.048
	Beryllium	10	0.048	0.048	0.048	0
	Cadmium	10	0.031	0.015	0.021	0.0037
	Chromium	10	0.73	0.061	0.38	0.16
	Copper	10	0.49	0.41	0.45	0.014
	Lead	10	0.020	0.0049	0.0098	0.0028
	Mercury	0				
	Nickel	10	0.47	0.39	0.44	0.016
	Selenium	10	0.39	0.39	0.39	0
	Silver	10	0.012	0.0043	0.0063	0.0016
	Thallium	10	0.030	0.023	0.026	0.0014
	Zinc	10	0.90	0.58	0.77	0.063

Table B.6. (contd)

Location	Metal	No. of Samples	Maximum	Minimum	Average	±2SEM[a]
300 Area	Antimony	10	0.20	0.17	0.18	0.0070
	Arsenic	10	0.77	0.49	0.59	0.070
	Beryllium	10	0.048	0.048	0.048	0
	Cadmium	10	0.038	0.015	0.020	0.0048
	Chromium	10	0.74	0.042	0.12	0.14
	Copper	10	0.60	0.44	0.47	0.029
	Lead	10	0.031	0.0099	0.017	0.0039
	Mercury	0				
	Nickel	10	0.47	0.38	0.42	0.016
	Selenium	10	0.39	0.39	0.39	0
	Silver	10	0.0064	0.0043	0.0048	0.00054
	Thallium	10	0.029	0.024	0.027	0.0011
	Zinc	10	5.4	0.63	1.4	0.92
Richland Pumphouse	Antimony	41	0.26	0.16	0.19	0.0053
	Arsenic	41	0.81	0.44	0.54	0.026
	Beryllium	41	0.048	0.012	0.020	0.0050
	Cadmium	41	0.046	0.011	0.022	0.0029
	Chromium	41	0.88	0.15	0.27	0.042
	Copper	41	0.74	0.39	0.55	0.037
	Lead	41	0.018	0.0011	0.0096	0.0013
	Mercury	11	0.0010	0.00036	0.00059	0.00014
	Nickel	41	0.42	0.077	0.26	0.031
	Selenium	41	0.44	0.064	0.25	0.037
	Silver	41	0.011	0.00095	0.0043	0.00059
	Thallium	41	0.037	0.020	0.028	0.0019
	Zinc	41	6.6	0.45	1.8	0.37

SEM = Standard error of the mean.

Table B.7. Radionuclide Concentrations in Sediment from the Columbia River and from Columbia River Riverbank Springs, 2000 Compared to Previous 5 Years

Location	Radionuclide	2000 No. of Samples	2000 Concentration, pCi/g Median[a]	2000 Concentration, pCi/g Maximum[b]	1995-1999 No. of Samples	1995-1999 Concentration, pCi/g Median[a]	1995-1999 Concentration, pCi/g Maximum[b]
River Sediment							
100-F Slough	Cobalt-60	1		0.016 ± 0.011	5	0.024	0.033 ± 0.011
	Cesium-137	1		0.32 ± 0.040	5	0.36	0.49 ± 0.054
	Europium-155	1		0.025 ± 0.026	5	0.033	0.061 ± 0.033
	Plutonium-239/240	1		0.0023 ± 0.00054	5	0.0020	0.0024 ± 0.00082
	Strontium-90	1		-0.0095 ± 0.020	5	0.0032	0.0062 ± 0.0047
	Uranium-235	1		0.011 ± 0.0068	5	0.0022	0.064 ± 0.068
	Uranium-238	1		0.29 ± 0.058	5	0.15	1.4 ± 0.41
Hanford Slough	Cobalt-60	1		-0.0092 ± 0.011	5	0.18	0.32 ± 0.046
	Cesium-137	1		0.011 ± 0.012	5	0.25	0.59 ± 0.068
	Europium-155	1		0.058 ± 0.030	5	0.068	0.083 ± 0.045
	Plutonium-239/240	1		0.00064 ± 0.00023	5	0.0037	0.0076 ± 0.0014
	Strontium-90	1		0.00015 ± 0.024	5	0.0059	0.016 ± 0.0090
	Uranium-235	1		0.012 ± 0.0070	5	0.040	0.24 ± 0.16
	Uranium-238	1		0.34 ± 0.067	5	1.4	2.4 ± 0.88
McNary Dam	Cobalt-60	2	0.017	0.030 ± 0.036	24	0.048	0.17 ± 0.032
	Cesium-137	2	0.36	0.45 ± 0.079	24	0.39	1.0 ± 0.11
	Europium-155	2	0.047	0.085 ± 0.080	24	0.054	0.091 ± 0.042
	Plutonium-239/240	2	0.0089	0.011 ± 0.0020	24	0.0080	0.014 ± 0.0026
	Strontium-90	2	0.021	0.029 ± 0.030	24	0.023	0.048 ± 0.011
	Uranium-235	2	0.020	0.022 ± 0.013	24	0.027	0.21 ± 0.10
	Uranium-238	2	0.64	0.67 ± 0.13	24	0.82	2.3 ± 0.71
Priest Rapids Dam	Cobalt-60	2	0.0075	0.0082 ± 0.016	23	0.0018	0.042 ± 0.041
	Cesium-137	2	0.39	0.44 ± 0.056	23	0.34	0.67 ± 0.077
	Europium-155	2	0.058	0.064 ± 0.039	23	0.049	0.10 ± 0.050
	Plutonium-239/240	2	0.0087	0.0096 ± 0.0017	23	0.0078	0.017 ± 0.0030
	Strontium-90	2	0.019	0.028 ± 0.028	23	0.013	0.019 ± 0.0058
	Uranium-235	2	0.68	0.73 ± 0.13	23	0.022	0.32 ± 0.17
	Uranium-238	2	0.61	0.65 ± 0.12	23	0.71	2.2 ± 0.71

Table B.7. (contd)

Location	Radionuclide	2000 No. of Samples	2000 Concentration, pCi/g Median[a]	2000 Concentration, pCi/g Maximum[b]	1995-1999 No. of Samples	1995-1999 Concentration, pCi/g Median[a]	1995-1999 Concentration, pCi/g Maximum[b]
Richland	Cobalt-60	1		-0.052 ± 0.19	5	0.035	0.065 ± 0.022
	Cesium-137	1		0.23 ± 0.051	5	0.24	0.34 ± 0.042
	Europium-155	1		0.047 ± 0.059	5	0.030	0.066 ± 0.034
	Plutonium-239/240	1		0.0011 ± 0.00050	5	0.0021	0.0034 ± 0.00073
	Strontium-90	1		0.00065 ± 0.020	5	0.0043	0.0063 ± 0.0040
	Uranium-235	1		0.0096 ± 0.0093	5	0.014	0.068 ± 0.13
	Uranium-238	1		0.24 ± 0.053	5	0.83	2.1 ± 0.54
White Bluffs Slough	Cobalt-60	1		0.061 ± 0.023	5	0.11	0.20 ± 0.031
	Cesium-137	1		0.53 ± 0.061	5	0.53	0.69 ± 0.077
	Europium-155	1		0.0065 ± 0.039	5	0.052	0.10 ± 0.034
	Plutonium-239/240	1		0.0058 ± 0.0011	5	0.0039	0.0050 ± 0.0012
	Strontium-90	1		-0.0041 ± 0.023	5	0.0052	0.010 ± 0.0057
	Uranium-235	1		0.027 ± 0.010	5	0.0087	0.16 ± 0.12
	Uranium-238	1		0.59 ± 0.11	5	1.0	1.9 ± 0.52
Riverbank Spring Sediment							
100-B Spring	Cobalt-60	1		0.00088 ± 0.010	5	0.021	0.051 ± 0.024
	Cesium-137	1		0.063 ± 0.019	5	0.095	0.14 ± 0.026
	Europium-155	1		0.077 ± 0.031	5	0.065	0.11 ± 0.072
	Strontium-90	1		0.0020 ± 0.024	5	0.0027	0.0041 ± 0.0083
	Uranium-235	1		0.0053 ± 0.0045	5	0.029	0.20 ± 0.10
	Uranium-238	1		0.21 ± 0.044	5	1.1	1.2 ± 0.38
100-F Spring	Cobalt-60	1		0.021 ± 0.032	5	0.018	0.044 ± 0.024
	Cesium-137	1		0.092 ± 0.045	5	0.19	0.32 ± 0.040
	Europium-155	1		0.042 ± 0.079	5	0.030	0.055 ± 0.031
	Strontium-90	1		0.013 ± 0.032	5	0.0043	0.0096 ± 0.010
	Uranium-235	1		0.016 ± 0.0082	6	0.067	0.17 ± 0.13
	Uranium-238	1		0.35 ± 0.065	6	0.83	1.4 ± 0.54

Table B.7. (contd)

Location	Radionuclide	1999 No. of Samples	1999 Concentration, pCi/g Median[a]	1999 Concentration, pCi/g Maximum[b]	1994-1998 No. of Samples	1994-1998 Concentration, pCi/g Median[a]	1994-1998 Concentration, pCi/g Maximum[b]
100-K Spring	Cobalt-60	[c]			2	0.011	0.015 ± 0.021
	Cesium-137	[c]			2	0.17	0.19 ± 0.046
	Europium-155	[c]			2	0.084	0.13 ± 0.066
	Strontium-90	[c]			2	0.0049	0.0085 ± 0.0048
	Uranium-235	[c]			2	0.17	0.20 ± 0.14
	Uranium-238	[c]			2	1.2	1.5 ± 0.54
300 Area Spring	Cobalt-60	2	0.011	0.013 ± 0.012	5	0.013	0.020 ± 0.010
	Cesium-137	2	0.16	0.27 ± 0.035	5	0.077	0.21 ± 0.029
	Europium-155	2	0.033	0.037 ± 0.037	5	0.045	0.086 ± 0.035
	Uranium-235	2			5	0.18	0.41 ± 0.16
	Uranium-238	2			5	2.2	5.2 ± 1.1
Hanford Spring	Cobalt-60	2	0.051	0.062 ± 0.017	5	0.059	0.086 ± 0.015
	Cesium-137	2	0.20	0.22 ± 0.031	5	0.23	0.29 ± 0.032
	Europium-155	2	0.073	0.10 ± 0.053	5	0.066	0.069 ± 0.035

(a) Median values are not provided when only one sample analyzed.
(b) Values are ± total propagated analytical uncertainty (2 sigma).
(c) Sediment was not available at the 2000 spring location.

Table B.8. Median Metal Concentrations (mg/kg dry wt.) in Columbia River Sediment, 2000

Metal	(n=2) Priest Rapids Dam	(n=4) Hanford Reach[a]	(n=2) McNary Dam	(n=6) Riverbank Springs[b]
Antimony	1.0	0.62	0.87	0.54
Arsenic	7.8	4.6	7.0	5.6
Beryllium	1.5	1.5	1.5	1.5
Cadmium	6.3	0.79	3.4	0.64
Chromium	82	54	57	74
Copper	57	22	35	16
Lead	44	30	27	23
Mercury	0.16	0.0028	0.11	0.014
Nickel	48	20	28	20
Selenium	0.59	0.40	0.46	0.26
Silver	0.47	0.27	0.37	0.31
Thallium	1.4	0.61	0.84	0.49
Zinc	570	260	360	150

(a) 100-F Slough, Hanford Slough, White Bluffs Slough, and Richland.
(b) 100-B Area, 100-F Area, Old Hanford Townsite, and 300 Area.

Table B.9. Radionuclide Concentrations Measured in Water from Riverbank Springs, 2000 Compared to Previous 5 Years

Location/Radionuclide	2000 No. of Samples	2000 Concentation,[a] pCi/L Maximum	2000 Concentation,[a] pCi/L Median	1995-1999 No. of Samples	1995-1999 Concentration,[a] pCi/L Maximum	1995-1999 Concentration,[a] pCi/L Median	Washington State Ambient Surface Water Quality Standard,[b] pCi/L
100-B Area Springs							
Alpha (gross)	3	2.9 ± 1.8	2.5	10	2.4 ± 1.2	1.2	15
Beta (gross)	3	8.1 ± 2.1	6.0	10	28 ± 3.8	11	50
Strontium-90	3	0.093 ± 0.23	0.032	8	7.4 ± 1.6	0.030	8
Technetium-99	1	2.0 ± 0.36	2.0	4	25 ± 3.2	14	900[c]
Tritium	3	7,600 ± 420	7,200	8	24,000 ± 1,800	13,000	20,000
100-D Area Springs							
Alpha (gross)	8	4.4 ± 2.3	0.97	16	3.6 ± 1.5	0.89	15
Beta (gross)	8	5.5 ± 1.8	4.2	16	14 ± 3.6	3.6	50
Strontium-90	2	1.4 ± 0.36	0.73	12	5.3 ± 1.2	0.78	8
Tritium	8	9,800 ± 730	1,100	7	5,900 ± 530	360	20,000
100-F Area Springs							
Alpha (gross)	4	5.3 ± 3.1	3.2	7	41 ± 18	6.3	15
Beta (gross)	4	13 ± 2.8	7.7	7	65 ± 11	15	50
Strontium-90	4	0.95 ± 0.32	0.085	7	0.094 ± 0.057	0.012	8
Tritium	4	960 ± 270	820	7	1,800 ± 240	1,200	20,000
Uranium (total)	1	2.5 ± 0.48	2.5	5	9.2 ± 4.3	4.6	--[d]
100-H Area Springs							
Alpha (gross)	6	1.6 ± 1.0	0.94	16	10 ± 3.7	1.7	15
Beta (gross)	6	15 ± 2.1	3.5	16	85 ± 8.8	7.1	50
Strontium-90	2	5.6 ± 1.3	2.8	4	17 ± 3.1	13	8
Technetium-99	2	0.30 ± 0.26	0.18	5	140 ± 15	18	900
Tritium	6	1,200 ± 320	310	11	2,500 ± 400	840	20,000
Uranium (total)	2	0.58 ± 0.14	0.45	5	9.3 ± 3.9	1.7	--
100-K Area Springs							
Alpha (gross)	2	1.9 ± 1.4	1.1	9	4.1 ± 2.1	0.78	15
Beta (gross)	2	5.2 ± 1.9	4.2	9	21 ± 3.2	4.5	50
Strontium-90	2	2.1 ± 0.52	1.1	4	0.59 ± 0.13	0.029	8
Technetium-99	1	0.27 ± 0.26	0.27	1	-0.021 ± 0.51	-0.021	900[c]
Tritium	2	5,400 ± 340	2,700	7	20,000 ± 1,500	4,400	20,000

Table B.9. (contd)

Location/Radionuclide	2000 No. of Samples	2000 Concentration,[a] pCi/L Maximum	2000 Concentration,[a] pCi/L Median	1995-1999 No. of Samples	1995-1999 Concentration,[a] pCi/L Maximum	1995-1999 Concentration,[a] pCi/L Median	Washington State Ambient Surface Water Quality Standard,[b] pCi/L
100-N Area Springs							
Alpha (gross)	1	1.6 ± 1.4	1.6	6	2.8 ± 1.2	0.78	15
Beta (gross)	1	5.9 ± 2.1	5.9	6	16,000 ± 1,400	3.2	50
Strontium-90	1	-0.0026 ± 0.037	-0.0026	5	9,900 ± 1,800	0.079	8
Tritium	1	18,000 ± 800	18,000	6	24,000 ± 1,900	16,000	20,000
300 Area Springs							
Alpha (gross)	2	120 ± 29	97	6	230 ± 49	50	15
Beta (gross)	2	29 ± 5.0	28	6	49 ± 7.9	15	50
Iodine-129	2	0.0057 ± 0.00053	0.0054	6	0.0062 ± 0.00056	0.0048	1
Technetium-99	2	16 ± 2.0	14	4	14 ± 1.9	11	900[c]
Tritium	2	9,900 ± 510	9,500	6	12,000 ± 940	9,900	20,000
Uranium (total)	2	130 ± 27	92	6	210 ± 99	70	--
Old Hanford Townsite Springs							
Alpha (gross)	3	3.1 ± 1.9	2.4	7	14 ± 5.9	3.2	15
Beta (gross)	3	30 ± 4.9	28	7	49 ± 7.9	22	50
Iodine-129	3	0.27 ± 0.029	0.15	7	0.41 ± 0.024	0.17	1
Technetium-99	3	80 ± 6.1	72	7	120 ± 8.0	57	900[c]
Tritium	3	79,000 ± 3,100	61,000	7	120,000 ± 8,800	75,000	20,000
Uranium (total)	3	3.2 ± 0.61	2.4	7	8.6 ± 1.5	3.1	--

(a) Maximum values are ± total propagated analytical uncertainty (2 sigma).
(b) WAC 246-290, 40 CFR 141, and Appendix D, Table D.2.
(c) WAC 173-201A-050 and EPA-570/9-76-003.
(d) Dashes indicate no concentration guides available.

Table B.10. Annual Average Dose Rates Measured on and around the Hanford Site in Calendar Year 2000

Location	Location Number	Annual Average (mrem/yr)[a]
Onsite[b]		
100 K Area	1	76 ± 22
100 D Area	2	80 ± 15
100 F Met Tower	3	81 ± 3
Hanford Townsite	4	76 ± 9
N of 200 E	5	92 ± 8
B Pond	6	93 ± 9
E of 200 E	7	90 ± 4
200ESE	8	86 ± 9
S of 200 E	9	94 ± 11
200 Tel. Exchange	10	83 ± 11
SW of B/C Cribs	11	77 ± 31
200 W SE	12	83 ± 4
Army Loop Camp	13	84 ± 8
3705 Bldg. 300 Area	14	81 ± 5
300 Water Intake	15	79 ± 7
300 Southwest Gate	16	81 ± 10
300 South Gate	17	81 ± 6
300 Trench	18	82 ± 9
300 NE	19	84 ± 7
400 E	20	81 ± 7
400 W	21	85 ± 6
400 S	22	81 ± 11
400 N	23	81 ± 9
US Ecology NE Corner	24	84 ± 8
US Ecology SE Corner	25	91 ± 12
US Ecology NW Corner	26	86 ± 6
US Ecology SW Corner	27	101 ± 13
Wye Barricade	28	83 ± 5
WPPSS 1; S of WNP 2	29	86 ± 8
Perimeter[c]		
Ringold Met Tower	1	92 ± 9
W End of Fir Road	2	92 ± 8
Dogwood Met Tower	3	91 ± 7
Byers Landing	4	106 ± 8
Battelle Complex	5	79 ± 6
WPPSS 4; WPS Warehse	6	77 ± 7
Horn Rapids Substa	7	83 ± 7
Prosser Barricade	8	89 ± 6
Yakima Barricade	9	96 ± 8
Rattlesnake Springs	10	89 ± 7
Wahluke Slope	11	90 ± 6
S End Vernita Bridge	12	86 ± 11
Community[c]		
Mattawa	13	75 ± 9
Othello	14	74 ± 5
Basin City	15	77 ± 4
Edwin Markham School	16	75 ± 15
Leslie Groves - Richlnd	17	72 ± 21
Pasco	18	88 ± 7
Kennewick -Ely Street	19	77 ± 2
Benton City	20	82 ± 4
Distant[c]		
Yakima	21	69 ± 6
Toppenish	22	69 ± 5
Columbia River Shoreline[d]		
Above 100 B Area	1	80 ± 18
Below 100B Ret Basin	2	96 ± 15
Above 1K Boat Ramp	3	83 ± 8
Below 100N Outfall	4	111 ± 9
Above Tip 100N Berm	5	93 ± 2
100 N Trench Spring	6	131 ± 7
Below 100 D Area	7	62 ± 17
100-D Island	8	77 ± 7
100 H Area	9	81 ± 14
Lo End Locke Isl	10	89 ± 8
White Bluffs Fy Lnd.	11	82 ± 11
White Bluffs Slough	12	86 ± 14
Below 100 F	13	76 ± 10
100 F Flood Plain	14	82 ± 10
Hanford Slough	15	92 ± 14
Hanf Powerline Xing	16	93 ± 8
Hanford RR Track	17	89 ± 12
Savage Isl Slough	18	77 ± 5
Ringold Island	19	89 ± 12
Powerline Crossing	20	85 ± 9
S End Wooded Island	21	91 ± 8
Islnd Above 300 Area	22	93 ± 6
Island Near 300 Area	23	88 ± 13
Port of Benton-River	24	81 ± 7
Isl DS Bateman Isl	25	92 ± 4

(a) ±2 standard deviation of the exposure rate.
(b) All locations are shown on Figure 4.7.1.
(c) All locations are shown on Figure 4.7.2.
(d) All locations are shown on Figure 4.7.3.

Table B.11. Geographic Composite Groupings of Air Samplers for the 2000 Hanford Site Wildfire

Geographic Composite Group/Area		Air Sampling Locations[a]
1	200-East	N019, N480, N481, N498, N499, N957, N967, N968, N973
2	200-East	N158, N969, N970, N972, N976, N977, N978, N984, N985, N999
3	200-West	N161, N433, N456, N457, N964, N965, N974, N987, N994
4	200-West	N155, N165, N168, N304, N441, N442, N956, N963, N966, N975
5	300	N130, N485, N486, N489
6	100-N and 100-K	N102, N103, N105, N106, N401, N402, N403, N404, N476, N478, N479
7	100-D	N468, N469, N470, N492, N493, N512, N513, N515
8	100-H and 100-F	N494, N495, N507, N508, N509, N510, N519, N520, N521, N522

(a) See PNNL-13487, APP. 2.

Table B.12. Surface Environmental Surveillance Project Samples Collected for the 2000 Hanford Site Wildfire

Sample Site Name	Sample Location[a]	Collected Number of Days Early	Priority Tests[c]
Prosser Barricade	31	1	Gross alpha, gross beta, gamma
Rattlesnake Springs	33	-1[b]	Gross alpha, gross beta, gamma
Leslie Groves	37	6	Gross alpha, gross beta, gamma
Kennewick	39	7	Gross alpha, gross beta, gamma
Pasco	38	7	Gross beta, gamma
Byers Landing	28	7	Gross alpha, gross beta, gamma
Dogwood Met Tower	27	7	Gross alpha, gross beta, gamma
W End Fir Rd.	26	7	Gross alpha, gross beta, gamma
Battelle Complex	29	0	Gross alpha, gross beta, gamma
Benton City	40	0	Gross beta, gamma
Horn Rapids Substation	30	0	Gross alpha, gross beta, gamma
Yakima Barricade	32	0	Gross alpha, gross beta, gamma
300 NE	19	0	Gross alpha, gross beta, gamma
300 South Gate	16	0	Gross alpha, gross beta, gamma
300 Trench	18	0	Gross alpha, gross beta, gamma
300 Water Intake	15	0	Gross alpha, gross beta, gamma
300 South West	17	0	Gross alpha, gross beta, gamma

(a) See Figure 4.1.1.
(b) Collected late due to no access to the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit.
(c) The air task routinely combines biweekly samples for nearby locations (or, in some cases, a single location) into quarterly composite samples (see Table 4.1.1). During the fire, some of the biweekly samples were analyzed individually for gamma-emitting radionuclides.

References

40 CFR 141. U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule." *Code of Federal Regulations*.

EPA-570/9-76-003. 1976. *National Interim Primary Drinking Water Regulations*. Office of Water Supply, U.S. Environmental Protection Agency, Washington, D.C.

PNNL-13487, APP. 1. 2001. *Hanford Site Environmental Surveillance Data Report for Calendar Year 2000*. L. E. Bisping, Pacific Northwest National Laboratory, Richland, Washington.

WAC 173-201A. "Water Quality Standards for Surface Waters of the State of Washington." Washington Administrative Code, Olympia, Washington.

WAC 246-290. "Group A Public Water Systems." Washington Administrative Code, Olympia, Washington.

Appendix C
Glossary

Words appearing in *italic* are defined in this glossary.

absorbed dose - Energy absorbed per unit mass from any kind of ionizing *radiation* in any kind of matter. Unit: *rad*.

activation product - Material made radioactive by *exposure* to *radiation* from a source such as a nuclear reactor's neutrons.

adsorption - The accumulation of gases, liquids, or solutes on the surface of a solid or liquid.

alpha particle - A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It has low penetrating power and short range. The most energetic alpha will generally fail to penetrate the skin. Alphas are hazardous when an alpha-emitting *isotope* is introduced into the body.

anion - A negatively charged ion.

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* 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 *radioactivity* equal to one nuclear transformation per second (1 Bq = 1 disintegration/s). Another unit of *radioactivity*, the *curie*, is related to the becquerel: 1 Ci = 3.7×10^{10} Bq.

beta particle - A charged particle emitted from a nucleus during radioactive *decay*. Large amounts of beta particles may cause skin burns and are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal or plastic.

boundary dose rate - *Dose rate* measured or calculated at publicly accessible locations on or near the Hanford Site boundary.

cation - A positively charged ion.

clean closed - A facility is classified as "clean closed" under RCRA regulations when all dangerous waste has been removed and *groundwater* monitoring is no longer required.

collective total effective dose equivalent - Sum of the *total effective dose equivalents* for individuals composing a defined population. The units for this are "*person-rems*" or "*person-sieverts*."

committed dose equivalent - The *dose equivalent* to organs or tissues that will be received from an intake of radioactive material by an individual during the 50-year period following intake.

committed effective dose equivalent - The sum of the *committed dose equivalent* from sources inside the body.

composite sample - Sample formed by mixing discrete samples taken at different times or from different locations.

confined aquifer - An *aquifer* bounded above and below by less-permeable layers. *Groundwater* in the confined aquifer is under a pressure greater than atmospheric pressure.

continuous sample - Sample formed by the continuous collection of the medium or contaminants within the medium during the entire sample period.

controlled area - An area to which access is controlled to protect individuals from *exposure* to *radiation* or radioactive and/or hazardous materials.

cosmic radiation - High-energy subatomic particles and electromagnetic *radiation* from outer space that bombard the earth. Cosmic *radiation* is part of natural *background radiation*.

crib - An underground structure designed to receive liquid waste that percolates into the soil directly or percolates into the soil after having traveled through a connected tile field.

curie (Ci) - A unit of *radioactivity* equal to 37 billion (3.7×10^{10}) nuclear transformations per second. The curie is related to the *becquerel*: 1 *Bq* = 0.000000000027 Ci.

decay - The decrease in the amount of any radioactive material with the passage of time. See *radioactivity*.

decay product - The atomic nucleus or nuclei that are left after radioactive transformation of a radioactive material. Decay products may be radioactive or non-radioactive (stable). Formerly called "daughter product." See *radioactivity*.

deep-dose equivalent - The *dose equivalent* at a tissue depth of 1 centimeter from *radiations* originating outside of the body.

derived concentration guide (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 *millirems* per year.

detection level - Minimum amount of a substance that can be measured with a specified or implied 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*.

dose rate - A quantity indicating how fast or slow *radiation* dose is accumulated over time. "Dose rate" is generally used to denote *absorbed dose* rate, *dose equivalent* rate, etc. Units: *rads* or millirads per hour (rad/h or mrad/h) for *absorbed dose* rate; *rems* or *millirems* per hour (rem/h or mrem/h) for *dose equivalent* rate.

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 - The sum of products of *dose equivalent* to each tissue or organ and the tissue weighting factor for each tissue or organ. The tissue weighting factors put doses to various tissues and organs on an equal basis in terms of health *risk*.

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.

facies - The aspect, appearance, and characteristics of a rock unit, usually reflecting the conditions of its origin (Bates and Jackson 1980).

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*; see below).

fission products - Elements formed from fissioning. Many fission products are radioactive.

gamma radiation - High-energy electromagnetic *radiation* originating in radioactive *decay* or nuclear reactions. If needed, shielding can be lead, steel, concrete, earth, or water. The needed thickness of the shield is determined by the intensity and duration of *exposure*.

grab sample - A short duration sample (e.g., air, water, soil) that is "grabbed" from the collection site.

grand mean - A "means of means" or an "overall *mean*" where there is some subdivision of the data where means were already provided for each subdivision.

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.

high-level waste - Highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains *fission products* and other *radioisotopes* in sufficient concentrations to require permanent isolation.

internal radiation - *Radiation* from radioactive material inside the body.

ion exchange - The reversible exchange of one species of ion for a different species of ion within a medium.

irradiation - *Exposure* to *radiation*.

isotopes - *Nuclides* of the same chemical element with differing number of neutrons. *Isotopes* of the same element (e.g., ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu) have almost identical chemical properties.

legacy waste - Waste that was generated prior to cleanup associated with deactivation and decommissioning.

low-level waste - Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, *transuranic waste*, byproduct material, or naturally occurring radioactive material.

lysimeter - An instrument to measure the water percolating through soil and determine the materials dissolved by the water.

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 *radionuclides/radiation* originating 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 n is the number of measurements and X_i is the ith measurement.

median - Middle value in a set of results when the data are ranked in increasing or decreasing order.

millirem - A unit of *radiation dose equivalent* that is equal to one one-thousandth (1/1000) of a *rem*. According to U.S. Department of Energy standards, an individual member of the public may receive no more than 100 millirems per year from a site's operation. This limit does not include *radiation* received for medical treatment or the ~300 millirems that people receive annually from natural *background radiation*.

minimum detectable amount or concentration - Smallest amount or concentration of a chemical or radioactive material that can be reliably detected in a sample.

mitigation - Prevention or reduction of expected *risks* to workers, the public, or the environment.

mixed waste - A dangerous, extremely hazardous, or acutely hazardous waste that contains both a nonradioactive hazardous component and a radioactive component.

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.

nuclide - A particular combination of neutrons and protons. A *radionuclide* is radioactive.

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 wastewater or other *effluents* into a ditch, pond, or river.

person-rem or person-sievert (person-Sv) - Unit of *collective total effective dose equivalent*. 1 person-Sv = 100 person-rems.

photon - A particle of high-energy electromagnetic *radiation*, characterized by energy, frequency, and wave length. *Gamma radiation* and x *radiation* (x-rays) are both comprised of photons.

plume - The cloud of a pollutant in air, surface water, or *groundwater* formed after the pollutant is released from a source.

plutonium - A heavy, radioactive, manmade metallic element consisting of several *isotopes*. One important *isotope* is ^{239}Pu, which is produced by the *irradiation* of ^{238}U. Routine analysis cannot distinguish between the ^{239}Pu and ^{240}Pu *isotopes*; hence, the term $^{239/240}$Pu as used in this report is symbolic of the presence of one or both of these *isotopes* in the analytical results.

quality assurance - Actions that provide confidence that an item or process meets or exceeds that user's requirements and expectations.

quality control - Comprises all those actions necessary to control and verify the features and characteristics of a material, process, product, or service to specified requirements. Quality control is an element of *quality assurance*.

rad - The unit of *absorbed dose*. 1 rad = 0.01 *gray* (Gy).

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 non-ionizing radiation.

radiation limit - The permissible upper bounds of *radiation* doses.

radioactivity - Property possessed by some *radioisotopes* of emitting *radiation* (such as alpha, beta, or gamma *photons*) spontaneously in their *decay* process.

radioisotope - An unstable *isotope* of an element that *decays* or disintegrates spontaneously, emitting *radiation* (Shleien 1992).

radionuclide - A species of atoms having a particular number of protons (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*.

remediation - Reduction of known *risks* to the public and environment to an agreed upon level.

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 1 roentgen typically causes an *effective dose* of 1 *rem*.

sievert (Sv) - Unit of *dose equivalent* and *effective dose equivalent* in the International System of Units (SI) equal to 100 *rems*.

special case waste - Waste for which there is an undetermined disposal path because of high levels of *radioactivity* and difficulties in characterization, classification, and packaging.

specific retention facilities - Historical structures consisting of cribs, ditches, trenches, or holes in the ground that received relatively small volumes of high concentration liquid radioactive waste. The small volume of liquid waste was designed to prevent flushing of the contaminants through the soil column to the *groundwater*.

spectrometer - A spectroscope with a calibrated scale for measuring the positions of spectral lines.

spectroscopy - The branch of physics concerned with the production, measurement, and interpretation of electromagnetic spectra arising from either emission or absorption of radiant energy by various substances.

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 (SE) of the mean is computed as

$$SE = \sqrt{\frac{S^2}{n}}$$

where S^2 is the variance of the measurements, n, computed as

$$S^2 = \frac{1}{n - 1} \sum_{i=1}^{n} (X_i - X)^2$$

X is the *mean* of n measurements.

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.

thiourea - An organic chemical soluble in cold water used in photography, photocopying, and thyroid medication.

transient calibration - The trial-and-error adjustment of aquifer parameters under conditions of changing flow velocity.

transuranic - An element with an atomic number greater than 92 (92 is the atomic number of uranium).

transuranic waste - Waste containing more than 100 nanocuries (10^{-9} *curies*) of alpha-emitting *transuranic isotopes* (*isotopes* with atomic numbers greater than uranium) per gram of waste with *half-lives* greater than 20 years.

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.

total effective dose equivalent - The sum of *committed effective dose equivalent* from intakes of radioactive material and *deep-dose equivalent* from *external radiation*. Unit: *rem* or *sievert*.

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*.

volatile organic compounds - Lightweight organic compounds that vaporize easily. Used in solvents and degreasing compounds as raw materials, volatile compounds are generally considered to be below the molecular weight of C_{10} hydrocarbons.

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 that shows how often winds of various speeds blow from different directions, usually based on yearly averages.

References

Bates, R. L. and J. A. Jackson (eds.). 1980. *Glossary of Geology*. American Geological Institute, Falls Church, Virginia.

Shleien, B. (ed.). 1992. *The Health Physics and Radiological Health Handbook, Revised Edition*. Scinta, Inc., Silver Spring, Maryland.

Appendix D
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 2000 are listed in the following tables. The state of Washington has water quality standards for the Columbia River, defined in Washington Administrative Code (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 D.1. Table D.2 summarizes drinking water standards from the U.S. Environmental Protection Agency (EPA) in the Code of Federal Regulations, (40 CFR 141) and WAC 246-290. Select surface freshwater quality criteria for toxic pollutants are included in Table D.3.

Environmental radiation protection standards are published in U.S. Department of Energy (DOE) Order 5400.5. The order establishes limits for public radiation dose and gives guidance to keep 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 initiated a policy to create and implement public radiation protection standards that are generally consistent with the standards used by the U.S. Nuclear Regulatory Commission to regulate and license non-DOE nuclear facilities, such as nuclear power plants. Table D.4 shows the radiation standards from DOE Order 5400.5, 40 CFR 61, and 40 CFR 141. These standards govern allowable public exposures to ionizing radiation from DOE operations.

DOE Order 5400.5 establishes the derived concentration guides that reflect the concentrations of radionuclides in water and air that an individual could continuously consume, inhale, or be immersed in at average annual levels without exceeding an effective dose equivalent of 100 millirems per year. Derived concentration guides are not exposure limits but are simply reference values that are provided to allow for comparisons of radionuclide concentrations in environmental media. Table D.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 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 issued a permit for Hanford Site radioactive air emissions. Permits to collect 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 D.6.

Table D.1. Washington State Water Quality Standards for the Hanford Reach of the Columbia River[a]

Parameter	Permissible Levels
Fecal coliform	1) Geometric mean value less than or equal to 100 colonies/100 milliliters 2) Less than or equal to 10% of samples may exceed 200 colonies/ 100 milliliters
Dissolved oxygen	Greater than 8 mg/L
Temperature	1) Less than or equal to 20°C(68°F) as a result of human activities 2) When natural conditions exceed 20°C (68°F), no temperature increases will be allowed that will raise the temperature of the receiving water by more than 0.3°C (32.5°F) 3) Incremental temperature increases resulting from point sources shall not at any time exceed 34/(T + 9), where T = background temperature. Incremental temperature increases resulting from non-point sources shall not exceed 2.8°C (37°F)
pH	1) 6.5 to 8.5 range 2) Less than 0.5 unit induced variation
Turbidity	Less than or equal to 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 level 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 D.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 D.3)

(a) WAC 173-201A.

Table D.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	20 pCi/L[d]	3 pCi/L[c]	DOH, EPA	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
Strontium-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	30 µg/L[h]		EPA[d]	Final[i]
Fluoride	4 mg/L		DOH,[c] EPA[d,j]	Final/under review
Nitrate, as NO_3^-	45 mg/L		DOH,[c] EPA[d,j]	Final
Chromium	100 µg/L		DOH,[c] EPA[d,j]	Final
Cyanide	200 µg/L		EPA[c,d,j]	Final
Trichlorethene	5 µg/L		DOH,[c] EPA[d,j]	Final
Tetrachloroethene	5 µg/L		DOH,[c] EPA[d,j]	Final
Carbon tetrachloride	5 µg/L		DOH,[c] EPA[d,j]	Final
Chloroform (THM)[k]	100 µg/L		DOH,[c] EPA[j]	Final
cis-1,2-Dichloroethene	0.07 mg/L		EPA[j]	Final

(a) DOH = Washington State Department of Health, EPA = U.S. Environmental Protection Agency.
(b) Excluding radium-226, radon, and uranium.
(c) WAC 246-290.
(d) 40 CFR 141.
(e) Beta and photon radioactivity from manmade radionuclides. Annual average activity shall not exceed a 4 mrem/yr effective dose equivalent.
(f) Activity assumed to yield an annual dose of 4 mrem/yr.
(g) EPA-570/9-76-003.
(h) Equivalent to 27 pCi/L (assuming typical uranium natural abundance in rock).
(i) Final rule promulgated December 7, 2000 (65 FR 76708).
(j) EPA 822-R-96-001.
(k) Standard is for total trihalomethanes (THM).

Table D.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]
Dissolved Metals			
Antimony	--	--	14
Arsenic	360.0	190.0	0.018
Cadmium	1.6[c]	0.59[d]	--
Chromium(VI)	16	10	--
Copper	8.4[e]	6.0[f]	--
Lead	28[g]	1.1[h]	--
Nickel	750[i]	83[j]	610
Silver	0.94[k]	--	--
Thallium	--	--	1.7
Zinc	60[l]	55[m]	--
Total Recoverable Metals			
Chromium(III)[n]	300[o]	96[p]	--
Mercury	2.1	0.012	0.14
Selenium	20	5.0	--
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
Tetrachloroethene	--	--	0.8
1,1,2-Trichloroethane	--	--	0.60
Trichloroethene	--	--	2.7
Vinyl chloride	--	--	2
1,4-Dichlorobenzene	--	--	400

(a) WAC 173-201A-040. For hardness dependent criteria, the minimum value of 47 mg $CaCO_3$/L for 1992-2000 water samples collected near Vernita Bridge by the U.S. Geological Survey is used.
(b) 40 CFR 131.36.
(c) (1.1017 - [ln(hardness)] 0.04184) exp(1.128[ln(hardness)]-3.828). Hardness expressed as mg $CaCO_3$/L.
(d) (1.1017 - [ln(hardness)] 0.04184) exp(0.7852[ln(hardness)]-3.490).
(e) (0.960) exp(0.9422[ln(hardness)]-1.464).
(f) (0.960) exp(0.8545[ln(hardness)]-1.465).
(g) (1.4620 - [ln(hardness)] 0.1457) exp(1.273[ln(hardness)]-1.460).
(h) (1.4620 - [ln(hardness)] 0.1457) exp(1.273[ln(hardness)]-4.705).
(i) (0.998) exp(0.8460[ln(hardness)]+3.3612).
(j) (0.997) exp(0.8460[ln(hardness)]+1.1645).
(k) (0.85) exp(1.72[ln(hardness)]-6.52).
(l) (0.978) exp(0.8473[ln(hardness)]+0.8604).
(m) (0.986) exp(0.8473[ln(hardness)]+0.7614).
(n) Where methods to measure trivalent chromium are unavailable, these criteria are to be represented by total recoverable chromium.
(o) (0.316) exp(0.8190[ln(hardness)]+3.688).
(p) (0.860) exp(0.8190[ln(hardness)]+1.561).
(q) Criteria based on weak and dissociable method.
(r) Dissolved in association with sodium.

Table D.4. Radiation Standards (dose limits[a]) for Protection of the Public from all Routine DOE Concentrations

All Pathways (limits from DOE Order 5400.5)

The effective dose equivalent for any member of the public from all routine DOE operations[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 waste 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 operations 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 D.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 operations[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 operations" 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 D.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	70,000	500,000
Chromium-51	1,000,000	60,000
Manganese-54	50,000	2,000
Cobalt-60	5,000	80
Zinc-65	9,000	600
Krypton-85	NS[d]	3,000,000[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 D.6. Environmental Permits

Clean Water Act Permit

Additional details are given in Section 2.2.

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 00-047b, issued by Washington State Department of Fish and Wildlife to Pacific Northwest National Laboratory for 2000; covered the collection of food fish, shellfish, and wildlife, including game fish, for environmental monitoring purposes. Renewed annually.

Federal Fish and Wildlife Permit No. MB671877-0, issued by the U.S. Fish and Wildlife Service to Pacific Northwest National Laboratory; covers the collection of migratory wildlife. Expires December 31, 2002.

National Pollutant Discharge Elimination System Permits (governing effluent discharges to the Columbia River)

Permit #WA-002591-7 includes the outfall for the 300 Area Treated Effluent Disposal Facility and two outfalls in the 100-K Area.

A multisector general stormwater permit and stormwater permit WAR-10-000F.

Copies of the regulations concerning these permits may be obtained from the following organizations:

State of Washington Department of Ecology P.O. Box 47600 Olympia, WA 92504-7600	U.S. Environmental Protection Agency Region 10 1200 Sixth Avenue Seattle, WA 98101	U.S. Department of Energy Richland Operations Office 825 Jadwin Ave. Richland, WA 99352

References

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." *Code of Federal Regulations*.

65 FR 76708. December 7, 2000. U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations; Radionuclides; Final Rule." *Federal Register*.

Clean Air Act. 1986. Public Law 88-206, as amended, 42 USC 7401 et seq.

Clean Water Act. 1977. Public Law 95-217, as amended, 91 Stat. 1566 and Public Law 96-148, as amended.

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.

WAC 173-201A. "Water Quality Standards for Surface Waters of the State of Washington." Washington Administrative Code, Olympia, Washington.

WAC 246-290. "Group A Public Water Systems." Washington Administrative Code, Olympia, Washington.

Appendix E
Dose Calculations

E. J. Antonio

The radiological dose that the public could have received in 2000 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 (millisievert)[(a)] for individuals and in units of person-rem for the collective dose received by the total population within an 80-kilometer (50-mile) radius of the site. This appendix describes how the doses in this report were calculated.

Releases of radionuclides from Hanford Site operations 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 radionuclide 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 radionuclide levels 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.

The biota dose calculator was used to screen the radionuclide concentrations in environmental media for exceeding conservatively set biota concentration guides. Both internal and external doses to aquatic, riparian, and terrestrial animals as well as to terrestrial plants are included in the screening process. The screening process is described in "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE 2000a and b).

The computer program, CAP88-PC, was used to calculate dose to a maximally exposed individual as required by the U.S. Environmental Protection Agency (EPA) through the Code of Federal Regulations (40 CFR 61, Subpart H) from airborne

(a) 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

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 2000 air emissions report (DOE/RL-2001-32).

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.

DOE Order 5400.5 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-years) internal exposure from radionuclides taken into the body during the current year. The effective dose equivalent is the sum of individual committed (50-years) 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.

The following types of radiological doses were estimated.

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.

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 that makes it 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.

Determination of the Location of Maximally Exposed 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. Since 1990, three separate locations (see Figure 6.1) have been used to assess the dose to the maximally exposed individual: 1) the Ringold area, 26 kilometers (16 miles) east of separations facilities in the 200 Areas; 2) the Sagemoor area, across the Columbia River from the 300 Area; and 3) the Riverview area across the river from Richland. Scientists consider where a person would receive the maximum exposure to radionuclides from both air and water. Although the Ringold area is closer than Riverview to Hanford facilities that historically released airborne effluents, at Riverview the maximally exposed individual receives a higher dose rate from radionuclides in the Columbia River than a Ringold resident. The applicable exposure pathways for Ringold and Sagemoor are described in the following paragraphs. In 1990, the maximally exposed individual was located at Ringold. In 1991, 1992, and again in 2000, the maximally exposed individual resided in the Riverview area. However, from 1996 through 1999, the hypothetical, maximally exposed individual was located across the Columbia River from the 300 Area at Sagemoor (see Figure 6.2).

Ringold Maximally Exposed Individual. The Ringold area is situated to maximize air pathway exposures from emissions in the 200 Areas, including direct exposure to a contaminated plume, inhalation, external exposure to radionuclides that deposit on the ground, and ingestion of locally grown food products contaminated by air deposition. 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 7.1). 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 also is considered for this individual, resulting in direct exposure from water and radionuclides deposited on the shoreline and doses from ingestion of locally caught fish.

Riverview Maximally Exposed Individual. The Riverview area is situated to maximize water pathway exposures to effluents from Hanford facilities. For the calculation, it was assumed that the Riverview maximally exposed individual obtained domestic water from a local water treatment system that pumped from the Columbia River just downstream of the Hanford Site. In addition, it was assumed that individuals at Riverview irrigate their crops with water taken from the Columbia River (discussed in Section 7.1). 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 was also considered, resulting in direct exposure from water and radionuclides deposited on the shoreline and doses from ingestion of locally caught fish. This individual also receives exposure via the air pathways, including direct exposure to a contaminated plume, inhalation, external exposure to radionuclides that deposit on the ground, and ingestion of locally grown food products contaminated by air deposition.

Sagemoor Maximally Exposed Individual. Because of the shift in site operations from nuclear weapons production to the current mission of managing waste products, restoring the environment, and researching new ideas and technologies for waste disposal and cleanup, the significance of air emissions from production facilities in the 200 Areas has decreased compared to those from research facilities in the 300 Area.

An individual at Sagemoor, located 1.5 kilometers (1 mile) directly across the Columbia River from the 300 Area, receives the maximum exposure to airborne emissions from the 300 Area, and other exposure pathways as an individual at Ringold. However, domestic water at this location

comes from wells rather than from the river, and wells in this region are not directly contaminated by radionuclides of Hanford origin (EPS-87-367A). Because the farms located across from the 300 Area obtain irrigation water from the Columbia River upstream of the Hanford Site, the conservative assumption was made that the diet of an individual from the Sagemoor location consisted totally of foods purchased from the Riverview area, which could contain radionuclides present in both the liquid effluent and air emissions pathways. The added contribution of radionuclides in the Riverview irrigation water maximizes the calculated dose from the air and water pathways combined.

80-kilometer (50-mile) Collective 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-kilometer (50-mile) radius of Hanford Site operations is required by DOE Order 5400.5. The radiological dose to the collective population within 80 kilometer (50 mile) 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-kilometer (50-mile) collective 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 ~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 kilometers (50 miles) 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 kilograms per year (33,075 pounds per year) (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 activities 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-kilometer (50-mile) radius of the Hanford Site operating areas are shown in PNNL-13487, APP. 1. 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-13487, APP. 1. 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 E.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 E.2 through E.4 give the parameters describing the diet, residency, and river recreation assumed for "maximally exposed" and "average" individuals.

Table E.1. Food Pathway Parameters used in Dose Calculations, 2000

Medium	Holdup, d[a]		Growing Period, d	Yield, kg/m²	Irrigation Rate, L/m²/mo
	Maximally Exposed Individual	Average Individual			
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 E.2. Dietary Parameters used in Dose Calculations, 2000

Medium	Consumption: Maximally Exposed Individual	Consumption: Average Individual
Leafy vegetables	30 kg/yr	15 kg/yr
Other vegetables	220 kg/yr	140 kg/yr
Fruit	330 kg/yr	64 kg/yr
Grain	80 kg/yr	72 kg/yr
Eggs	30 kg/yr	20 kg/yr
Milk	270 L/yr	230 L/yr
Red meat	80 kg/yr	70 kg/yr
Poultry	18 kg/yr	8.5 kg/yr
Fish	40 kg/yr	--[(a)]
Drinking water	730 L/yr	440 L/yr

(a) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg (33,075 lb).

Table E.3. Residency Parameters used in Dose Calculations, 2000

Parameter	Exposure, h/yr: Maximally Exposed Individual	Exposure, h/yr: 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 E.4. Recreational Parameters used in Dose Calculations, 2000

Parameter	Exposure, h/yr[(a)]: Maximally Exposed Individual	Exposure, h/yr[(a)]: 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 hours for the maximally exposed individual and 13 hours for the average individual. Correspondingly lesser times were used for other locations.

Dose Calculation Documentation

DOE established the Hanford Dose Overview Panel to promote consistency and defensibility of environmental dose calculations at Hanford. The panel is responsible for defining standard, documented computer codes and input parameters 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). The calculations were then reviewed by the panel. Summaries of dose calculation technical details for this report are shown in Tables E.5 through E.9 and in PNNL-13487, APP. 1.

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 2000 are given in Table E.10.

Air Surveillance Inhalation Doses

Radionuclide concentrations measured in ambient air at locations on or near the Hanford Site were used to calculate radiological doses from breathing. Inhalation rates were taken from ICRP 66. Occupancy times ranged from 100% at offsite locations to 33% for onsite locations.

Table E.5. Technical Details of 100 Areas Airborne Release Dose Calculations, 2000

Facility name	100-K Area
Releases (Ci)	^{60}Co (3.4 x 10^{-8}), ^{90}Sr (4.1 x 10^{-5}), ^{137}Cs (1.1 x 10^{-4}), ^{238}Pu (8.4 x 10^{-7}), $^{239/240}$Pu (5.4 x 10^{-6})(a), ^{241}Pu (6.8 x 10^{-5}), ^{241}Am (2.6 x 10^{-6})
Meteorological conditions	2000 annual average, calculated from data collected at the 100-K Area and the Hanford Meteorology Station from January through December 2000, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual, 2.3 x 10^{-9} s/m^3 at 53 km (33 mi) SSE; 80-km (50-mi) population, 8.7 x 10^{-4} s/m^3 person-s/m^3
Release height	89-m (292-ft) effective stack height
Population distribution	375,000 (PNNL-13487, APP. 1, Table D-1)
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

(a) This value includes gross alpha release data. Gross alpha and unspecified alpha results assumed to be $^{239/240}$Pu for dose calculations.

Table E.6. Technical Details of 100-N Area Liquid Release Dose Calculations, 2000

Facility name	100-N Area
Releases (Ci)	^{3}H (1.5×10^{-1}), ^{90}Sr (2.8×10^{-1}), ^{238}Pu (9.2×10^{-6}), ^{239}Pu (3.9×10^{-5}), ^{241}Am (7.9×10^{-6})
Mean river flow	3,404 m^3/s (120,000 ft^3/s)
Shore-width factor	0.2
Population distribution	70,000 for drinking water pathway 125,000 for aquatic recreation 2,000 for consumption of irrigated foodstuffs 15,000 kg/yr (33,075 lb/yr) total harvest of Columbia River fish
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to irrigated soil, to river water, and to shoreline sediments Ingestion of aquatic foods and irrigated farm products
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90 Bioaccumulation Factor Library, Rev. 10-26-92

Table E.7. Technical Details of 200 Areas Airborne Release Dose Calculations, 2000

Facility name	200 Areas
Releases (Ci)	200-East Area ^{90}Sr (9.1 x 10^{-5}), ^{125}Sb (1.8 x 10^{-6}), ^{129}I (1.2 x 10^{-3}), ^{137}Cs (6.7 x 10^{-5}), ^{238}Pu (9.8 x 10^{-8}), $^{239/240}Pu$ (2.5 x 10^{-6}), ^{241}Pu (6.1 x 10^{-6}), ^{241}Am (4.8 x 10^{-6}) 200-West Area ^{90}Sr (1.9 x 10^{-4}), ^{137}Cs (2.1 x 10^{-9}), ^{238}Pu (1.1 x 10^{-5}), $^{239/240}Pu$ (5.1 x 10^{-4}), ^{241}Pu (3.1 x 10^{-4}), ^{241}Am (8.7 x 10^{-5})
Meteorological conditions	2000 annual average, calculated from data collected at the Hanford Meteorology Station from January through December 2000, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual, 1.1 x 10^{-8} s/m^3 at 43 km (27 mi) SE; 80-km (50-mi) population, 1.6 x 10^{-3} person-s/m^3
Release height	89-m (292-ft) effective stack height
Population distribution	376,000 (PNNL-13487, APP. 1, Table D-2)
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

Table E.8. Technical Details of 300 Area Airborne Release Dose Calculations, 2000

Facility name	300 Area
Releases (Ci)	^{3}H (as HT)[(a)] (4.3 x 10^{1}), ^{3}H (as HTO)[(a)] (7.9 x 10^{1}), ^{90}Sr (8.4 x 10^{-6}), ^{238}Pu (7.7 x 10^{-10}), $^{239/240}$Pu (6.5 x 10^{-7}), ^{241}Am (9.8 x 10^{-9})
Meteorological conditions	2000 annual average, calculated from data collected at the 300 Area and the Hanford Meteorology Station from January through December 2000, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual at residence, 7.5 x 10^{-7} s/m^{3} at 13 km (8 mi) SSE; 80-km (50-mi) population, 5.7 x 10^{-3} person-s/m^{3}
Release height	10 m (33 ft)
Population distribution	282,000 (PNNL-13487, APP. 1, Table D-3)
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

(a) HT = elemental tritium; HTO = tritiated water vapor.

Table E.9. Technical Details of 400 Area Airborne Release Dose Calculations, 2000

Facility name	400 Area
Releases (Ci)	^{3}H (as HTO)[a] (8.8×10^{-1}), ^{137}Cs (3.5×10^{-6})
Meteorological conditions	2000 annual average, calculated from data collected at the 400 Area and the Hanford Meteorology Station from January through December 2000, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual at residence, 9.0×10^{-8} s/m^3 at 22 km (14 mi) SSE; 80-km (50-mi) population, 4.1×10^{-3} person-s/m^3
Release height	10 m (33 ft)
Population distribution	283,000 (PNNL-13487, APP. 1, Table D-4)
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

(a) HTO = tritiated water vapor.

Table E.10. Annual Dose to Workers in the 400 Area from Ingestion of Drinking Water Obtained from Groundwater Wells, 2000

Radionuclide	Drinking Water Activity, pCi/L[a]	Intake, pCi/yr[b]	Ingestion Dose Factor, rem/pCi[c]	Ingestion Dose, rem/yr (Sv/yr)
Gross beta[d]	6.11 ± 0.24	1,466	5.00×10^{-8}	7.3×10^{-5} (7.3×10^{-7})
Tritium	3,853 ± 211	9.24×10^{6}	6.40×10^{-11}	5.9×10^{-5} (5.9×10^{-7})
Total				1.3×10^{-4} (1.3×10^{-6})

(a) Drinking water activities are annual averages obtained from quarterly samples taken during 2000.
(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 International System of Units (SI). Where the document lists dose factors for more than one chemical form of a radionuclide, the most soluble chemical form was assumed.
(d) Gross beta activities were assumed to be ^{137}Cs for the purposes of this analysis.

Table E.11. Offsite Dose from Inhalation due to the Hanford Site Wildfire, June 2000 (based on maximum EPA measured offsite air concentrations)

Radionuclide	Maximum Concentration (pCi/m^3)	Breathing Rate (liters/day)	Dose Conversion Factor (rem/μCi)	Exposure Period (days)	Committed Effective Dose Equivalent
Strontium-90	0.0066	23,000	0.23	30	0.001
Uranium-234	0.0003	23,000	130	30	0.027
Uranium-235	0.00021	23,000	120	30	0.017
Uranium-238	0.00046	23,000	120	30	0.038
Plutonium-239/240	0.00042	23,000	330	30	0.096
Total					**0.18**

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Appendix F
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 F.1. These radionuclides may be natural or result from Hanford Site operations. 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 uranium-235 or plutonium-239. Some of these radionuclides may not be discussed in the main body of this report if they are below detection levels.

Table F.1. Radionuclides Analyzed by Gamma Spectroscopy

Radionuclide	Symbol	Source
Beryllium-7[(a)]	^{7}Be	Natural
Sodium-22	^{22}Na	Activation product
Sodium-24	^{24}Na	Activation product
Potassium-40[(a)]	^{40}K	Natural
Manganese-54	^{54}Mn	Activation product
Cobalt-58	^{58}Co	Activation product
Cobalt-60[(a)]	^{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[(a)]	^{106}Ru	Fission product
Antimony-125[(a)]	^{125}Sb	Activation product
Iodine-131	^{131}I	Fission product
Cesium-134[(a)]	^{134}Cs	Activation product
Cesium-137[(a)]	^{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[(a)]	^{154}Eu	Activation product
Europium-155[(a)]	^{155}Eu	Activation product

(a) Routinely reported by contracting laboratory for Pacific Northwest National Laboratory environmental surveillance samples.

Appendix G
Threatened and Endangered Species

R. K. Zufelt

This appendix discusses the federal and state threatened and endangered species, candidate species, and plant species of concern potentially found on the Hanford Site. Threatened and endangered species are listed by the federal government in Title 50, Code of Federal Regulations, Part 17; Washington Natural Heritage Program (2000); and Washington State Department of Fish and Wildlife (2000).

Threatened or Endangered Species

The purposes of the *Endangered Species Act*, as amended, are to 1) provide a means to conserve critical ecosystems, 2) provide a program for the conservation of threatened and endangered species, and 3) ensure that appropriate steps are taken to achieve the purposes of the treaties and conventions established in the Act. Threatened and endangered species of plants and animals occurring or potentially occurring on the Hanford Site are listed in Table G.1.

Identification of candidate species can assist environmental planning efforts by providing advance notice of potential listing as a threatened or endangered species, allowing resource managers to alleviate threats and thereby possibly remove the need to list species as endangered or threatened. Even if a candidate species is subsequently listed, the early notice could result in fewer restrictions on human activities in the environment by prompting candidate conservation measures to alleviate threats to the species. Washington State candidate species animals occurring or potentially occurring on the Hanford Site are listed in Table G.2. Plant species not listed as threatened or endangered but considered "candidates" for listing are identified by Washington State as "species of concern." Washington State plant species of concern potentially found on the Hanford Site are listed in Table G.3.

Hanford Status

No plants or mammals on the federal list of endangered and threatened species (50 CFR 17) are known to occur on the Hanford Site. There are, however, one bird species and two fish species on the federal list of threatened and endangered species (see Table G.1). In addition, eight species of plants, and five species of birds have been listed as either threatened or endangered by Washington State. The National Marine Fisheries Service has the responsibility for the federal listing of anadromous fish (i.e., fish which require both saltwater and freshwater to complete a life cycle). Upper-Columbia River steelhead and upper-Columbia River spring-run chinook salmon were listed as endangered evolutionary significant units by National Marine Fisheries Service (2000) in August 1997 and March 1999, respectively.

Several species of plants and animals are under consideration for formal listing as candidate species by Washington State. There are 15 state-level candidate species of plants and animals (see Table G.2) and 46 plant species of concern (see Table G.3).

Table G.1. Federal or Washington State Threatened and Endangered Species on the Hanford Site

Common Name	Scientific Name	Federal	State
Plants			
Columbia milkvetch	*Astragalus columbianus*	SC	T
Dwarf evening primrose	*Camissonia (= Oenothera) pygmaea*		T
Hoover's desert parsley	*Lomatium tuberosum*	SC	T
Loeflingia	*Loeflingia squarrosa var. squarrosa*		T
Persistent sepal yellowcress	*Rorippa columbiae*	SC	T
Umtanum desert buckwheat	*Eriogonum codium*	C	E
White Bluffs bladderpod	*Lesquerella tuplashensis*	C	E
White eatonella	*Eatonella nivea*		T
Fish			
Spring-run chinook	*Oncorhynchus tshawytscha*	E	C
Steelhead	*Oncorhynchus mykiss*	E	C
Birds			
American white pelican	*Pelecanus erythrorhychos*		E
Bald eagle[(a)]	*Haliaeetus leucocephalus*	T	T
Ferruginous hawk	*Buteo regalis*	SC	T
Sandhill crane	*Grus canadensis*		E
Western sage grouse	*Centrocercus urophasianus phaios*	SC	T

(a) Currently under review for change in status.
C = Candidate, 50 CFR 17.
E = Endangered.
SC = Species of concern.
T = Threatened.

Table G.2. Washington State Candidate Animal Species on the Hanford Site

Common Name	Scientific Name
Molluscs	
Giant Columbia River spire snail[a]	*Fluminicola* (= *Lithoglyphus*) *columbiana*
Giant Columbia River limpet	*Fisherola* (= *Lanx*) *nuttalli*
Fish	
Spring-run chinook[b]	*Oncorhynchus tshawytscha*
Steelhead[b]	*Oncorhynchus mykiss*
Insects	
Columbia River tiger beetle[c]	*Cicindela columbica*
Birds	
Burrowing owl[a]	*Athene cunicularia*
Common loon	*Gavia immer*
Golden eagle	*Aquila chrysaetos*
Loggerhead shrike[a]	*Lanius ludovicianus*
Merlin	*Falco columbarius*
Northern goshawk[a,d]	*Accipter gentilis*
Sage sparrow	*Amphispiza belli*
Sage thrasher	*Oreoscoptes montanus*
Reptiles	
Striped whipsnake	*Masticophis taeniatus*
Mammals	
Black-tailed jackrabbit	*Lepus californicus*
Merriam's shrew	*Sorex merriami*
Washington ground squirrel[d,e]	*Spermophilus washingtoni*
White-tailed jackrabbit	*Lepus townsendii*

(a) Federal species of concern.
(b) Federal endangered.
(c) Probable, but not observed, on the Hanford Site.
(d) Reported, but seldom observed, on the Hanford Site.
(e) Federal candidate.

Table G.3. Washington State Plant Species of Concern on the Hanford Site

Common Name	Scientific Name	State Listing[a]
Annual paintbrush	*Castilleja exilis*	R1
Awned halfchaff 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
Coyote tobacco	*Nicotiana attenuata*	S
Crouching milkvetch	*Astragalus succumbens*	W
Desert dodder	*Cuscuta denticulata*	S
Desert evening-primrose	*Oenothera caespitosa*	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. robustior*	R1
Kittitas larkspur	*Delphinium multiplex*	W
Lowland toothcup	*Rotala ramosior*	R1
Miner's candle	*Cryptantha scoparia*	R1
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
Winged combseed	*Pectocarya linearis*	R1

The following species have been reported 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.

Beaked spike-rush	*Eleocharis rostellata*	S
Dense sedge	*Carex densa*	S
Few-flowered collinsia	*Collinsia sparsiflora var. bruciae*	S
Giant helleborine	*Epipactis gigantea*	S
Medic milkvetch	*Astragalus speirocarpus*	W
Orange balsam	*Impatiens aurella*	R2
Palouse milkvetch	*Astragalus arrectus*	S
Palouse thistle	*Cirsium brevifolium*	W
Porcupine sedge	*Carex hystericina*	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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