HANFORD SITE
ENVIRONMENTAL REPORT

for Calendar Year 2006

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The cover photo shows rabbitbrush on the Hanford Site with the White Bluffs along the Columbia River in the background. The photo is from Lockheed Martin Information Technology, Richland, Washington. The cover design is by SB Neely, Pacific Northwest National Laboratory, Richland, Washington.

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for Calendar Year 2006

(Including Some Early 2007 Information)

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September 2007

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and Washington Closure Hanford LLC

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Richland, Washington

Preface

The Hanford Site environmental report is prepared annually for the U.S. Department of Energy (DOE) in accordance with the requirements in DOE Manual 231.1-1A, "Environment, Safety, and Health Reporting Manual," and DOE Order 231.1A, "Environment, Safety, and Health Reporting." The report provides an overview of activities at the site; demonstrates the status of the site's compliance with applicable federal, state, and local environmental laws and regulations, executive orders, and DOE policies and directives; and summarizes environmental data that characterize Hanford Site environmental management performance. The report also highlights significant environmental and public protection programs and efforts. Some historical and early 2007 information is included where appropriate. More detailed environmental compliance, monitoring, and surveillance information is provided in additional reports referenced in the text.

Although this report was primarily written to meet DOE reporting requirements and guidelines, it is also intended to provide a broad spectrum of environmental and environmentally related information to DOE managers, the public, Indian tribes, public officials, regulatory agencies, Hanford Site contractors, and elected representatives. Appendix A lists scientific notation, units of measure, unit conversion information, and nomenclature that may help readers understand the report. Appendix B is a glossary of terms.

The Pacific Northwest National Laboratory's Public Safety and Resource Protection Project produced this report for the DOE Richland Operations Office. Battelle Memorial Institute (Battelle) operates the Pacific Northwest National Laboratory for the DOE. Battelle is a non-profit, independent, contract research institute. Personnel from the Pacific Northwest National Laboratory and Fluor Hanford, Inc. and its principal subcontractors wrote major portions of the report. Washington Closure Hanford LLC; Bechtel National, Inc.; and CH2M HILL Hanford Group, Inc. also prepared or provided significant input to selected sections.

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Report Availability

This report was produced in both paper and electronic formats. The paper formats include this technical report, two supplemental data appendixes, and a less-detailed summary report (PNNL-16623-SUM). Electronically, the report is available in portable document format (PDF) on compact disk and at the following website: http://hanford-site.pnl.gov/envreport. Report copies are also available at libraries in communities near the Hanford Site, at several university libraries in Washington and Oregon, and at the DOE's Public Reading Room located at the Consolidated Information Center in Richland, Washington. All versions of the report can be obtained from R. W. (Bill) Hanf, Pacific Northwest National Laboratory, P.O. Box 999, MS K6-75, Richland, Washington, 99352 (bill.hanf@pnl.gov) while supplies last.

Summary

R. W. Hanf

Each year, the U.S. Department of Energy (DOE) publishes this integrated environmental report about the Hanford Site. Individual sections of the report are designed to:

- Describe the Hanford Site and its mission
- Summarize the Hanford Site's compliance with all applicable laws and regulations
- Discuss the status and results of Hanford Site cleanup and remediation activities
- Describe the environmental and groundwater monitoring programs at the Hanford Site, and summarize and discuss monitoring information
- Discuss potential radiation doses to people living around the Hanford Site in 2006
- Discuss methods used to assure data quality.

The current mission of the DOE at the Hanford Site includes cleaning up the site and reducing its size. It is the DOE's policy that all of its activities be carried out in compliance with applicable federal, state, and local laws and regulations; DOE Orders; Secretary of Energy Notices; and directives, policies, and guidelines from DOE Headquarters.

Compliance with Federal, State, and Local Laws and Regulations in 2006

A key element in Hanford's compliance program is the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement). The Tri-Party Agreement is an agreement among the Washington State Department of Ecology, U.S. Environmental Protection Agency (EPA), and the 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). The Tri-Party Agreement has evolved to meet the changing conditions and needs of cleanup as cleanup activities have progressed. During 2006, there were 49 specific Tri-Party Agreement cleanup milestones scheduled for completion: 41 were completed on or before their required due dates, 2 were completed beyond their established due dates, and 6 were not yet complete at the end of 2006. During 2006, 17 negotiated change requests to the Tri-Party Agreement were approved.

The Hanford Site's compliance with federal acts in 2006 is summarized in Table S.1 and discussed in detail in Chapters 3 and 5 of this report.

Cleanup Operations

Since cleanup activities began at the Hanford Site in 1996, the primary focus of cleanup has been on former liquid effluent waste sites. After nearly 10 years of work, the number of liquid effluent waste sites requiring remediation has been reduced, and cleanup activities are now turning to remediation of waste burial grounds. The volume of contamination in waste burial grounds is less than in liquid effluent waste sites; however, the burial grounds may contain unknown materials and additional time may be required to characterize the materials and dispose of them properly.

Remediation of 100 Areas Waste Sites. Remediation in the 100 Areas focused on waste burial grounds and miscellaneous waste sites in the 100-B/C, 100-K, 100-N, 100-D, and 100-F Areas in 2006 (Section 6.1.3). A total of 356,947 metric tons (393,548 tons) of contaminated soil from 100 Areas remediation activities was disposed of at

Table S.1. Status of Compliance with Federal Acts at the Hanford Site in 2006

Regulation	What It Covers	2006 Status
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.	During 2006, 166 cultural resource reviews were requested on the Hanford Site. The DOE determined that 144 activities would not affect cultural resources and were exempt from further review; 6 requests were exempted from full cultural review by programmatic agreement; 16 requests required full reviews. Seventeen sites were visited in 2006 to assess the effects of erosion, weathering, and unauthorized excavation and collection. Three new archaeological sites and three new isolated finds were recorded on the Hanford Site in 2006. Excavations were conducted at two other locations to collect data.
Atomic Energy Act	Proper management of radioactive materials.	In 2006, the DOE issued a manual and a guidance document that potentially impact the management and control of radioactive materials. In addition, a DOE technical standard pertaining to the management and control of radioactive materials was significantly revised in 2006.
Clean Air Act	Air quality, including emissions from facilities and from unmonitored sources.	The Hanford Site air operating permit was reissued by the Washington State Department of Ecology in December 2006. The Benton Clear Air Authority regulates open-air burning and oversees the site's compliance with asbestos regulations. In 2006, 22 *Clean Air Act* enforcement inspections were conducted on the Hanford Site.
Clean Water Act	Point-source discharges to U.S. surface waters.	The Hanford Site has one National Pollutant Discharge Elimination System Permit, one storm water permit, and several state sanitary wastewater discharge permits. There were no permit violations in 2006.
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	Sites already contaminated by hazardous materials.	Several CERCLA records of decision required reviews of institutional controls for specific areas covered by the records of decision. These reviews were conducted in 2006. There were no CERCLA or WAC reportable spills or non-permitted discharges from the Hanford Site during calendar year 2006.
Emergency Planning & Community Right to Know Act	The public's right to information about hazardous materials in the community and establishes emergency planning procedures.	The *2006 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* was issued to the Washington State Department of Ecology, local emergency planning committees, and the fire departments of the Hanford Site and the city of Richland. The *2006 Hanford Site Toxic Chemical Release Inventory* is scheduled for release in 2007.
Endangered Species Act	Rare species of plants and animals.	Numerous plants and animals at the Hanford Site are state or federally listed as endangered, threatened, sensitive, or candidate species. Ecological compliance reviews are conducted prior to initiating a project at the Hanford Site to prevent adverse impacts to biological resources, including listed species. In 2006, 188 reviews were performed. Also in 2006, two informal meetings were held (one each) with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service to discuss *Endangered Species Act* issues.
Federal Insecticide, Fungicide, and Rodenticide Act	Storage and use of pesticides.	At the Hanford Site, pesticides are applied by commercial pesticide operators licensed by the state.
Migratory Bird Treaty Act	Migratory birds or their feathers, eggs, or nests.	All Hanford Site projects with a potential to affect federal- or state-listed species of concern complied with the requirements of this act by using an ecological compliance review to minimize adverse impacts to migratory birds.

Table S.1. (contd)

Regulation	What It Covers	2006 Status
National Environmental Policy Act	Environmental impact statements for major federal projects that have the potential to significantly affect the quality of the human environment.	In February 2006, the DOE announced its intention to prepare a new environmental impact statement titled *Notice of Intent to Prepare the Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, WA*. Four public scoping meetings for this impact statement were held in 2006. The U.S. Fish and Wildlife Service issued a document for review in December 2006 titled *Draft Hanford Reach National Monument Comprehensive Conservation Plan and Environmental Impact Statement*. The DOE Richland Operations Office is co-manager of the monument and a cooperating agency in preparing this impact statement.
Resource Conservation and Recovery Act (RCRA)	Tracking hazardous waste from generator to treatment, storage, or disposal (referred to as cradle-to-grave management).	The DOE is operating under an expired facility RCRA permit at the Hanford Site while the Washington State Department of Ecology drafts a new permit. During 2006, four revisions to the RCRA Permit Part A Form and four RCRA Part B Permit applications were submitted to the state for review and approval. One RCRA non-compliance document was received at the Hanford Site in 2006 alleging that the DOE failed to submit a complete application for a new RCRA permit. The DOE responded and is awaiting a reply from the state.
Safe Drinking Water Act	Drinking water systems operated by the DOE at the Hanford Site.	There were nine public drinking water systems on the Hanford Site in 2006. The systems were monitored for radiological and chemical contaminants and disinfectant residuals and disinfection byproducts. All contaminant concentrations in 2006 were below state and federal limits. There were three total-coliform detections in 2006 but follow-up sampling and analyses yielded satisfactory results.
Toxic Substances Control Act	Primarily regulation of polychlorinated biphenyls (PCBs).	The *2005 Polychlorinated Biphenyl Annual Document Log – Report for the Hanford Site* and a 2005 PCB annual report were submitted to the EPA in 2006 as required. EPA-approved risk-based disposal approvals were used in 2006 for retrieving waste from selected single-shell underground waste storage tanks and for removing containers of treated sludge from the K Basin North Load-Out Pit. In 2006, a risk-based disposal approval application was submitted for storage of two water tower tanks on the Hanford Site that contain PCB-contaminated paint.

DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
WAC = Washington Administrative Code.

the Environmental Restoration Disposal Facility (near the 200-West Area) during 2006. The bulk of contaminated soil was from the 100-B/C and 100-F Areas. Several remediated and backfilled waste sites in the 100-B/C, 100-K, and 100-N Areas were revegetated with native grass seed and sagebrush seedlings in 2006. Several pump-and-treat systems operated in the 100 Areas in 2006 to help remove contaminants from groundwater (Table S.2).

K Basins Closure Activities. During 2006, clean out of the K Basins continued. For nearly 30 years, the K Basins contained 2,100 metric tons (2,300 tons) of N Reactor spent fuel and a small quantity of irradiated fuel from older Hanford Site reactors. This fuel was removed in a major effort that ended in 2004, but fuel corrosion left behind 53.8 cubic meters (70.35 cubic yards) of sludge. In addition, the K Basins contained more than 272 metric tons (300 tons) of debris. During 2006, all debris was removed, packaged, and readied for shipment to the Environmental Restoration Disposal Facility; all remaining sludge was removed from the K Basins and containerized. These and other 2006 K Basins remediation and closure activities are discussed in Section 6.1.3.2.

Remediation of 200 Areas Waste Sites. Remedial investigation or feasibility study activities continued on a large number of waste sites in the 200 Areas in 2006. Discussions of these study activities are provided in Section 6.1.2.

Table S.2. Summary of Groundwater Pump-and-Treat Systems and a Vadose Zone Soil-Vapor Extraction System

Location	Startup Date	Contaminant	Mass Removed 2006	Mass Removed Since Startup
100-D Area (100-DR-5 Pump-and-Treat System)	2004	Chromium	64.6 kilograms (142 pounds)	106.8 kilograms (235 pounds)
100-D and 100-H Areas (100-HR-3 Pump-and-Treat System)	1997	Chromium	28.8 kilograms (63 pounds)	299.9 kilograms (661 pounds)
100-K Area (100-KR-4 Pump-and-Treat System)	1997	Chromium	21 kilograms (46 pounds)	304.2 kilograms (670 pounds)
100-N Area (100-NR-2 Pump-and-Treat System)	1995	Strontium-90	0.04 curies (1.48 gigabecquerels)	1.83 curies (67.7 gigabecquerels)
200-West Area (200-ZP-1 Pump-and-Treat System)	1994	Carbon tetrachloride	890 kilograms (1,962 pounds)	10,420 kilograms (22,970 pounds)
200-West Area (200-UP-1 Pump-and-Treat System)	1994	Carbon tetrachloride	None	34.6 kilograms (76.3 pounds)
		Nitrate	None	34,716 kilograms (76,534 pounds)
		Technetium-99	None	118.9 grams (0.262 pound)
		Uranium	None	211.8 kilograms (467 pounds)
Waste Management Area S-SX	2003	Technetium-99	~0.072 gram (0.003 ounce)	0.27 gram (0.01 ounce)
200-West Area (Soil-Vapor Extraction System)	1991	Carbon tetrachloride	173 kilograms (381 pounds)	78,900 kilograms (174,000 pounds)

Pump-and-treat systems and a soil-vapor extraction system operated in the 200 Areas in 2006 to help remove contaminants from groundwater and the vadose zone (Table S.2).

Remediation of 300 Area Waste Sites. Remediation continued at the 300-FF-2 Operable Unit in 2006. Remediation at this site began in 2002. In 2006, 49,035 metric tons (54,063 tons) of contaminated soil from 300 Area waste sites were removed and disposed of at the Environmental Restoration Disposal Facility. A design solution for cleaning up the 618-10 and 618-11 burial grounds was submitted to the DOE in December 2006 for evaluation. Several cleaned and backfilled 300 Area waste sites were revegetated in 2006 (Section 6.1.4).

Facility Decommissioning Activities

Decommissioning of 100 Areas Facilities. Decontamination and decommissioning activities continued during 2006 with a focus on the 100-N Area, where more than 20 facilities were demolished (Section 6.2.4).

Decommissioning of 200 Areas Facilities. Transition and decommissioning of facilities continued in the 200 Areas during 2006. Activities to decontaminate and deactivate the processing facilities at the Plutonium Finishing Plant continued (Section 6.2.1.1). Surveillance, maintenance, and decontamination or stabilization of over 500 waste sites on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit and in the 200-East, 200-West, and 200-North Areas continued. Periodic surveillances, radiation surveys, and herbicide applications were performed (Section 6.2.1.2). In December 2006, the DOE issued the *Remedial Design/Remedial Action Work Plan for the 221-U Facility* (DOE/RL-2006-21, Draft A) for review by regulatory agencies. The 221-U Facility (U Plant) was selected for demolition using a close in place – collapsed structure alternative (referred to as the Canyon Disposition Initiative). This remediation effort will be a prototype for the other four canyon buildings at the Hanford Site (Section 6.2.1.3).

Decommissioning of 300 Area Facilities. During 2006, 300 Area deactivation, decontamination, decommissioning, and demolition activities focused on removing physical barriers to performing remedial actions in the 300-FF-2 Operable Unit. More than 30 facilities and buildings were demolished in the 300 Area in 2006 (Section 6.2.2).

Decommissioning of 400 Area Facilities – Fast Flux Test Facility. After multiple studies, a final decision was made to complete facility deactivation, including removing all nuclear fuel, draining the sodium systems, and deactivating systems and equipment to place the facility in a low-cost, long-term surveillance and maintenance condition by September 2009. During 2006, fuel removal from the 400 Area Property Protected Area continued. Eight interim-storage casks with fuel were transferred to the 200 Areas Interim Storage Area. Draining of bulk-liquid sodium metal from the Fast Flux Test Facility also continued in 2006. One hundred and nine core-component pots were removed from the interim-decay storage vessels and placed into two storage boxes. Each storage box contained about 757 liters (200 gallons) of contaminated sodium. The removal of the component pots allowed the remaining sodium in interim-decay storage vessels to be successfully drained and transferred to the Sodium Storage Facility. Materials were removed and equipment dismantled in the Interim Examination and Maintenance Cell Training Facility in the 309 Building in preparation for demolition (Section 6.2.3).

Waste Management

Hanford Site cleanup activities generate non-regulated, radioactive, non-radioactive, mixed, and hazardous waste (Chapters 5 and 6). Mixed waste has both radioactive and hazardous non-radioactive substances. Hazardous waste contains either dangerous waste or extremely hazardous waste, or both. This waste is handled and prepared for safe storage at the site or shipped to offsite facilities for treatment and disposal. A summary of waste stored, generated, and treated at the site or received from offsite in 2006 is provided in Table S.3.

In addition to newly generated waste, significant quantities of legacy waste remain from years of nuclear materials 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 places awaiting cleanup and ultimate safe storage or disposal. Examples include high-level radioactive waste stored in single-shell and double-shell underground waste storage tanks and transuranic waste stored in vaults and on storage pads (Sections 6.3 and 6.4).

Solid Waste Management. Waste management at the Hanford Site in 2006 included the treatment, storage, and disposal of solid waste at many site locations (Section 6.3.2). Onsite solid-waste facilities include the Central Waste Complex, Waste Receiving and Processing Facility, T Plant complex, Environmental Restoration Disposal Facility, Radioactive Mixed Waste Disposal Facility, and low-level burial grounds.

Waste is received at the Central Waste Complex (Section 6.3.3.1) in the 200-West Area from sources at the Hanford Site, and any offsite sources authorized by the DOE to ship waste to the Hanford Site for treatment, storage, and disposal. Ongoing cleanup, research, and development activities at the Hanford Site generate most waste received at the Central Waste Complex. Characteristics of waste received vary greatly, including low-level, transuranic, or mixed waste, and radioactively contaminated polychlorinated biphenyls (PCBs).

The Central Waste Complex can store as much as 20,796 cubic meters (27,200 cubic yards) of low-level mixed waste and transuranic waste. This capacity is adequate to store the projected volumes of low-level, transuranic, and mixed waste, and radioactively contaminated PCBs to be generated from the activities identified above, 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 waste container is established at the point-of-origin based on process knowledge or sample analysis. The current volume of waste stored at this complex totals approximately 6,950 cubic meters (9,100 cubic yards).

Waste destined for the Waste Receiving and Processing Facility (Section 6.3.3.2) includes stored waste as well as newly generated waste from current Hanford Site cleanup activities. The waste consists primarily of contaminated

Table S.3. Hanford Site Waste Summary, 2006

Activity	Waste Type	Amount
Solid waste generated during onsite cleanup activities	Solid mixed waste	315,188 kilograms (347 tons)
	Radioactive waste	465,340 kilograms (513 tons)
Solid waste received at Hanford from off the site	Solid mixed waste	152,487 kilograms (168 tons)
	Radioactive waste	71,244 kilograms (79 tons)
Dangerous waste shipped off the Hanford Site	Containerized waste	18,700 kilograms (21 tons)
	Bulk solids	0 kilograms
	Bulk liquids	917 kilograms (1 ton)
Waste volume pumped from underground single-shell waste storage tanks to double-shell waste storage tanks	Liquid waste	2.9 million liters (780,000 gallons)
Waste volume in underground single-shell waste storage tanks at the end of 2006	Liquid waste	113.6 million liters (30 million gallons)
Waste volume evaporated at the 242-A evaporator	Liquid waste	902,000 liters (238,000 gallons)
Waste added to underground double-shell waste storage tanks	Liquid waste	3.5 million liters (937,000 gallons)
Waste volume in underground double-shell waste storage tanks at the end of 2006	Liquid waste	101 million liters (27 million gallons)
Waste dispositioned and shipped offsite from the Waste Receiving and Processing Facility	Solid waste	586 cubic meters (767 cubic yards)
Waste treated or directly disposed of at the Mixed Low-Level Waste Treatment and Disposal Facility	Mixed low-level solid waste	988 cubic meters (1,292 cubic yards)
Waste disposed of at the Environmental Restoration Disposal Facility	Solid waste	475,792 metric tons (524,474 tons)
Volume of aqueous waste received at the Liquid Effluent Retention Facility	Wastewater containing low levels of organic compounds and tritium	7.08 million liters (1.87 million gallons)
Volume of liquid effluent treated at the Effluent Treatment Facility	Wastewater containing toxic metals, radionuclides, ammonia, and organic compounds	15.6 million liters (4.13 million gallons)
Volume of wastewater treated at the 242-A evaporator	Liquid waste from single-shell tanks	2.095 million liters (553,400 gallons)
Volume of effluent disposed of at the 200 Area Treated Effluent Disposal Facility	Uncontaminated liquid waste	765.3 million liters (202.2 million gallons)
Volume of wastewater treated and disposed of at the 300 Area Treated Effluent Disposal Facility	Industrial wastewater	139.5 million liters (36.87 million gallons)

cloth, paper, rubber, metal, and plastic. This facility, which began operating in 1997, dispositioned and shipped offsite 586 cubic meters (767 cubic yards) of waste in 2006.

The T Plant complex in the 200-West Area provides waste treatment, storage, and decontamination services for the Hanford Site as well as for offsite facilities (Section 6.3.3.3). The T Plant complex currently operates under RCRA interim status.

During 2006, there were 988 cubic meters (1,292 cubic yards) of mixed low-level waste treated or disposed of at the Mixed Low-Level Waste Treatment and Disposal Facility (Section 6.3.3.4).

There was one defueled reactor compartment from the U.S. Navy shipped to trench 94 in the 200-East Area in 2006. The total number of Navy reactor compartments received to date is 115 (Section 6.3.3.5).

During 2006, approximately 475,792 metric tons (524,474 tons) of remediation waste were disposed of at the Environmental Restoration Disposal Facility (Section 6.3.3.6). Approximately 6.2 million metric tons (6.8 million tons) of remediation waste have been placed in the Environmental Restoration Disposal Facility from initial operations start-up through 2006. The total available expansion area of the Environmental Restoration Disposal Facility site was authorized in the 1995 record of decision to cover as much as 4.1 square kilometers (1.6 square miles).

The Radioactive Mixed Waste Disposal Facility consists of two trenches in the 200-West Area (Section 6.3.3.7). Disposal to the first trench began in September 1999 and the first layer of waste packages has been completed and covered with sand and gravel. The second waste layer has been started. Currently, there are approximately 4,010 cubic meters (5,244 cubic yards) of waste in the first trench. There are approximately 293 cubic meters (383 cubic yards) of waste in the second trench, which opened for operations in July 2004.

The low-level burial grounds (Section 6.3.3.8) consist of eight burial grounds located in the 200-East and 200-West Areas that are used for the disposal of low-level waste and mixed waste (i.e., low-level radioactive waste with a dangerous waste component). The low-level burial grounds have been permitted to remain operational under a RCRA Part A permit since 1985. Transuranic waste has not been placed in the low-level burial grounds without specific DOE approval since August 19, 1987. On June 23, 2004, the DOE issued a record of decision for the Solid Waste Program at the Hanford Site. Part of the record of decision stated that the DOE will dispose of low-level waste in lined disposal facilities. Only two of the low-level burial ground trenches are lined (trenches 31 and 34); therefore, since that date, all low-level waste as well as mixed low-level waste has been disposed of in these two trenches (Section 6.3.3.7). Disposal of U.S. Navy reactor compartments (Section 6.3.3.5) in the low-level burial grounds is not affected by this record of decision.

Liquid Waste Management. Liquid effluent is managed in facilities to comply with federal and state regulations and facility permits (Section 6.3.4).

Approximately 31.42 million liters (8.30 million gallons) of liquid waste were stored at the Liquid Effluent Retention Facility at the end of 2006 (Section 6.3.4.1). The volume of wastewater received for interim storage in 2006 was approximately 7.08 million liters (1.87 million gallons). The volume of wastewater transferred to this facility for treatment in 2006 was 15.6 million liters (4.13 million gallons).

The Effluent Treatment Facility (Section 6.3.4.2) in the 200-East Area treats liquid effluent to remove toxic metals, radionuclides, and ammonia, and destroy organic compounds. The treated effluent is stored in tanks, sampled and analyzed, and discharged to the State-Approved Land Disposal Site (also known as the 616-A crib). The volume of wastewater treated and disposed of in 2006 was approximately 15.6 million liters (4.13 million gallons).

The 200 Area Treated Effluent Disposal Facility (Section 6.3.4.3) disposed of 765.3 million liters (202.2 million gallons) of unregulated effluent in 2006. The major source of this effluent was uncontaminated cooling water and steam condensate from the 242-A evaporator.

Industrial wastewater generated throughout the Hanford Site is collected and treated in the 300 Area Treated Effluent Disposal Facility (Section 6.3.4.4). The wastewater

consists of cooling water, steam condensate, and other industrial wastewater. The volume of industrial wastewater treated and disposed of during 2006 was 139.5 million liters (36.87 million gallons).

The 242-A evaporator (Section 6.3.4.5) in the 200-East Area concentrates diluted-liquid tank waste by evaporation. This reduces the volume of liquid waste sent to the double-shell tanks for storage and reduces the potential need for more double-shell tanks. The 242-A evaporator completed a cold-run campaign for training purposes and one waste campaign in 2006. The volume of waste treated was 2.095 million liters (553,400 gallons), reducing the waste volume by 901,682 liters (238,200 gallons), or approximately 43% of the total volume. The volume of process condensate transferred to the Liquid Effluent Retention Facility for subsequent treatment in the Effluent Treatment Facility was 1.249 million liters (330,000 gallons).

Underground Waste Storage Tanks. During 2006, 2.9 million liters (780,000 gallons) of waste were pumped from single-shell tanks. At the end of 2006, there were 101 million liters (26.8 million gallons) of waste in the double-shell tanks (Section 6.4).

Hanford Waste Treatment and Immobilization Plant (Waste Treatment Plant). The Hanford Waste Treatment and Immobilization Plant (Waste Treatment Plant) is being built on 26 hectares (65 acres) located adjacent to the 200-East Area to treat radioactive and hazardous waste currently stored in 177 underground tanks. Four major facilities are being constructed: a pretreatment facility, a high-level waste vitrification facility, a low-activity waste vitrification facility, and an analytical laboratory. Supporting facilities also are being constructed.

Construction on these facilities continued in 2006, although the technical challenges associated with designing and building a first-of-its-kind project, coupled with overcoming stagnation of the U.S. nuclear industry, led to major changes in the projects' execution plan and the development of a new schedule (Section 6.5).

Washington State Initiative 297: *Cleanup Priority Act*

The *Cleanup Priority Act* was passed by Washington State voters in November 2004. In December 2004, the U.S. Department of Justice sought and received a temporary restraining order from the U.S. District Court that enjoined application or enforcement of the act at the Hanford Site or Pacific Northwest National Laboratory, except to the extent it prohibited import of mixed waste to the site. The U.S. Department of Justice filed a motion for summary judgment arguing the *Cleanup Priority Act* is preempted by federal law, violates the principle of sovereign immunity, and burdens the flow of interstate commerce in violation of the U.S. Constitution. In February 2005, Washington State officials asked the federal court to certify five issues for interpretation by the Washington State Supreme Court. The federal court agreed and then prohibited application of the entire initiative, including waste importation prohibitions, until all claims are resolved in both federal and state courts. In 2006, the federal court ruled the initiative was "invalid in its entirety" because it violated the U.S. Constitution in several areas. Washington State officials appealed the ruling in late 2006 (Section 6.3.5).

Radiological Release of Property from the Hanford Site

No property with detectable residual radioactivity was released from the Hanford Site in 2006 (Section 7.0.1).

Radiological Release of Personal Property Potentially Contaminated with Hard-to-Detect Radionuclides. Traditionally, field detectable or "easy-to-detect" radionuclides have been used as an analog for the entire mixture of radionuclides encountered, and real property control and release criteria have been adjusted downward to account for the portion of the activity that is not detectable by field survey methods. As the ratio of hard-to-detect radionuclides to easy-to-detect radionuclides increases, the criteria are reduced to a point where adjusted limits are difficult or impossible to verify with field instruments. Decades of radioactive decay have reduced the contributions of easy-to-detect radionuclides to such low levels that current

control and release methodologies are no longer sufficient for verifying that contaminant levels comply with existing, approved DOE property-release guidelines. In 2006, a request was submitted to increase the release criteria (authorized limits) for hard-to-detect radionuclides on real property to 50,000 dpm/100 cm^2 (average), 150,000 dpm/100 cm^2 (maximum), and 10,000 dpm/100 cm^2 (removable). These would apply to beta-gamma surface contamination only and volumetric contamination or contamination of people is excluded (Section 7.0.1).

River Corridor Baseline Risk Assessment

Sampling of upland, riparian, and near-shore environments for the 100 and 300 Areas for the River Corridor Baseline Risk Assessment was completed in 2006 and collected samples were analyzed. Results are being used to prepare a draft risk assessment report for the 100 and 300 Areas Component of the baseline risk assessment (Section 7.0.2.1).

River Corridor Long-Term Stewardship

In 2006, a draft for a Hanford Site long-term stewardship plan report was prepared and reviewed by the DOE. Also in 2006, orphan site evaluations were completed in the 100-D Area in response to a regulatory agency request to perform this work sooner than originally planned. In addition, work started on orphan site evaluations in the 100-IU-2 and 100-IU-6 Operable Units located between the 100-F and 100-H Areas (Section 7.0.2.2).

Environmental Occurrences

Environmental releases of radioactive and regulated materials from the Hanford Site are reported to the 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 occurrence. The Hanford Site Occurrence Notification Center maintains both a computer database and a hardcopy file of event descriptions and corrective actions. Six significance categories have been established and include operational emergency, recurring, Category 1 (significant impact), Category 2 (moderate impact), Category 3 (minor impact), and Category 4 (some impact) (Section 8.0).

In 2006, there were no occurrences ranked as significance impact Category 1, operational emergency, or recurring on the Hanford Site. There was one Category 2 occurrence with potential environmental implications on the Hanford Site in 2006: Three metal canisters purchased as excess in 1985 were found to be contaminated with detectable levels of fixed alpha. The canisters were returned to the site and disposed of properly.

In 2006, there was one Category 3 event. Removable beta-gamma contamination was found on two mixed waste metal burial boxes that were shipped from Pacific EcoSolutions, Inc, (now Perma-Fix Northwest, Inc.) (offsite) to the Hanford Site's low-level burial grounds. These boxes were shipped on public roads and could have potentially spread contamination.

There were three Category 4 occurrences in 2006 and all involved grass fires on the Hanford Site.

Pollution Prevention and Waste Minimization

The Pollution Prevention and Waste Minimization Program (Section 9.0) is an organized and continuing effort to reduce the quantity and toxicity of hazardous, radioactive, mixed, and sanitary waste generated at the Hanford Site.

Affirmative procurement (the purchase of environmentally preferable products containing recycled material) at the Hanford Site achieved 100% of the 2006 goal.

In 2006, 1,115 metric tons (1,230 tons) of sanitary and hazardous waste were recycled. This recycled waste included 127 metric tons (140 tons) of mixed office paper and cardboard, 413 metric tons (455 tons) of iron/steel, 54 metric tons (59 tons) of non-ferrous metal, 251 metric tons (277 tons) of PCB oil, and 82 metric tons (90 tons) of computers and electronics.

The Hanford Site generated 4,278 cubic meters (5,595 cubic yards) of cleanup/stabilization waste (i.e., low-level waste, mixed low-level waste, and hazardous waste).

Environmental and Resource Protection Programs

DOE Orders require that emission, effluent, and environmental monitoring programs be conducted at the Hanford Site to verify protection of the site's environmental and cultural resources, the public, and workers on the site, and to comply with government regulations (Table S.4; Section 10.0).

Air Emissions

Hanford Site contractors monitor airborne emissions from site facilities to assess the effectiveness of emission treatment and control systems, pollution management practices, and to determine compliance with state and federal regulatory requirements. Small quantities of tritium, strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, americium-241, and a few other isotopes are released at state and federally permitted discharge points, usually stacks or vents, in the 100, 200, 300, 400, and 600 Areas of the Hanford Site (Section 10.1.1).

Non-radioactive air pollutants are emitted from power-generating and chemical-processing facilities. These facilities are monitored when activities are known to generate potential pollutants of concern, which include gaseous ammonia, particulate matter, sulfur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, and lead (Section 10.1.2).

Ambient-Air Monitoring

Radioactive constituents in air are monitored on the Hanford Site near facilities and operations, at site-wide locations away from facilities, and offsite around the perimeter of the site and in nearby and distant communities.

Ambient-Air Monitoring Near Facilities and Operations. In 2006, ambient air was monitored at 77 locations on the Hanford Site near facilities and operations (Section 10.2.1). Samplers were located primarily at or within approximately 500 meters (1,640 feet) of sites or facilities having the potential for, or a history of, environmental releases. Samples were collected biweekly and analyzed. The 2006 data indicate a large degree of variability. Samples collected from locations at or directly adjacent to Hanford Site facilities had higher radionuclide concentrations than did samples collected farther away. In general, analytical results for most radionuclides were at or near Hanford Site background levels, which are much less than EPA concentration limits but greater than those measured offsite. The data also show that concentrations of certain radionuclides were higher and widely variable within different onsite operational areas. Naturally occurring beryllium-7 and potassium-40 were routinely identified.

Site-Wide and Offsite Ambient-Air Monitoring. During 2006, samples were collected at 42 continuously operating site-wide and offsite locations: 23 onsite (site-wide), 11 at perimeter locations, 7 in nearby communities, and 1 in a distant community (Section 10.2.2). Airborne particle samples are collected at each station biweekly and monitored for gross alpha and gross beta concentrations. Biweekly samples are combined into quarterly composite samples and analyzed for gamma-emitting radionuclides. At 20 locations, samples of atmospheric water vapor are collected every 4 weeks and analyzed for tritium. All sample results showed very low radiological concentrations in 2006. All radionuclide concentrations in air samples collected in 2006 were low enough to be below the EPA *Clean Air Act* dose standard of 10 mrem (100 μSv) per year.

Liquid Effluent Monitoring

Liquid effluents are discharged from some facilities at the Hanford Site. Effluent streams are sampled for gross alpha and gross beta concentrations, as well as for concentrations of selected radionuclides. In 2006, only facilities in the 200 Areas discharged radioactive liquid effluent to the ground, at a single location, the State-Approved Land Disposal Site. Non-radioactive hazardous materials in liquid effluent are monitored in the 100, 200, 300, and 400 Areas. The effluent is discharged to the State-Approved Land Disposal Site and to the Columbia River (Section 10.3).

Surface-Water and Sediment Monitoring

Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the concentrations of radiological and chemical contaminants

Table S.4. Summary of Contaminant Monitoring On and Around the Hanford Site, 2006

	What Was Monitored?	The Bottom Line
Air	Radioactive and non-radioactive emissions were monitored at Hanford Site facilities. Air particles and gases were monitored for radioactivity onsite near facilities and offsite. Air samples were collected at 77 locations near Hanford Site facilities, at 23 locations around the Hanford Site away from facilities, at 11 site perimeter locations, and at 8 community locations.	All measurements of radioactive materials in air were below recommended guidelines. In general, radionuclide concentrations near facilities were at or near Hanford Site background levels, and were much less than DOE-derived concentration guides. Some Hanford Site values were greater than concentrations measured offsite. The data also show that concentrations of certain radionuclides were higher and widely variable within different onsite operational areas.
Columbia River Water and Sediment	Columbia River water and sediment samples were collected from multiple Hanford Reach sampling points and from locations upstream and downstream of the Hanford Site. The samples were analyzed for radioactive and chemical materials.	As in past years, small amounts of radioactive materials were detected downriver from the Hanford Site. However, the amounts were far below federal and state limits. During 2006, there was no indication of any deterioration of Columbia River water or sediment quality resulting from operations at the Hanford Site.
Columbia River Shoreline Spring Water and Sediment	Groundwater beneath the Hanford Site discharges to the Columbia River along the Hanford Site shoreline. Discharges above the water level of the river are identified as shoreline springs. Samples of spring water and sediment were collected at locations along the Hanford Site shoreline of the Columbia River.	Samples collected at the shoreline springs contained some contaminants at levels above those observed in near-shore river water but similar to Hanford Site groundwater. However, concentrations in river water downstream of the shoreline springs remained far below federal and state limits. Contaminant concentrations in sediment samples from shoreline springs were similar to background levels, except for uranium concentrations at the 300 Area, which were above background levels.
Food and Farm Products	Samples of asparagus, apples, leafy vegetables, milk, potatoes, tomatoes, and wine were collected from locations upwind and downwind of the Hanford Site.	Radionuclide concentrations in samples of food and farm products were at normal environmental levels.
Fish and Wildlife	Game animals and other animals of interest on the Hanford Site and fish from the Hanford Reach of the Columbia River were monitored. Carcass, liver, and muscle samples were analyzed to evaluate radionuclide and metals concentrations. Populations of selected fish and wildlife species were also surveyed or monitored.	Samples of carp, sucker, quail, and deer were collected and analyzed. Radionuclide levels in wildlife samples were well below levels that are estimated to cause adverse health effects to animals or to the people who may consume them. Concentrations of 17 trace metals were similar to concentrations measured in samples from background locations.
Soil	Ninety-seven routine soil samples were collected onsite near facilities and operations in 2006 to verify known radiological conditions. There were also soil samples collected to investigate potential contamination at non-routine sampling locations in 2006.	In general, radionuclide concentrations in routine samples collected from or adjacent to waste-disposal facilities in 2006 were higher than concentrations measured in distant communities in 2004. There were 25 instances of radiological contamination in soil samples investigated in 2006. Of the 25, 22 were cleaned up. The contamination levels at the other locations did not exceed the radiological control limits for the sites and the soil was left in place.
Vegetation	Samples of perennial vegetation were collected near Hanford Site facilities and operations in 2006 and analyzed for radiological contaminants. Plant populations, including rare plants, were surveyed and monitored to assess the abundance, vigor or condition, and distribution of populations and species.	Concentrations of radionuclides were elevated in vegetation samples collected near facilities and operations when compared to concentrations in samples from distant communities collected in 2004.

from the Hanford Site. Surface water bodies included the Columbia River, onsite ponds, and offsite irrigation sources. Aquatic sediment monitoring was conducted for the Columbia River and one onsite pond.

Columbia River Water. During 2006, Columbia River water samples were collected with automated samplers at fixed-location monitoring stations at Priest Rapids Dam and at Richland, Washington (analyzed for radionuclides), and from cross-river transects and near-shore locations near the Vernita Bridge, 100-N Area, Hanford town site, 300 Area, and the city of Richland (analyzed for both radionuclides and chemicals). Transect samples were collected at multiple locations on a line across the Columbia River and at several near-shore locations. Radiological constituents of interest included gamma-emitting radionuclides, tritium, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240. Gross beta and gross alpha concentrations were also monitored. Chemicals of interest included metals and anions. All radiological contaminant concentrations measured in Columbia River water at the fixed sampling locations during 2006 were less than 1/25th of the DOE standard of 100 mrem (1 mSv) per year. Tritium, strontium-90, uranium-234, and uranium-238 were consistently measured in transect and near-shore samples but all measured concentrations were less than applicable Washington State ambient surface-water quality criteria. Metals and anions were detected in Columbia River transect water samples both upstream and downstream of the Hanford Site. All concentrations measured in 2006 were below regulatory limits (Section 10.4.1).

Columbia River Sediment. During 2006, samples of the surface layer of Columbia River sediment were collected from six locations that were permanently submerged (Section 10.4.2). Samples were collected from the Priest Rapids Dam reservoir and from the McNary Dam reservoir. Samples were also obtained from slack water areas along the Hanford Reach and at the city of Richland. Radionuclides consistently detected in Columbia River sediment in 2006 included potassium-40, cesium-137, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240. In addition, europium-52 was detected at White Bluffs Slough (Section 10.4.2.2). Detectable amounts of most metals were found in all river sediment samples; however, there are no Washington State freshwater sediment quality criteria for comparison to the measured values (Section 10.4.2.3).

Pond Water and Sediment. Two onsite ponds, West Lake and the Fast Flux Test Facility pond, were sampled in 2006. Samples were obtained quarterly and included water from both ponds and sediment from West Lake. All samples were analyzed for tritium and samples from the Fast Flux Test Facility pond were also analyzed for gross alpha, gross beta, and gamma-emitting radionuclides. All radionuclide concentrations in onsite pond water samples were less than applicable DOE-derived concentration guides. Concentrations in sediment samples were similar to concentration measured in prior years (Section 10.4.3.2).

Offsite Irrigation Water. In 2006, samples were collected from an irrigation water canal in the Riverview area of Pasco and from an irrigation water supply in Benton County near the southern boundary of the Hanford Site. All radionuclide concentrations were at the same levels detected in Columbia River water obtained upstream of the Hanford Site (Section 10.4.4).

Columbia River Shoreline Springs Monitoring

Samples of Columbia River shoreline spring water and sediment were collected along the Hanford Reach and analyzed for Hanford-associated radiological and chemical contaminants that are present in groundwater beneath the site (Section 10.5).

Columbia River Shoreline Springs Water. Grab samples were obtained from numerous locations in the fall when Columbia River flows were low. Most samples were analyzed for gamma-emitting radionuclides, gross alpha, gross beta, and tritium. Samples from selected springs were analyzed for strontium-90, technetium-99, uranium-234, uranium-235, and uranium-238. Most samples were also analyzed for metals and anions. Samples from some locations were monitored for volatile organic compounds. All radiological contaminants measured in shoreline springs during 2006 were less than the applicable DOE concentration guides (Section 10.5.1.2). For most locations, the 2006 chemical sample results were similar to those reported previously.

Concentrations of volatile organic compounds were near or below their detection limits in all samples. Trace amounts of chlorinated organic compounds were observed at some locations. The concentrations of most metals measured in spring water samples in 2006 were below Washington State ambient surface-water chronic toxicity levels. However, the maximum concentrations of dissolved chromium in water at some locations were above the Washington State ambient surface water chronic and acute toxicity levels. Concentrations of arsenic in all samples exceeded the EPA limit for the protection of human health for the consumption of water and organisms (Section 10.5.1).

Columbia River Shoreline Springs Sediment. Shoreline springs sediment samples were collected in the 100-B, 100-F, and 100-H Areas, the 300 Area, and at the Hanford town site. Radionnuclide concentrations were similar to concentrations measured in Columbia River sediment, with the exception of the 300 Area where uranium concentrations were above the background concentration measured in the sediments from the reservoir behind Priest Rapids Dam. Metals concentrations in all samples were also similar to concentrations measured in Columbia River sediment samples (Section 10.5.2).

Radiological Monitoring of Hanford Site Drinking Water

Samples of treated drinking water were collected monthly at facilities in the 100-K, 100-N, 200-West, and 400 Areas. Water used in the 400 Area is pumped from wells. Water treated at the other locations is obtained from the Columbia River. Water samples were analyzed for gross alpha, gross beta, tritium, strontium-90, iodine-131, radium-226, and radium-228. During 2006, annual average concentrations of all monitored radionuclides in Hanford Site drinking water were below state and federal maximum allowable contaminant levels (Section 10.6).

Groundwater Monitoring

At the Hanford Site, liquid waste released to the ground over many years has reached groundwater. Hazardous chemicals in the groundwater include carbon tetrachloride, chromium, and nitrate. Radioactive contaminants include iodine-129, strontium-90, technetium-99, tritium, and uranium. Currently, groundwater contaminant levels are greater than drinking water standards beneath 12% of the area of the Hanford Site. This is down from 17.5% just a few years ago. Site groundwater is not a source of public drinking water and does not significantly affect offsite drinking water sources, such as the Columbia River and city wells. There are, however, possible near-shore effects where Hanford Site groundwater flows into the Columbia River (Section 10.7).

Food and Farm Products Monitoring

During 2006, food and farm products including asparagus, apples, leafy vegetables, milk, potatoes, tomatoes, and wines were collected at places around the Hanford Site and analyzed for radiological contaminants. The concentrations of most radionuclides in food and farm product samples in 2006 were below levels that could be detected by the analytical laboratories. However, tritium and uranium-234 were detected in low levels in some samples, as was naturally occurring potassium-40 (Section 10.8).

Soil Monitoring

In 2006, soil samples were collected on the Hanford Site near facilities and operations to evaluate long-term trends in the environmental accumulation of radioactive materials, to detect potential contaminant migration, and to monitor the deposition of facility emissions. Samples were analyzed for radionuclides expected to occur in the areas sampled. In general, radionuclide concentrations in soil samples collected from or adjacent to waste-disposal facilities in 2006 were higher than the concentrations in samples collected farther away and were significantly higher than concentrations measured offsite in previous years. The data also show that concentrations of certain radionuclides in 2006 were higher within different operational areas when compared to concentrations measured in distant communities in previous years. Generally, the predominant radionuclides detected were activation and fission products in the 100-N Area, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas (Section 10.9).

Vegetation Monitoring

Section 10.10 includes discussions on surveys and monitoring of Hanford Site plant populations, monitoring contaminants in perennial vegetation growing near facilities and operations on the site, and control of contaminated or unwanted vegetation on the site.

Plant Communities and Population Surveys. Plant populations monitored on the Hanford Site include taxa listed by Washington State as endangered, threatened, or sensitive, and species listed as review group 1. Data are used to develop baseline information and to monitor for changes resulting from Hanford Site operations. During 2006, work focused on 1) developing a computer model to map shrub canopy cover using field-measured shrub canopy cover and texture data derived from aerial imagery; 2) surveys for rare annual species within specific areas inside specific habitat types; and 3) monitoring established transects to examine the condition and status of persistent sepal yellowcress along the Columbia River shoreline near the 100-F Area and on three Hanford Reach islands (Section 10.10.1).

Vegetation Monitoring Near Hanford Site Facilities and Operations. Vegetation samples were collected on or adjacent to former waste-disposal sites and from locations downwind and near or within the boundaries of operating facilities and remedial action sites to monitor for radionuclide contaminants. In general, radionuclide concentrations in vegetation samples collected from, or adjacent to, waste-disposal facilities in 2006 were higher than concentrations in samples collected farther away, and were significantly higher than concentrations measured offsite in prior years. The data also show that concentrations of certain radionuclides in 2006 were higher within different operational areas when compared to concentrations measured in distant communities in previous years. Generally, the predominant radionuclides detected were activation and fission products in the 100-N Area, fission products in the 200 and 600 Areas and uranium in the 300 and 400 Areas (Section 10.10.2.2).

Investigations of Radioactivity in Vegetation Near Hanford Site Facilities and Operations. During 2006, radiological contamination was found in 75 vegetation samples collected around areas of known or suspected contamination or around specific project sites. Seventy-four of the samples were tumbleweed fragments and one was listed as moss. All were field surveyed for gross alpha and gross beta, but none were analyzed for specific radionuclides. All were disposed of in onsite burial grounds (Section 10.10.2.3).

Vegetation Control Activities. Vegetation control at the Hanford Site consists of cleaning up contaminated plants that can be a threat to workers or the public, controlling or preventing the growth or re-growth of plants in contaminated or potentially contaminated areas on the site, and monitoring and removing 10 high-priority noxious plant species (Section 10.10.4).

Fish and Wildlife Monitoring

Fish and wildlife monitoring on the Hanford Site includes conducting surveys of and monitoring Hanford Site animal populations, monitoring fish and wildlife tissues for contaminants from the site, and managing organisms that might affect workers or have become radiologically contaminated.

Wildlife Population Monitoring. Four fish and wildlife species on the Hanford Site are monitored annually: fall Chinook salmon, steelhead, bald eagles, and mule deer (Section 10.11.1). The number of fall Chinook salmon redds in the Hanford Reach is estimated by aerial surveys. The peak redd count in the fall of 2006 was estimated at 6,190, below the 5-year average for 2001–2005 of 8,023. One aerial survey was conducted to identify possible steelhead spawning areas; none were found. A pair of adult bald eagles returned in November 2006 to occupy the historical nest site in the vicinity of the former site of the town of White Bluffs. Surveys were conducted in early 2007 to re-evaluate the current distribution of bald eagle night roosts and assess the rates of roost use along the Hanford Reach shoreline from the Vernita Bridge to the 300 Area. Thirty-six bald eagles were observed using roosts. This total may include multiple observations of one or more birds. Roadside surveys were conducted for mule deer on the Hanford Site to assess age and sex ratios and the frequency of testicular atrophy in males.

Monitoring Fish and Wildlife for Hanford-Produced Contaminants. In 2006, mule deer, California quail,

common carp, and suckers were collected at locations on and around the Hanford Site (Section 10.11.4). Tissue samples were monitored for strontium-90 contamination and gamma emitters, including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples. Cesium-137 was not detected in any sample in 2006. Strontium-90 was detected at low levels in all deer samples collected onsite, in 1 of 6 onsite quail samples, and in 8 of 10 Hanford Reach fish samples. Liver tissues from most organisms were monitored for up to 17 trace metals that have the potential to accumulate in certain tissues and are potential contaminants of concern. For most trace metals, concentrations in samples collected on the Hanford Site or in the Hanford Reach in 2006 were approximately the same as concentrations in samples collected at reference locations.

Control of Pests and Contaminated Biota. Animals (including insects) must be controlled when they become a nuisance, potential health problem, or are contaminated with radioactivity (Section 10.11.5). Biological control personnel responded to approximately 28,000 animal control requests from Hanford Site employees in 2006. There were 21 contaminated animals or animal-related materials discovered in 2006.

External Radiation Monitoring

In 2006, external radiation at the Hanford Site was monitored onsite in relative close proximity to known, suspected, or potential radiation sources (Section 10.13). The Harshaw thermoluminescent dosimeter system is used to measure external radiation at the Hanford Site. Additionally, radiation surveys with portable instruments were conducted at some locations to monitor and detect contamination to provide a coarse screening for external radiation fields.

Thermoluminescent Dosimeters. During the year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover. At most locations in 2006, measured radiation levels were similar to or lower than levels measured in 2005 (Section 10.13.1). During part of the year, radiation levels at one location in the 100-K Area were significantly higher then those measured at other locations when sludge was being transferred out of the K-Basins. Readings around the 200-North Area in 2006 were also elevated relative to most other locations on the site but were lower than levels measured in 2005.

Radiation Surveys. In 2006, 515 radiation surveys were conducted at and around active and inactive waste-disposal sites (Section 10.13.1.2). It was estimated that the external dose rate at 80% of the outdoor contamination areas was less than 1 mrem (0.01 mSv) per hour, though direct dose rate readings from isolated radioactive specks could have been higher. In 2006, the Hanford Site had approximately 3,583 hectares (8,853 acres) of outdoor contaminated areas of all types and approximately 600 hectares (1,483 acres) that contained underground radioactive materials, not including active facilities.

Potential Radiological Doses from 2006 Hanford Site Operations

During 2006, potential radiological doses to the public and biota from Hanford Site operations were evaluated to determine compliance with pertinent regulations and limits (Section 10.14). Doses were assessed in terms of 1) total dose (multiple pathways) to the hypothetical, maximally exposed individual at an offsite location (0.068 mrem [0.68 µSv] per year at Sagemoor); 2) average dose to the collective population living within 80 kilometers (50 miles) of Hanford Site operating areas (0.001 mrem [0.01 µSv]); 3) dose for air pathways using EPA methods (0.066 mrem [0.00066 mSv] per year at Sagemoor); 4) dose to workers on the site consuming drinking water (0.4 mrem [4 µSv] per year); 5) inhalation doses associated with measured radionuclide concentrations in air (ranging from 0.0015 mrem [0.000015 µSv] in the 300 Area to 0.036 mrem [0.00036 mSv] at the site perimeter); 6) doses from non-DOE industrial sources on and near the Hanford Site (less than 0.02 mrem [0.0002 mSv] per year); and 7) absorbed dose received by animals exposed to contaminants released to the Columbia River and in onsite surface water bodies.

Cultural and Historic Resources

The DOE is responsible for managing and protecting the Hanford Site's cultural and historic resources. The

Hanford Cultural and Historic Resources Program, which is maintained by the DOE, makes certain that cultural and historic resources entrusted to the DOE are managed responsibly and in accordance with applicable regulatory requirements (Section 10.15).

Cultural resources reviews must be conducted before a federally funded, federally assisted, or federally licensed ground disturbance or building alteration/demolition project can take place. As such, cultural resource reviews are required at the Hanford Site 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 affect any such property. During 2006, 166 cultural resource reviews were requested by Hanford Site contractors.

The Hanford Site has a monitoring program to assess the effects of weathering and erosion or unauthorized excavation and collection upon the site's cultural resources. Activities include onsite inspections of important sites. In 2006, 17 sites were visited and minor impacts due to recreation, natural erosion, and animal activity were recorded.

Climate and Meteorology

Meteorological measurements support Hanford Site emergency preparedness, site operations, and atmospheric dispersion calculations. Activities include weather forecasting and maintaining and distributing climatological data (Section 10.16).

The calendar year 2006 average temperature was slightly above normal and precipitation was above normal. The average temperature for 2006 was 12.3°C (54.1°F), which was 0.3°C (0.5°F) above normal (12.0°C [53.6°F]). Five months during 2006 were warmer than normal; seven months were cooler than normal, and two were normal. January had the greatest positive departure, 3.7°C (6.6°F) above normal; December, at 1.5°C (2.7°F) below normal, had the greatest negative departure.

Precipitation during 2006 totaled 21.5 centimeters (8.46 inches), which is 121% of normal (17.7 centimeters [6.98 inches]). Snowfall for 2006 totaled 11.2 centimeters (4.4 inches), compared to normal snowfall of 39.1 centimeters (15.4 inches).

The average wind speed during 2006 was 3.5 meters per second (7.8 miles per hour), which was 0.1 meter per second (0.2 mile per hour) above normal. The peak gust for the year was 33.1 meters per second (74 miles per hour) on December 15.

One dust storm was recorded at the Hanford Meteorology Station during 2006. There has been an average of five dust storms per year at the Hanford Meteorology Station during the entire period of record (1945-2006).

Quality Assurance

Comprehensive quality assurance programs, which include various quality control practices and methods to verify data, are maintained by monitoring and surveillance projects to assure data quality (Section 10.17). 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.

Samples are collected and analyzed according to documented standard 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.

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1.0 Introduction

R. W. Hanf

This report, published annually since 1959 (http://hanford-site.pnl.gov/envreport), includes information and summary analytical data that 1) provide an overview of U.S. Department of Energy (DOE) activities at the Hanford Site during calendar year 2006; 2) demonstrate the site's compliance with applicable federal, state, and local environmental laws and regulations, permits, executive orders, and DOE policies and directives; 3) characterize Hanford Site environmental management performance; and 4) highlight significant environmental, public, and worker protection programs.

Specifically, this report provides a short introduction to the Hanford Site, discusses the site mission, and briefly describes the site's various environmental-related programs. Included are sections that discuss the following:

- Site compliance with local, state, and federal environmental laws and regulations
- Site operations, including environmental restoration efforts and cleanup and closure activities
- Environmental occurrences
- Effluent and emissions from site facilities
- Results of onsite and offsite environmental and groundwater monitoring efforts
- Cultural and biological resource assessments.

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 *Environmental Monitoring Plan, United States Department of Energy Richland Operations Office* (DOE/RL-91-50, Rev. 3).

1.0.1 Current Site Mission

The primary mission at the DOE's Hanford Site is to complete waste cleanup. The report *Performance Management Plan for the Accelerated Cleanup of the Hanford Site* (DOE/RL-2002-47, Rev. D) states the cleanup mission includes six strategies:

1. Restoring the Columbia River corridor by cleaning up Hanford Site sources of radiological and chemical contaminants that threaten the air, groundwater, or Columbia River. It is estimated that most river corridor projects will be completed by 2012.
2. Ending the tank waste program by 2033 by accelerating waste retrieval, increasing the capacity of the Waste Treatment Plant (under construction in 2006), and starting the process of closing the underground waste storage tanks.
3. Cleaning up other Hanford Site facilities that are considered urgent risks.
4. Treating and disposing of mixed low-level waste and the retrieval of transuranic waste and its shipment off the site.
5. Cleaning up excess facilities on the Central Plateau.
6. Cleaning up and protecting groundwater beneath the Hanford Site.

The main goal of these strategies is to speed up completion of Hanford Site cleanup and to do so in a cost-effective manner that protects public and worker health and safety, and the environment.

1.0.2 Hanford Site Overview

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State

(Figure 1.0.1). The site occupies an area of approximately 1,517 square kilometers (586 square miles) located north of the city of Richland (DOE/EIS-0222-F). This area has restricted public access and provides a buffer for areas on the site that were used for nuclear materials production, waste storage, and waste disposal. The Columbia River flows eastward through the northern part of the site and then turns south, forming part of the eastern site boundary.

Major DOE operational, administrative, and research areas on and around the Hanford Site (Figure 1.0.1) include the following:

- **100 Areas** – These areas are located along the south and west shores of the Columbia River. These are the sites of nine retired plutonium-production reactors. The 100 Areas occupy approximately 11 square kilometers (4 square miles).
- **200-West and 200-East Areas** – These areas are located on the Central Plateau, approximately 8 and 11 kilometers (5 and 7 miles), respectively, south and west of the Columbia River. The surface of the plateau is approximately 100 meters (328 feet) above the level of the Columbia River and about 85 meters (280 feet) above the underlying water table. These areas contain underground waste storage tanks and house facilities that extracted plutonium from dissolved irradiated fuel. The facilities were called "separations plants." The 200-East and 200-West Areas cover approximately 16 square kilometers (6 square miles).
- **300 Area** – This area is located just north of the city of Richland and covers approximately 1.5 square kilometers (0.6 square mile). From the early 1940s until the advent of the cleanup mission, most research and development activities at the Hanford Site were performed in the 300 Area. The 300 Area was also the location of nuclear fuel fabrication.
- **400 Area** – This area is located northwest of the 300 Area, and covers approximately 0.61 square kilometer (0.23 square mile). The 400 Area is the location of the Fast Flux Test Facility, which was being deactivated and decommissioned during 2006. This nuclear reactor was designed to test various types of nuclear fuel.
- **600 Area** – This area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas.
- **Former 1100 Area** – This area is located between the 300 Area and the city of Richland and covers 3.1 square kilometers (1.2 square miles). On October 1, 1998, this area was transferred to the Port of Benton as a part of the 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.
- **Richland North Area** (offsite) – This area includes the Environmental Molecular Sciences Laboratory, the Pacific Northwest National Laboratory, and other DOE and contractor facilities (mostly office buildings), generally located in the northern part of the city of Richland.
- **700 Area** (offsite) – This area includes DOE administrative buildings in the central part of the city of Richland.
- **Volpentest Hazardous Materials Management and Emergency Response Training and Education Center** (also called HAMMER) – This worker safety-training facility is located at the Hanford Site near the city of Richland. It consists of a 0.31-square-kilometer (0.12-square-mile) main site and a 40.4-square-kilometer (15.6-square-mile) law enforcement and security training site. The facility is owned by the DOE, managed by Fluor Hanford, Inc., and used by site contractors, federal and state agencies, tribal governments, and private industries.

Other site-related facilities (office buildings) are located within the Tri-Cities of Richland, Pasco, and Kennewick.

Non-DOE Operations and Activities on Hanford Site Leased Land – These include commercial power production by Energy Northwest at the Columbia Generating Station (4.4 square kilometers [1.6 square miles]) and operation of a commercial low-level radioactive waste burial site by US Ecology Washington, Inc. (0.4 square kilometer [0.2 square mile]). The Laser Interferometer Gravitational Wave Observatory (LIGO) is located west of the 400 Area and is operated jointly by the California and Massachusetts Institutes of Technology and sponsored by the National Science Foundation.

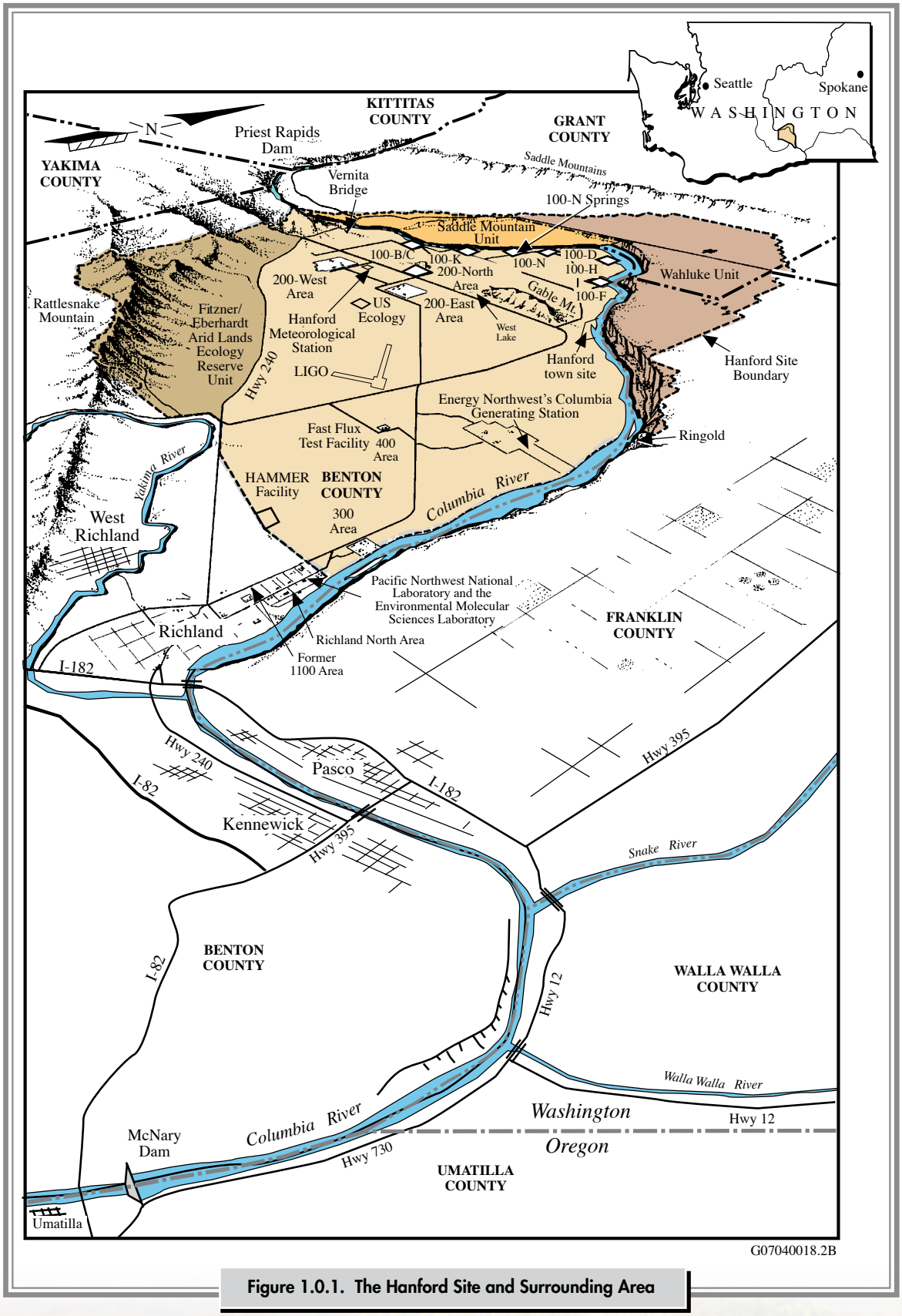

Figure 1.0.1. The Hanford Site and Surrounding Area

Non-DOE Nuclear Operations Near the City of Richland – Immediately adjacent to the southern boundary of the Hanford Site, AREVA NP, Inc. operates a commercial nuclear fuel fabrication facility, and Perma-Fix Northwest, Inc. operates a low-level and mixed low-level radioactive waste processing facility.

Hanford Reach National Monument – The 789-square-kilometer (305-square-mile) Hanford Reach National Monument (Figure 1.0.2) was established on the Hanford Site by a Presidential Proclamation in June 2000 (65 FR 37253). The purpose of the monument is to protect the nation's only non-impounded stretch of the Columbia River upstream of Bonneville Dam in the United States, and a remnant of the shrub-steppe ecosystem that once blanketed the Columbia River Basin.

1.0.3 Hanford Site Management

The DOE is responsible for operating the Hanford Site. The DOE's Richland Operations Office and Office of River Protection jointly manage the Hanford Site through several contractors and their subcontractors. Each contractor is responsible for safe, environmentally sound, maintenance and management of its activities or facilities; for waste management; for measuring all discharges to the environment; and for monitoring any potential effluent to assure environmental regulatory compliance. The DOE, U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife each manage portions of the Hanford Reach National Monument.

The DOE Richland Operations Office. The DOE Richland Operations Office serves as landlord of the Hanford Site and manages cleanup of legacy waste, related research, and other programs. During 2006, the principal contractors for the DOE Richland Operations Office, and their respective responsibilities, included the following:

- Washington Closure Hanford LLC, a limited liability company owned by Washington Group International, Bechtel National, and CH2M HILL, Inc. was awarded the River Corridor Closure Contract in March 2005. The purpose of this contract is to clean up waste sites and conduct environmental restoration along the Columbia River Corridor, an area of roughly 544 square kilometers (210 square miles) along the Benton County side of the Columbia River's Hanford Reach. This contractor's work includes placing the remaining deactivated plutonium-production reactors in interim safe storage (also known as cocooning the reactors), continuing with cleanup of the remaining waste sites located near the Columbia River, demolishing contaminated facilities, and operating the Environmental Restoration Disposal Facility. A principal subcontractor to Washington Closure Hanford LLC is Eberline Services Hanford, Inc.
- Fluor Hanford, Inc. manages the Project Hanford Management Contract. The purpose of this contract is to dismantle former nuclear processing facilities at the Hanford Site, monitor and clean up site contaminated groundwater, retrieve and process transuranic waste for offsite shipment, maintain site infrastructures, provide fire protection and security, and operate the Volpentest Hazardous Materials Management and Emergency Response Training and Education Center (HAMMER). In 2006, Fluor Hanford, Inc.'s principal subcontractors were Energy*Solutions* Federal Services of Hanford, Inc. and Numatec Hanford Corporation. Other subcontractors to Fluor Hanford, Inc. included Lockheed Martin Information Technology, and the Fluor Government Group.
- AdvanceMed Hanford was the occupational health contractor on the Hanford Site in 2006. The company provides occupational medicine and nursing; medical surveillance and evaluations; ergonomics assessment; exercise physiology; case management; psychology counseling and evaluations; fitness-for-duty evaluations; health education; infection control; immediate health care; industrial hygiene; and health, safety, and risk assessment.

The DOE Richland Operations Office also manages portions of the Hanford Reach National Monument. The portion of the monument administered by the DOE Richland Operations Office includes the 36.4-square-kilometer (14-square-mile) McGee Ranch/Riverlands Unit (north and west of State Highway 24 and south of the Columbia River) in Benton County, and the Columbia River Corridor Unit, which includes the Hanford Reach islands in Benton County and a 0.4-kilometer- (0.25-mile-) wide strip

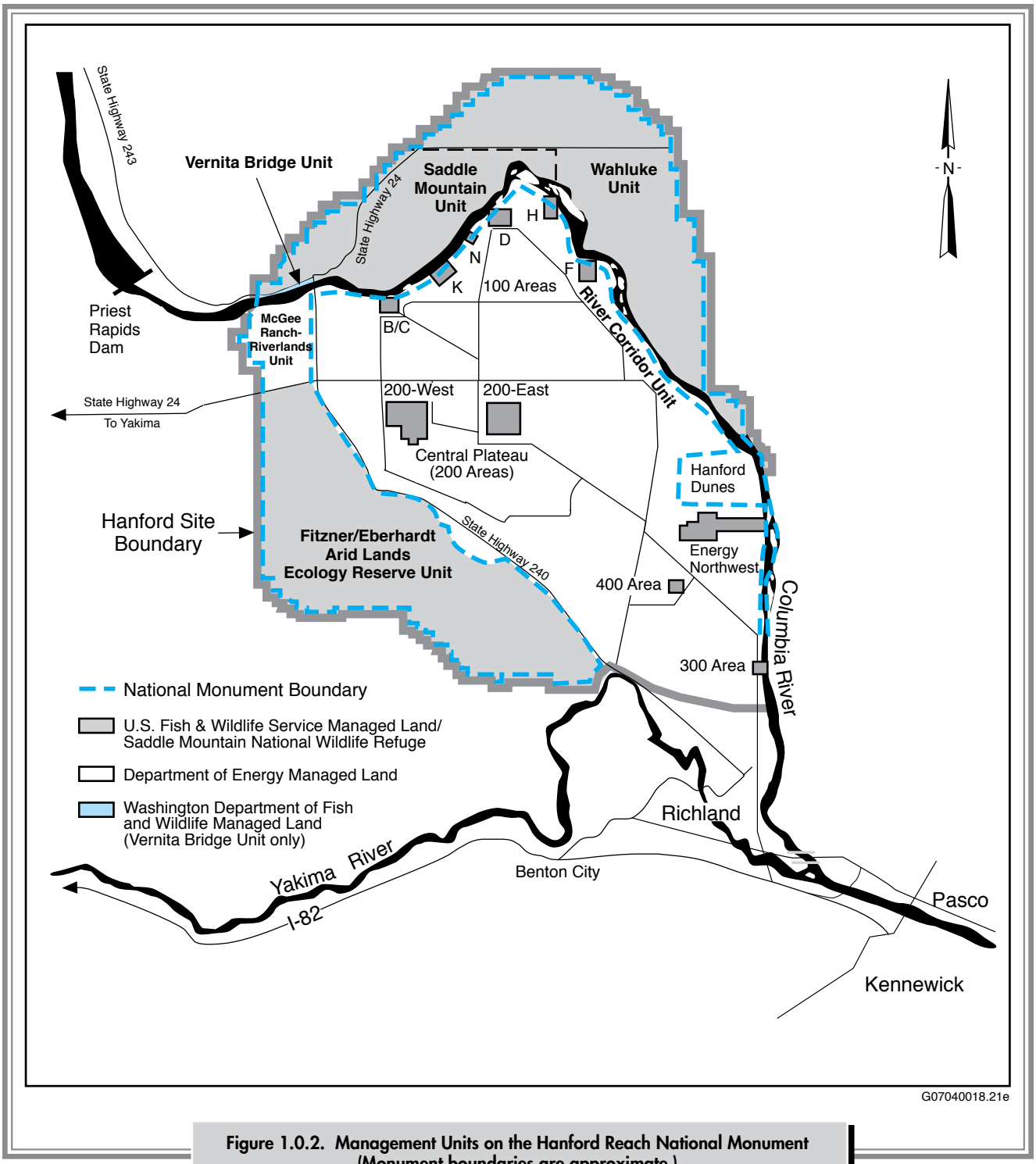

Figure 1.0.2. Management Units on the Hanford Reach National Monument (Monument boundaries are approximate.)

of land along the Hanford Reach shoreline from the Vernita Bridge to just north of the 300 Area. This 101-square-kilometer (39-square-mile) unit in Benton, Franklin, and Grant Counties also includes the 25.6-square-kilometer (9.9 square-mile) Hanford Site dunes area north of Energy Northwest (Figure 1.0.2).

The DOE Office of River Protection. The DOE Office of River Protection was established by Congress in 1998 as a field office to manage Hanford Site tank-waste storage, retrieval, treatment, and disposal. The prime contractors for the DOE Office of River Protection in 2006 and their respective responsibilities included the following:

- Bechtel National, Inc. – This contractor's mission is to design, build, and start up the Waste Treatment and Immobilization Plant on a 0.26-square-kilometer (0.1-square-mile) site on the Central Plateau of the Hanford Site to convert liquid radioactive waste into a stable glass form (vitrification). The 10-year contract for this work was awarded in December 2000.
- Washington Group International – A subcontractor to Bechtel National, Inc., Washington Group International participates in the mission to design and construct the Waste Treatment and Immobilization Plant.
- CH2M HILL Hanford Group, Inc. – This contractor is responsible for storing, retrieving, and disposing of approximately 201 million liters (53 million gallons) of radioactive and chemically hazardous waste stored in 177 underground tanks at the Hanford Site. The company also maintains the tank farm infrastructure in a safe and stable configuration.
- Advanced Technologies and Laboratories International, Inc. – This contractor provides analytical services to Hanford Site cleanup and restoration contractors. The company operates the 222-S Laboratory in the 200-West Area; receives, handles, analyzes, and stores samples; and reports analytical results to the appropriate contractor.

The DOE Office of Science. The Pacific Northwest Site Office of the DOE Office of Science oversees Pacific Northwest National Laboratory, including the Environmental Molecular Sciences Laboratory, to support DOE's Science and Technology programs, goals, and objectives. Pacific Northwest National Laboratory, a DOE facility in Richland, Washington, is operated by Battelle for the DOE's national security and energy missions. The core mission is to perform basic and applied scientific research to deliver breakthrough science and technology for national needs and humanity.

U.S. Fish and Wildlife Service. During 2006, the U.S. Fish and Wildlife Service administered three major management units of the Hanford Reach National Monument totaling about 668 square kilometers (258 square miles). These included 1) the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit, a 312-square-kilometer (120-square-mile) tract of land in Benton County with no general public access located in the southwestern portion of the Hanford Site; 2) the Saddle Mountain Unit, a 130-square-kilometer (50-square-mile) tract of land in Grant County with no general public access located north-northwest of the Columbia River; and 3) the Wahluke Unit, a 230-square-kilometer (89-square-mile) tract of land located north of the Columbia River and adjacent to (east of) the Saddle Mountain Unit (Figure 1.0.2). All of these land units have served as a safety and security buffer zone for Hanford Site operations since 1943, resulting in an ecosystem that has been relatively untouched for more than 60 years. Together, these units comprise the Saddle Mountain National Wildlife Refuge.

Washington Department of Fish and Wildlife. This department manages the approximately 3.2-square-kilometer (1.25-square-mile) Vernita Bridge Unit of the Hanford Reach National Monument, along the north side of the Columbia River, west of the Vernita Bridge, and south of State Highway 243, in Grant County. This unit is open to the public year round.

Additional information about Hanford Site management and contractors can be accessed at the following websites:

- AdvanceMed Hanford: http://www.hanford.gov/?page=65&parent=62
- Advanced Technologies and Laboratories International, Inc.: http://www.atlintl.com/
- Bechtel National, Inc.: http://www.hanford.gov/?page=68&parent=62

- CH2M HILL, Inc.: http://www.ch2m.com/corporate/
- CH2M HILL Hanford Group, Inc.: http://www.hanfordcleanup.info/
- DOE Office of River Protection: http://www.hanford.gov/orp/
- DOE Office of Science: http://www.er.doe.gov/
- DOE Richland Operations Office: http://www.hanford.gov
- DOE Science and Technology: http://www.energy.gov/sciencetech/
- Eberline Services Hanford, Inc.: http://www.eberlineservices.com/page_field.htm
- Energy*Solutions*: http://www.energysolutions.com/Government/DOE_hanford.php
- Environmental Molecular Sciences Laboratory: http://www.emsl.pnl.gov/
- Environmental Restoration Disposal Facility: http://www.hanford.gov/rl/backgrounder/EnvRest.pdf
- Fluor Hanford, Inc., Project Hanford Management Contract: http://www.fluor.com/ias/gov/projects.asp
- Hanford Reach National Monument: http://www.fws.gov/hanfordreach/index-expanded.html
  - Columbia River Corridor Unit: http://www.fws.gov/hanfordreach/documents/riverfactsheet.pdf
  - Fitzner/Eberhardt Arid Lands Ecology Reserve Unit: http://www.fws.gov/hanfordreach/documents/alefactsheet.pdf
  - McGee Ranch/Riverlands Unit: http://www.fws.gov/hanfordreach/documents/mcgeefactsheet.pdf
  - Saddle Mountain National Wildlife Refuge: http://www.fws.gov/refuges/profiles/index-cfm?id=13701
  - Saddle Mountain Unit: http://www.fws.gov/hanfordreach/documents/saddlemountainfactsheet.pdf
  - Vernita Bridge Unit: http://www.fws.gov/hanfordreach/documents/vernitafactsheet.pdf
  - Wahluke Unit: http://www.fws.gov/hanfordreach/documents/wahlukefactsheet.pdf
- Hanford Tours: http://www.hanford.gov/?page=317&parent=0
- Fast Flux Test Facility: http://www.hanford.gov/rl/?page=304&parent=0
- Laser Interferometer Gravitational Wave Observatory (LIGO): http://www.ligo-wa.caltech.edu/
- Lockheed Martin Information Technology: http://www.hanford.gov/?page=74&parent=62
- Numatec Hanford Corporation: http://www.hanford.gov/?page=75&parent=62
- Pacific Northwest National Laboratory: http://www.pnl.gov/
- Volpentest Hazardous Materials Management and Emergency Response Training and Education Center (HAMMER): http://www.hammertraining.com/
- Washington Group International: http://www.wgint.com/
- Washington Closure Hanford LLC: http://www.washingtonclosure.com/

Additional information about the local area and region can be accessed at the following websites:

- City of Kennewick: http://www.ci.kennewick.wa.us/
- City of Pasco: http://www.ci.pasco.wa.us/
- City of Richland: http://www.ci.richland.wa.us/
- Columbia Plateau: http://www.dnr.wa.gov/geology/columbia.htm
- Columbia River Basin: http://www.blm.gov/education/00_resources/articles/Columbia_river_basin/article.html
- Port of Benton: http://www.portofbenton.com/
- Tri-Cities: http://www.visittri-cities.com/
- U.S. Fish and Wildlife Service: http://www.fws.gov/
- Washington Department of Fish and Wildlife: http://wdfw.wa.gov/

Additional information about other companies in the area can be accessed at the following websites:

- Battelle Memorial Institute: http://www.battelle.org/
- Energy Northwest, Columbia Generating Station: http://www.energy-northwest.com/generation/cgs/index.php
- US Ecology Washington, Inc.: http://www.americanecology.com/richland.htm
- Perma-Fix Northwest, Inc.: http://www.perma-fix.com/northwest

1.0.4 References

65 FR 37253. June 9, 2000. "Establishment of the Hanford Reach National Monument." Proclamation 7319, of June 9, 2000, by the President of the United States of America. *Federal Register*.

DOE/EIS-0222-F. 1999. *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*. U.S. Department of Energy, Washington, D.C. Accessed on April 13, 2007, at http://www.hanford.gov/doe/eis/hraeis/maintoc.htm.

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2.0 Public Involvement at the Hanford Site

J. P. Duncan

The U.S. Department of Energy (DOE) encourages information exchange and participation in decisions regarding cleanup and remediation of contaminated waste at the Hanford Site. Participants include the public; federal, state, and local governmental agencies; Indian tribes; advisory boards; activist groups; and other entities in the public and private sectors. The roles of these stakeholders are described in the following sections.

2.0.1 Role of Indian Tribes

K. V. Clarke

The Hanford Site is located on land ceded to the United States government by The Confederated Tribes and Bands of the Yakama Indian 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 reserve the right to fish at all usual and accustomed places, hunt animals and gather roots and berries, and allow horses and cattle to graze on open and unclaimed pasture land. The Wanapum 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 used the area 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 safely use these resources in the future and want to assure themselves that the Hanford Site is environmentally clean and healthy. American Indian tribal governments have a special and unique legal and political relationship with the U.S. government as defined by history, treaties, statutes, court decisions, and the U.S. Constitution. In recognition of this relationship, the DOE and each tribe interact and consult directly. Tribal government representatives from The Confederated Tribes and Bands of the Yakama Indian 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, and the Hanford Cultural and Historic Resources Program. As part of their involvement in these DOE-supported groups, they also review and comment on draft documents. Both the Wanapum and the Confederated Tribes of the Colville Reservation also are provided an opportunity to comment on documents and participate in cultural resource management activities.

The DOE *American Indian & Alaska Native Tribal Government Policy* (DOE 2006) guides the DOE's interaction with tribes for Hanford Site 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."

In addition to the DOE *American Indian & Alaska Native Tribal Government Policy* (DOE 2006), laws such as the *American Indian Religious Freedom Act*, the *National Environmental Policy Act* (NEPA), 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, regulations, and the federal trust responsibility

provides the basis for tribal participation in Hanford Site plans and activities. The DOE provides financial assistance through cooperative agreements with The Confederated Tribes and Bands of the Yakama Indian Nation, The Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe to support their involvement in Hanford Site environmental management activities.

2.0.2 Consultations and Meetings with Tribes, Interested Parties, and the State Historic Preservation Office

E. P. Kennedy

Federal legislation and policies require programs such as the DOE's Hanford Cultural and Historic Resources Program to formally consult with the Washington State Department of Archaeology & Historic Preservation, Indian tribes, and interested parties on cultural resource matters. Specifically, Section 106 of the *National Historic Preservation Act* requires the DOE to seek and gather input from tribes and interested parties, and obtain concurrence from the Washington State Department of Archaeology & Historic Preservation on the identification of cultural resources, evaluation of the significance of these resources, and assessment of impacts of DOE undertakings on cultural resources. The DOE's Cultural and Historic Resources Program routinely conducts formal Section 106 and NEPA consultations with the Washington State Department of Archaeology & Historic Preservation, The Confederated Tribes of the Umatilla Indian Reservation, The Confederated Tribes and Bands of the Yakama Indian Nation, Confederated Tribes of the Colville Reservation, Nez Perce Tribe, and Wanapum. Program officials occasionally consult with parties that have expressed an interest in cultural resources located on the Hanford Site. These include groups such as the B Reactor Museum Association, White Bluffs Pioneers, Benton County Historical Society, East Benton County Historical Museum, and the Franklin County Museum.

Program officials also conduct regular meetings with tribal cultural resources personnel from The Confederated Tribes of the Umatilla Indian Reservation, The Confederated Tribes and Bands of the Yakama Indian Nation, Confederated Tribes of the Colville Reservation, Nez Perce Tribe, and Wanapum. Discussions focus on cultural resource reviews and issues that concern the protection of Hanford Site cultural resources. Program officials hold meetings with interested parties on an as-needed basis. Section 10.15 of this report further addresses cultural and historic resources activities.

2.0.3 Hanford Natural Resource Trustee Council

D. C. Ward

The President of the United States, by Executive Order 12580, "Superfund Implementation" (52 FR 2923), has appointed the heads of some federal departments 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 hazardous substance release. For example, the President appointed the Secretary of Energy as the primary trustee for all natural resources located on, over, or under land administered by the DOE, including the Hanford Site. Other designated federal trustees for Hanford Site natural resources include the U.S. Department of the Interior represented by the U.S. Fish and Wildlife Service, and the U.S. Department of Commerce represented by the National Oceanic and Atmospheric Administration (NOAA). The *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) authorizes state governors to designate a state trustee to coordinate all state trustee responsibilities. CERCLA further states that chairpersons (or heads of governing bodies) of Indian tribes have essentially the same trusteeship over natural resources belonging to or held in trust for the tribes as state trustees. In that regard, Indian tribes and state organizations have been designated as natural resource trustees for certain natural resources at or near the Hanford Site by the "National Oil and Hazardous Substances Pollution Contingency Plan" (55 FR 8666) and Executive Order 12580 (52 FR 2923). Indian tribes include The Confederated Tribes and Bands of the Yakama Indian Nation, The Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe. State organizations include the Washington State Department of Ecology, Washington Department of Fish and Wildlife, and Oregon Department of Energy.

The DOE cooperates and coordinates with trustees' assessments, investigations, and planning and with devising and implementing environmental restoration plans. Hanford Site trustees signed a Memorandum of Agreement in 1996 establishing the Hanford Natural Resource Trustee Council. The primary purpose of the council is to facilitate the coordination and cooperation of the trustees in their efforts to mitigate the effects to natural resources that result from either hazardous substance releases on the Hanford Site or remediation of those releases. The council has adopted bylaws to direct the process of arriving at consensus agreements.

During 2006, the trustees met as a formal council four times to discuss CERCLA natural resource issues concerning the Hanford Site's Central Plateau and Columbia River Corridor. The senior trustees (upper-management level representatives from each trust organization) met three times in 2006 to discuss policy and management issues. Information about the council, including its history and projects, can be found at the website http://www.hanford.gov/?page=29&parent=0.

During 2006, the trustees accomplished the following:

- Worked with the DOE and River Corridor Closure Contractor (Washington Closure Hanford LLC) to provide input to the environmental study design for the 100 and 300 Areas.
- Continued to be active in all phases of the Central Plateau Data Quality Objectives process. Workshops were attended and information from the DOE and its contractors was shared with the trustees. These workshops helped focus DOE attention on additional topics of concern regarding the Central Plateau.
- Supported efforts by NOAA to compile a bibliography of information pertaining to past ecological studies and monitoring conducted at the Hanford Site. NOAA received funding from the DOE to conduct this activity. With trustees' input, NOAA developed a data compilation matrix that will be used to determine if there are any data or information gaps concerning Hanford Site biota that the various ongoing ecological risk assessments should address. Results from this multi-year effort were made available in 2006 to the DOE and trustees.
- Developed a budget request with the DOE for fiscal years 2007 and 2008.
- Endeavored to be informed on ongoing cleanup efforts at the Hanford Site and associated potential impacts to natural resources, particularly the biota and groundwater.
- Attended workshops and participated in conference calls pertaining to groundwater remediation and natural resource actions at the Hanford Site.
- Progressed in writing action plans to address council strategies and priorities, budget and resource utilization, and governance.
- Issued a joint Washington State Department of Ecology – Trustee Council letter discussing reference site concerns to the DOE. The trustees are concerned that the DOE is not selecting the proper reference sites or a sufficient number of reference sites.
- Worked with NOAA as the lead in producing a restoration proposal for consideration by the DOE to re-establish natural resources (plants and animals) to conditions similar to what they may have been prior to DOE operations. This action is continuing.
- Planned and held three senior trustee meetings where high-level policy issues such as Hanford Site restoration and trustee-working relationships were discussed.

2.0.4 Public Participation in Hanford Site Decisions

K. Lutz and T. E. Olds

The DOE's Richland Operations Office and Office of River Protection believe public involvement is essential to the success of Hanford Site cleanup. These offices coordinate, plan, and integrate scheduling of public participation activities for the DOE at the Hanford Site.

The *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan* (Tri-Party Agreement Agencies 2002) outlines the public participation processes used by the Tri-Parties (Washington State Department of Ecology, the U.S. Environmental Protection Agency [EPA], and the DOE) and identifies various ways the public can participate in Hanford Site cleanup decisions (see Section 3.0.1). The plan was developed and approved with public input in 1990

and revised in 2002. The most current revision is available on the Hanford Site website located at http://www.hanford.gov under the Public Involvement section. In addition, public participation guidance developed by both the DOE and EPA is followed.

A key goal of public involvement is to facilitate broad-based participation and obtain Indian tribe, natural resource trustees (see Section 2.0.3), stakeholder, and public perspectives on Hanford Site cleanup decisions. The DOE is committed to maintaining a government-to-government relationship with the Indian tribes that retain certain rights at the Hanford Site. The DOE consults with tribal governments prior to taking action, making decisions, or implementing programs that may affect the tribes.

Stakeholders are individuals who perceive themselves affected by and/or have an interest in Hanford Site-related issues. They commit time and energy to participate in decisions. Hanford Site stakeholders include local governments, local and regional businesses, the site workforce, local and regional environmental interest organizations, and local and regional public health organizations. The public is comprised of individuals who are aware of but may choose not to be involved in decisions. It is the DOE's responsibility to provide the public with meaningful information on upcoming decisions so they can choose whether or not to become involved in Hanford Site-related decisions.

The DOE uses various forums to inform the public of upcoming public involvement and participation opportunities. These include, but are not limited to, the following:

- **The Hanford Cleanup Line** – The Hanford Cleanup Line (1-800-321-2008) responds to information requests about the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement; Ecology et al. 1989) Hanford Site cleanup activities. The Tri-Parties (Washington State Department of Ecology, the EPA, and the DOE) strive to provide a timely response to all requests. The line is advertised frequently in a variety of ways, including all Tri-Party Agreement newspaper notices, brochures, meeting notices, fact sheets, etc.
- **Mailing List** – The Tri-Party Agreement agencies maintain a mailing list of about 3,300 individuals who have expressed interest in Hanford Site cleanup issues. The mailing list is used to provide information to the public on upcoming cleanup decisions and activities. Information can be received by mail or electronically. To be added to the list, call the Hanford Cleanup Line at 1-800-321-2008.
- ***The Hanford Update*** – A newsletter titled *The Hanford Update*, a synopsis of Tri-Party Agreement public-involvement activities and information about ongoing Hanford Site cleanup activities, is published quarterly and distributed to interested stakeholders and the general public through an established mailing list. The newsletter can also be accessed at the following website: http://www.hanford.gov/?page=102&parent=91.
- **Hanford Site Public Involvement Activities** – A Hanford Site Public Involvement Activities document is produced quarterly to provide an overview of anticipated public involvement opportunities for the coming months. It identifies the current forums and emerging opportunities to inform and involve stakeholders and the public. It is available at the following website under the Public Involvement section: http://www.hanford.gov. Additionally, a list of current public involvement opportunities is posted at http://www.hanford.gov/public/calendar/.
- **Fact and Focus Sheets** – Fact and focus sheets provide information on Hanford Site issues, cleanup activities, and opportunities for public involvement.
- **Meeting Summaries** – Summaries of certain public meetings are available upon request from the DOE's Public Reading Room located in the Consolidated Information Center, 2710 University Drive, in Richland, Washington.
- **Comment and Response Documents** – Following a DOE or Tri-Party Agreement public comment period, a Comment and Response document is developed to record the public comments received on an issue. Comment and Response documents are distributed to those members of the public who provide comments or request copies. The documents are posted in the DOE's Public Reading Room and in the Tri-Party Agreement's Administrative Record as part of the decision documentation, and at the following website: http://www.hanford.gov/?page=91&parent=0.
- **Informational Public Meetings** – In an effort to provide broad and timely perspectives to the public on Hanford Site cleanup priorities and budget decisions,

the Tri-Party agencies regularly conduct public information meetings. All Tri-Party Agreement quarterly public involvement planning meetings, semiannual meetings, special meetings, and workshops are open to the public. In addition, the Tri-Parties welcome opportunities for co-sponsoring meetings organized by local, state, and tribal governments and members of citizen groups.

Cleanup documents are also made available to the general public through the Tri-Party Agreement's Administrative Record and Public Information Repository located at the following website: http://www2.hanford.gov/arpir.

The public is provided a variety of opportunities to offer input and influence Hanford Site cleanup decisions. These opportunities include informal and formal public comment periods, such as those described in the Tri-Party Agreement (Ecology et al. 1989), CERCLA, the *Resource Conservation and Recovery Act* (RCRA), and NEPA; Hanford Advisory Board meetings; annual state of the site and budget meetings; and other Hanford Site-related public involvement/information meetings, workshops, or activities.

For more information about Hanford Site cleanup activities, contact the Tri-Party Agreement agencies at the following contact numbers:

- DOE Richland Operations Office (509) 376-7501
- DOE Office of River Protection (509) 372-8656
- Washington State Department of Ecology's Hanford Cleanup Line (800) 321-2008
- EPA (509) 376-8631.

To view public involvement and outreach activities conducted by the Tri-Party Agreement agencies, visit the Hanford Site website at www.hanford.gov.

2.0.5 Hanford Advisory Board

K. Lutz and T. E. Olds

The Hanford Advisory Board is an independent, nonpartisan, and broadly representative body consisting of a balanced mix of the diverse interests affected by Hanford Site cleanup decisions. The board was created in 1994 by the Tri-Party agencies (Washington State Department of Ecology, the EPA, and the DOE) and ultimately chartered as one of nine environmental management site-specific advisory boards. It provides recommendations and advice to all three agencies on Hanford Site cleanup decisions. The Hanford Advisory Board is comprised of 31 members and their alternates including representatives from the Nez Perce Tribe and The Confederated Tribes and Bands of the Yakama Indian Nation tribal governments. A representative of The Confederated Tribes of the Umatilla Indian Reservation participates on the board in an ex-officio status.

The Hanford Advisory Board is intended to be an integral component for some Hanford Site tribal and general public involvement activities, but not the sole conduit for public involvement activities. Through its open public meetings, advice on the Tri-Party agencies' public involvement activities, and the responsibilities of board members to communicate with their constituencies, members assist the broader public in becoming more informed and meaningfully involved in Hanford Site cleanup decisions. The organization provides significant advice on cleanup issues, and the DOE relies on the board to provide input and advice that reflects the values of their constituents.

In 2006, the Hanford Advisory Board held 2-day meetings in Seattle, Richland, and Kennewick, Washington; Pendleton and Hood River, Oregon; and Lewiston, Idaho. Eleven pieces of advice were issued to the Tri-Party agencies.

During 2006, the Hanford Advisory Board contributed to or participated in Hanford Site decisions, including the following:

- Tank Closure and Waste Management Environmental Impact Statement Scoping Process
- Notice of Intent to Prepare the Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, WA (71 FR 8569)
- Fiscal Year 2007 Budget
- Fiscal Year 2008 Budget
- Contracting Strategy Tank Waste Systems Integration
- Tank Waste Systems Integration
- CERCLA Five-Year Review

- State of the Site Meetings
- Waste Treatment Plant
- Double-Shell Tank Integrity Assessment Report (RPP-28538)
- Multi-Tier Pension and Benefits Program.

Information about the Hanford Advisory Board, including its charter, and copies of its advice and responses can be found at the website http://www.hanford.gov/public/boards/hab/.

2.0.6 References

52 FR 2923, January 29, 1987. Executive Order 12580, "Superfund Implementation." *Federal Register*.

55 FR 8666. "National Oil and Hazardous Substances Pollution Contingency Plan." *Federal Register*.

71 FR 5655. "Notice of Intent to Prepare the Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, WA." *Federal Register*.

American Indian Religious Freedom Act. 1978. Public Law 95-341, as amended, 42 USC 1996, 1996 note.

Archaeological Resources Protection Act. 1979. Public Law 96-95, as amended, 16 USC 470-470ii.

Comprehensive Environmental Response, Compensation, and Liability Act. 1980. Public Law 96-510, as amended, 94 Stat. 2767, 42 USC 9601 et seq. Accessed May 1, 2007, at http://www.epa.gov/region5/defs/html/cercla.htm.

DOE. 2006. *American Indian & Alaska Native Tribal Government Policy*. Office of Congressional & Intergovernmental Affairs, U.S. Department of Energy, Washington, D.C.

Ecology – Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. 1989. *Hanford Federal Facility Agreement and Consent Order*. Document No 89-10, as amended (The Tri-Party Agreement), Olympia, Washington. Accessed May 1, 2007, at http://www.hanford.gov/?page=91&parent=0.

Memorandum of Agreement. 1996. *Memorandum of Agreement Among the United States Department of Energy, United States Department of the Interior, Nez Perce Tribe, State of Oregon, Confederated Tribes of the Umatilla Indian Reservation, State of Washington (including the Departments of Ecology and Fish and Wildlife), and the Confederated Tribes and Bands of the Yakama Indian Nation*. U.S. Department of Energy, Richland Operations Office, Richland, Washington.

National Environmental Policy Act. 1969. Public Law 91-190, as amended, 42 USC 4321 et seq.

National Historic Preservation Act. 1966. Public Law 89-665, as amended, 16 USC 470 et seq.

Native American Graves Protection and Repatriation Act. 1990. Public Law 101-601, as amended, 25 USC 3001 et seq.

Resource Conservation and Recovery Act. 1976. Public Law 94-580, as amended, 90 Stat. 2795, 42 USC 6901 et seq. Accessed May 1, 2007, at http://www.epa.gov/region5/defs/html/rcra.htm.

RPP-28538. 2006. *Double-Shell Tank System Integrity Assessment, HFFACO M-48-14*. Prepared by Los Alamos Technical Associates for CH2M HILL Hanford Group, Inc., Richland, Washington.

Tri-Party Agreement Agencies. 2002. *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Accessed June 12, 2006, at http://www.hanford.gov/?page=113&parent=91.

3.0 Regulatory Oversight at the Hanford Site

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. These agencies include the U.S. Environmental Protection Agency (EPA), the Washington State Department of Ecology, the Washington State Department of Health, and the Benton Clean Air Authority. The EPA is the primary federal regulatory agency that develops, promulgates, and enforces environmental regulations and standards as directed in statutes enacted by Congress. In some instances, the 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 the EPA's requirements. In other activities, the state program is assigned direct environmental oversight of the U.S. Department of Energy (DOE) program, as provided by federal law. Where federal regulatory authority is not delegated or only partially authorized to the state, the EPA Region 10 office for the Pacific Northwest is responsible for reviewing and enforcing compliance with EPA regulations as they pertain to the Hanford Site. The EPA periodically reviews state environmental programs and may directly enforce federal environmental regulations.

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

T. W. Noland

The *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement; Ecology et al. 1989) is an agreement among the Washington State Department of Ecology, the EPA, and the DOE to achieve environmental regulation compliance at the Hanford Site with the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA); the *Superfund Amendments and Reauthorization Act* remedial action provisions; and 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. A companion document to the Tri-Party Agreement is the *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan* (Tri-Party Agreement Agencies 2002). This plan describes how public information and involvement activities are conducted for Tri-Party Agreement decisions.

The Tri-Party Agreement has evolved as Hanford Site cleanup has progressed. Changes to the agreement have been negotiated since its publication in 1989 to meet the changing conditions and needs of cleanup at the Hanford Site. All significant changes undergo a process of public involvement that enhances communication and addresses public concerns prior to final approvals. Copies of the Tri-Party Agreement are publicly available at the DOE's Public Reading Room located in the Consolidated Information Center, 2710 University Drive, in Richland, Washington, and at information repositories in Seattle and Spokane, Washington, and Portland, Oregon. The Tri-Party Agreement can be accessed at the following website: http://www.hanford.gov/?page=91&parent=0.

To be placed on the mailing list to obtain Tri-Party Agreement information, contact the EPA or the DOE directly,

or call the Washington State Department of Ecology at (800) 321-2008. Requests can be sent to the following address:

Hanford Mailing List
P.O. Box 1000
M/S B3-30
Richland, WA 99352

3.0.2 Status of Tri-Party Agreement Milestones

T. W. Noland

The Tri-Party Agreement (Ecology et al. 1989) commits the DOE to achieve compliance with the remedial action provisions of CERCLA, and with RCRA treatment, storage, and disposal unit regulations and corrective action provisions, including Washington State's implementing regulations (WAC 173-303, "Dangerous Waste Regulations"). From 1989 through 2006, a total of 946 Tri-Party Agreement milestones were completed, and 293 target dates were met. During 2006, there were 49 specific cleanup milestones scheduled for completion; 41 were completed on or before their required due dates, 2 were completed beyond their established due date, and 6 were not yet complete at the end of 2006.

3.0.3 Approved Modifications to the Tri-Party Agreement

T. W. Noland

During 2006, 17 negotiated change requests to the Tri-Party Agreement were approved. These approved change requests may be viewed in the Tri-Party Agreement's Administrative Record at the following website: http://www2.hanford.gov/arpir.

3.0.4 Washington State Department of Health

J. A. Bates

The Washington State Department of Health Office of Radiation Protection has regulatory authority to enforce federal and state standards applicable to all sources of ionizing radiation in the state. The EPA provided delegation of authority to the Radioactive Air Emissions Section of the Office of Radiation Protection to implement and enforce the federal standards and requirements in 40 CFR 61, Subparts A and H. Subpart H of 40 CFR 61, which covers radioactive air emissions, also enforces the state standards and requirements of WAC 246-247, "Radiation Protection–Air Emissions," issued under the authority of the *Washington Clean Air Act*. These regulations include requirements for the DOE to obtain Washington State Department of Health approval prior to constructing any new or modified source of airborne radionuclide emissions, and for the Washington State Department of Health to issue and enforce the resulting licenses covering construction and operation. The Washington State Department of Health also conducts a program for inspection of all emission sources in the state that may emit airborne radioactive material to assure the operations, emissions, and record keeping and reporting are in compliance with all applicable licenses and federal and state regulations. The state enforces an as low as reasonably achievable environmental approach to minimize airborne emissions to protect public health and safety.

3.0.5 References

40 CFR 61, Subpart A. "National Emission Standards for Hazardous Air Pollutants; General Provisions." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 61, Subpart H. "National Emission Standards for Hazardous Air Pollutants; National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

Comprehensive Environmental Response, Compensation, and Liability Act. 1980. Public Law 96-510, as amended, 94 Stat. 2767, 42 USC 9601 et seq. Accessed May 1, 2007, at http://www.epa.gov/region5/defs/html/cercla.htm.

Ecology – Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. 1989. *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement). Document No. 89-10, as amended, Olympia, Washington. Accessed May 1, 2007, at http://www.hanford.gov/?page=91&parent=0.

Resource Conservation and Recovery Act. 1976. Public Law 94-580, as amended, 90 Stat. 2795, 42 USC 6901 et seq. Accessed May 1, 2007, at http://www.epa.gov/region5/defs/html/rcra.htm.

Superfund Amendments and Reauthorization Act. 1986. Public Law 99-499, as amended, 100 Stat. 1613, 42 USC 11001 et seq.

Tri-Party Agreement Agencies. 2002. *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Accessed May 1, 2007, at http://www.hanford.gov/?page=113&parent=91.

WAC 173-303. "Dangerous Waste Regulations." *Washington Administrative Code*, Olympia, Washington.

WAC 246-247. "Radiation Protection–Air Emissions." *Washington Administrative Code*, Olympia, Washington.

Washington Clean Air Act. Revised Code of Washington (RCW) 70.94, as amended.

4.0 Environmental Program Information

The U.S. Department of Energy (DOE) requires that all Hanford Site contractors develop environmental and chemical management systems. The following sections provide information on these systems.

4.0.1 Environmental Management Systems

H. T. Tilden II, P. C. Miller, J. L. Nuzum, and M. L. Proctor

Hanford Site contractors have established integrated environment, safety, and health management systems as mandated by their contracts with the DOE. These systems are intended to protect workers, the public, and the environment by integrating environmental, safety, and health considerations into the way work is planned, performed, and improved. The international voluntary consensus standard International Organization for Standardization (ISO) 14001, *Environmental Management Systems – Specifications with Guidance for Use*, and DOE Order 450.1, "Environmental Protection Program," were considered during the development of these systems.

The DOE verified that all Hanford Site entities under DOE P 450.4, "Safety Management System Policy," had integrated environmental, safety, and health management systems in place prior to the specified implementation date of December 31, 2005. This included the Hanford Central Plateau Project, the Hanford River Corridor Project, the DOE Office of River Protection, and Pacific Northwest National Laboratory. Implementation dates were as follows: CH2M HILL Hanford Group, Inc. (May 2000); Fluor Hanford, Inc. (August 2000); and Pacific Northwest National Laboratory (1998). Pacific Northwest National Laboratory obtained ISO 14001 (1996) third-party registration of its Environmental Management System in 2002 and was re-registered to the updated ISO 14001 (2004) standard in 2005. Based in part on its environmental management systems, Pacific Northwest National Laboratory was accepted into the EPA's National Environmental Performance Track program for a 3-year membership beginning in 2004. Washington Closure Hanford LLC maintains an environmental management system that is integrated with the company's Integrated Environment, Safety, and Health Management System. Efforts continued in 2006 to improve these environmental, safety, and health programs.

4.0.2 Chemical Management Systems

M. T. Jansky

Hanford Site contractors developed and documented formal systems to manage chemicals in 1997 that are still in use today. These chemical 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 Standards" (29 CFR 1910, Subpart Z, Appendices A and B). The chemical management systems have been reviewed periodically and improved as needed. Details on the inventories of hazardous chemicals stored at the Hanford Site in 2006 are provided in Section 5.1.1.

4.0.3 References

29 CFR 1910, Subpart Z. "Occupational Safety and Health Standards." Subpart Z, "Toxic and Hazardous Substances." *Code of Federal Regulations*, U.S. Department of Labor.

DOE Order 450.1. 2003. "Environmental Protection Program." U.S. Department of Energy, Washington, D.C.

DOE P 450.4. 1996. "Safety Management System Policy." U.S. Department of Energy, The Office of Environment, Safety and Health, Washington, D.C.

ISO 14001. 1996 and 2004. *Environmental Management Systems – Specifications with Guidance for Use*. American Society for Testing and Materials, West Conshohocken, Pennsylvania.

5.0 Compliance Summary

J. P. Duncan

U.S. Department of Energy (DOE) policy mandates that all DOE activities at the Hanford Site are performed in compliance with applicable federal, state, and local environmental laws and regulations; DOE Orders; Secretary of Energy Notices; and DOE Headquarters and site operations office directives, policies, and guidance. This includes specific requirements, actions, plans, and schedules identified in the *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement; Ecology et al. 1989) and other compliance or consent agreements. Both the DOE Richland Operations Office and the DOE Office of River Protection recognize the importance of maintaining a proactive program of self-assessment and regulatory reporting to assure environmental compliance is achieved and maintained at the Hanford Site.

This section summarizes the various laws and regulations that impact Hanford Site activities with regard to federal environmental protection statutes and associated state and local environmental regulations. Permits required under specific environmental protection regulations are also discussed.

5.1 Hazardous Materials

This section provides information about federal statutes related to the regulation of hazardous materials at the Hanford Site.

5.1.1 *Emergency Planning & Community Right to Know Act*

R. E. Johnson

The *Emergency Planning & Community Right to Know Act* requires each state to establish an emergency response commission and local emergency planning committees, and to develop a process to distribute information on hazardous chemicals present in facilities. These committees 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 (quantities that trigger notifications to the state and local emergency response organizations) must identify themselves to the state emergency response commission and local emergency planning committee and periodically provide information to support the emergency planning process. The threshold planning quantities are predetermined amounts established by the state and local authorities. Facilities must also notify the state emergency response commission and local emergency planning committee immediately after an accidental release of an extremely hazardous substance (40 CFR 355, Appendices A and B) over the reportable quantity. Two annual reports are required by the *Emergency Planning & Community Right to Know Act*: 1) the *Tier Two Emergency and Hazardous Chemical Inventory*, which contains information about hazardous chemicals stored at each facility in amounts exceeding minimum threshold levels; and 2) the *Toxic Chemical Release Inventory*, which contains information about total annual releases of certain toxic chemicals and associated waste management activities.

In early 2006, Hanford Site officials issued the *2006 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2007-10, Rev. 0) to the Washington State Department of Ecology's Community Right-To-Know Unit; local emergency planning committees for Benton, Franklin, and Grant Counties; and to both the city of Richland and Hanford Site fire departments. The *2006 Hanford Site Toxic Chemical Release Inventory* (DOE/RL-2007-12, Rev. 0), which included releases and waste management activities involving the metal lead and the chemical propylene, is scheduled to be provided on or before July 1, 2007, to the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology. Table 5.1.1 provides an overview of 2006 reporting under the *Emergency Planning & Community Right to Know Act*.

Types, quantities, and locations of hazardous chemicals are tracked through prime-contractor-specific chemical management system requirements (Section 4.0.2). Table 5.1.2 summarizes the information reported and lists the average quantities of the 10 hazardous chemicals stored in greatest quantity at the Hanford Site in 2006.

5.1.2 *Resource Conservation and Recovery Act*

M. J. Hartman

The *Resource Conservation and Recovery Act* (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 hazardous waste management. The

Table 5.1.1. *Emergency Planning & Community Right to Know Act* Compliance Reporting at the Hanford Site, 2006

Sections of the Act	Yes[a]	No[a]	Not Required[a]
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 releases were too small to require action or no releases occurred.
(b) These notifications apply to the Hanford Site but were completed prior to 2006.

Table 5.1.2. Average Quantity of Ten Hazardous Chemicals[a] Stored in Greatest Quantity on the Hanford Site, 2006

Hazardous Chemical	Average Quantity, kg (lb)
Mineral oil	1,100,000 (2,430,000)
Sodium	1,100,000 (2,430,000)
Portland cement	290,000 (639,000)
Diesel fuel (Grades 1 and 2)	270,000 (595,000)
Fly ash (class F)	180,000 (397,000)
Propane	120,000 (265,000)
Argon	74,000 (163,000)
Nitrogen	69,000 (152,000)
Sulfuric acid	51,000 (112,000)
Gypsum sulfate	40,000 (88,200)

(a) Includes chemicals defined as hazardous under "Hazard Communication" in 29 CFR 1910.1200(c).

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 to enforce RCRA requirements in the state under WAC 173-303, "Dangerous Waste Regulations." At the Hanford Site, RCRA applies to 72 hazardous waste treatment, storage, and disposal units that have received waste since implementation of the act.

5.1.2.1 Hanford Facility RCRA Permit

S. A. Thompson

The Washington State Department of Ecology issued the Hanford Facility RCRA Permit on September 27, 1994 (Ecology 1994). The permit is the foundation for RCRA permitting on the Hanford Site in accordance with provisions established in the Tri-Party Agreement (Ecology et al. 1989) and WAC 173-303. The permit is issued to seven permittees: the DOE Richland Operations Office and the DOE Office of River Protection as the owners/operators of the Hanford Site, and to five of their contractors as co-operators. The permit expired on September 27, 2004; however, the DOE continues to operate under the expired permit until a new permit is in effect. The Washington State Department of Ecology is working on a draft of the new permit.

5.1.2.2 RCRA/Dangerous Waste Permit Applications and Closure Plans

S. A. Thompson

The Hanford Site is considered a single facility for purposes of RCRA and WAC 173-303. The facility encompasses 72 treatment, storage, and disposal units. The Tri-Party Agreement (Ecology et al. 1989) recognized that not all of the units could be issued dangerous waste permits simultaneously, and a schedule was established to submit unit-specific permit applications and closure plans to the Washington State Department of Ecology.

During 2006, four revisions to the RCRA Permit Part A Form (Ecology 1994) were submitted to the Washington State Department of Ecology for review and approval. These revisions to the Part A Form included modifications to information for the Waste Encapsulation and Storage Facility (200-East Area); the 222-S Dangerous and Mixed Waste Treatment, Storage, and Disposal Unit (200-West Area); the Single-Shell Tank System (200-East and 200-West Areas); and the 400 Area Waste Management Unit (400 Area).

In 2006, four RCRA Part B permit applications were submitted to the Washington State Department of Ecology. The submittals included Hanford Facility Dangerous Waste Permit Applications for the 331-C Storage Unit (Washington State Department of Ecology Permit #WA7890008967, Operating Unit 15); the 222-S Dangerous and Mixed Waste Treatment, Storage, and Disposal Unit (DOE/RL-91-27, Rev. 1); the Waste Encapsulation and Storage Facility (DOE/RL-2006-35, Rev. 0); and the 400 Area Waste Management Unit (DOE/RL-2006-61, Rev. 0).

5.1.2.3 RCRA Groundwater Monitoring

M. J. Hartman

RCRA groundwater monitoring is part of the Hanford Site Soil and Groundwater Remediation Project (Section 10.7). Proposals for new wells for monitoring under RCRA, *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), and the *Atomic Energy Act* are reviewed and approved annually as defined under a Tri-Party Agreement milestone (Ecology et al. 1989). Proposals for new wells are integrated and documented via the data quality objectives process, which integrates the borehole and well data needed by the various Hanford Site regulatory driven projects. Based on results of the data quality objectives process, the Washington State Department of Ecology, the EPA, and the DOE (the Tri-Parties) annually negotiate an integrated well drilling list that coordinates and prioritizes the requirements of RCRA, CERCLA, and the *Atomic Energy Act* under the Tri-Party Agreement (Ecology et al. 1989) Milestone M-24-57. During 2006, drillers completed 6 RCRA monitoring wells and 47 other wells.

At the end of 2006, 15 RCRA sites were monitored to determine whether they were contaminating groundwater with hazardous constituents. Eight sites were monitored to assess the extent of known contaminants, and two were monitored to determine the progress of groundwater contamination cleanup activities. Twelve of the sites monitored under RCRA are scheduled for closure under the Hanford Facility RCRA Permit (Ecology 1994). The Liquid Effluent Retention Facility and low-level burial grounds (Waste Management Areas 1 through 4) will receive permits as operating RCRA facilities. The Integrated Disposal Facility received a RCRA operating permit in June 2006 and is under a unit-specific groundwater monitoring plan.

A summary of groundwater monitoring activities for these sites during 2006 is provided in Section 10.7; more detailed information is available in the *Hanford Site Groundwater Monitoring Report for Fiscal Year 2006* (PNNL-16346).

5.1.2.4 RCRA Inspections

D. L. Hagel

Hanford Site contractors and the DOE work to resolve notices of violation and non-compliance warning letters received from the Washington State Department of Ecology. These documents identify conditions that are alleged to be non-compliant with RCRA requirements. The following item summarizes the single RCRA non-compliance document received in 2006.

Failure to Submit a Complete Application for a New RCRA Permit. Permit condition Part I, Subsection F of the *Hazardous and Solid Waste Amendments* (of 1984) portion of the Hanford RCRA permit states that the permittee must submit a complete application for a new permit at least 180 days before the permit expires.

In a letter dated July 14, 2006, the EPA issued a notice of violation for failure to submit a complete application for a new RCRA permit. The *Hazardous and Solid Waste Amendments* portion of the Hanford RCRA permit expired on September 27, 2004. Therefore, the DOE Richland Operations Office should have provided a complete application for a new permit to the EPA by March 30, 2004. The EPA

alleges that the submittal received on March 30, 2004, was incomplete and did not satisfy the *Hazardous and Solid Waste Amendments* requirement. Specifically, the application did not address the waste minimization requirements of 40 CFR 264.73.

In a letter to the EPA, dated July 27, 2006, the DOE Richland Operations Office responded to the notice of violation and provided documentation that the renewal application included the waste minimization information. The DOE Richland Operations Office requested the EPA withdraw the notice of violation.

5.1.3 *Washington Administrative Code* Groundwater Monitoring

M. J. Hartman

Groundwater monitoring was required for three regulated, non-RCRA waste facilities in 2006. The 200 Area Treated Effluent Disposal Facility and the State-Approved Land Disposal Site are monitored under state discharge permits (WAC 173-216). The Solid Waste Landfill is monitored for compliance with requirements in WAC 173-304, "Minimum Functional Standards for Solid Waste Handling." Wells near these facilities were monitored in 2006 for waste constituents specified in the facility permits.

A summary of groundwater monitoring activities for these sites during 2006 is provided in Section 10.7; more detailed information is available in the *Hanford Site Groundwater Monitoring Report for Fiscal Year 2006* (PNNL-16346).

5.1.4 *Toxic Substances Control Act*

Hanford Site PCB Technical Team (Point of Contact: A. L. Prignano)

Toxic Substances Control Act requirements that apply to the Hanford Site primarily involve regulation of polychlorinated biphenyls (PCBs). Federal regulations for PCB use, storage, and disposal are provided in 40 CFR 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." Washington State also regulates certain classes of PCBs not regulated by the *Toxic Substances Control Act* through WAC 173-303. Non-radioactive and certain categories of radioactive PCB waste are stored or disposed of in accordance with 40 CFR 761. Other radioactive PCB waste remains in storage onsite pending the development of adequate treatment and disposal technologies and capacities. Electrical equipment that might contain PCBs is maintained and serviced in accordance with 40 CFR 761.

During 2006, the DOE Richland Operations Office submitted both the 2005 PBC Annual Document Log report for the Hanford Site (DOE/RL-2006-42, Rev. 0) and a 2005 PCB annual report (DOE/RL-2006-43, Rev. 0) to the EPA as required by 40 CFR 761.180. These two documents describe the PCB waste management and disposal activities occurring at the Hanford Site. The *Framework Agreement for Management of Polychlorinated Biphenyls in Hanford Tank Waste* (Ecology et al. 2000), signed on August 31, 2000, resulted in the EPA, the Washington State Department of Ecology, and the DOE and its Hanford Site contractors working together to resolve the regulatory issues associated with managing PCB waste at the Waste Treatment and Immobilization Plant (now under construction), in the waste tank farms, and at affected waste management units upstream and downstream of the waste tank farms. The flexibility of the 1998 PCB disposal amendments in 40 CFR 761 is used at the Hanford Site to allow necessary storage and to expedite disposal of PCB waste regulated under the *Toxic Substances Control Act*. In addition, the *Toxic Substances Control Act Polychlorinated Biphenyls Hanford Site Users Guide* (DOE/RL-2001-50, Rev. 1) published in 2003, is used to encourage consistent interpretation and implementation of the *Toxic Substances Control Act* PCB regulations throughout the Hanford Site.

During 2006, double-shell tank supernatant was used to retrieve 245,000 liters (64,700 gallons) of waste from tank 241-C-103 and 40,900 liters (10,800 gallons) of waste from tank 241-C-108, both single-shell tanks. These activities were performed in accordance with EPA Phase I and II Risk-Based Disposal Approvals for the use of double-shell tank PCB remediation waste. A Risk-Based Disposal Approval is defined in 40 CFR 761.61(a)(c). It is a method of approval from the EPA (based on risk, similar to a risk assessment) to treat or dispose of *Toxic Substances Control*

Act-regulated PCB waste in a manner other than prescribed in the regulations. Phase I identifies general conditions that apply to the overall strategy and retrieval process, and Phase II identifies tank-specific conditions. Approvals have been received for eight tanks with seven remaining tanks identified in the Risk-Based Disposal Approval for which EPA approval has not been issued. An approval specifies which double-shell tank can supply the supernatant to the single-shell tank and to which double-shell tank the supernatant will be returned.

Following the conditions in a risk-based disposal approval letter from the EPA (2005), a total of three hundred and thirty-two 208-liter (55-gallon) containers of treated sludge from the K-Basin North Load-Out Pit were generated during 2005 and 2006. The North Load-Out Pit sludge is a multi-phasic (mixture of liquid and non-liquid phases) PCB remediation waste. The waste was solidified to meet radiological treatment standards in preparation for disposal.

In September 2006, a Risk-Based Disposal Approval application was submitted for storage of two water tower tanks at the Hanford Site. The paint on the tanks' interior walls contains PCBs at greater than 500 parts per million; therefore, the tanks are classified as PCB bulk-product waste. The Risk-Based Disposal Approval will allow continued storage of the tanks while management and disposal alternatives are considered.

5.1.5 Comprehensive Environmental Response, Compensation, and Liability Act

W. E. Toebe

During 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. During 1986, CERCLA was extensively amended by the *Superfund Amendments and Reauthorization Act*, which made several important changes and additions, including clarification that federal facilities are subject to the same provisions of CERCLA as private industries. Federal facilities identified on the National Priorities List, the EPA's list of the most serious uncontrolled or abandoned hazardous waste sites, must enter into an interagency agreement with the EPA. At the Hanford Site, the EPA is responsible for oversight of the DOE's implementation of CERCLA regulations. There is significant overlap between the Washington State RCRA corrective action program (Section 5.1.2) and the CERCLA program. Many waste management units at the Hanford Site are potentially 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 (Ecology et al. 1989) addresses CERCLA implementation at the Hanford Site and is generally consistent with 40 CFR 300. There are several remediation activities ongoing at the Hanford Site that are part of the CERCLA process.

5.1.5.1 Hanford Site Institutional Controls Plan

J. P. Sands

Section 4.2 of the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41, Rev. 1) requires the DOE to conduct a site-wide assessment every 5 years coinciding with the CERCLA Five-Year Review. The next site-wide institutional control review is scheduled in 2011. In addition, several CERCLA records of decision require annual reviews of institutional controls for specific areas covered by the records of decision. Annual reviews of these institutional controls are reported in the Unit Manager's meeting each September; however, the 2006 review was delayed, and the review was held in October. The minutes from the Unit Manager's meeting are provided in the Tri-Party Agreement's Administrative Record and can be accessed at the following website: http://www2.hanford.gov/arpir.

The Central Plateau did not have any CERCLA institutional controls that required review in 2006. The River Corridor has a number of institutional controls in both interim action and final records of decision. An evaluation

was completed in April 2006. The following three evaluation questions were considered:

- **Question**: Are institutional control requirements being properly reflected in waste site closeout documents?

  Answer: *Appropriate institutional control language was present in the documents that were reviewed.*

- **Question**: Do subcontractor documents require that signage on new haul roads be maintained during remediation?

  Answer: *All the subcontractor documents reviewed contained language requiring that signage be installed and maintained.*

- **Question**: Is access control maintained and are warning signs posted along access roads for the 300 Area waste sites?

  Answer: *The documents stated that warning signs were present at all openings to access areas; however, there were no physical barriers preventing access to a Washington Closure Hanford LLC-controlled road in the northwest portion of the 300 Area. An action was taken to install a fence with a locking gate along Apple Street and around the waste container queue in the northwest portion of the 300 Area to provide more positive access control.*

5.1.5.2 CERCLA and *Washington Administrative Code* Reportable Releases to the Environment

W. E. Toebe

Releases that are reportable to the state and/or the EPA include spills or discharges of hazardous substances or dangerous waste to the environment, other than releases permitted under state or federal law. Releases of hazardous substances that equal or exceed specified reportable quantities, including releases that are continuous and stable in quantity and rate but exceed specified limits must be reported as required by CERCLA, Section 103. There were no CERCLA reportable spills or releases on or from the Hanford Site during calendar year 2006.

Reporting of spills or non-permitted discharges of dangerous waste or hazardous substances to the environment is also required by state regulations (WAC 173-303-145). That requirement applies to spills or discharges onto the ground, into groundwater or surface water (e.g., the Columbia River), or into the air such that human health or the environment are threatened, regardless of the quantity of dangerous waste or hazardous substance. There were no reportable spills or non-permitted discharges on or from the Hanford Site during calendar year 2006.

5.1.6 *Federal Insecticide, Fungicide, and Rodenticide Act*

J. M. Rodriguez

The *Federal Insecticide, Fungicide, and Rodenticide Act* is administered by the EPA. The standards administered by the Washington State Department of Agriculture to regulate implementation of the act in Washington State include the *Washington Pesticide Control Act*, the *Washington Pesticide Application Act*, and rules relating to general pesticide use codified in WAC 16-228, "Pesticide Regulations." 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 licensed private commercial applicator.

5.2 Air Quality

K. A. Peterson

This section provides information about federal statutes and assessments related to Hanford Site air quality.

5.2.1 *Clean Air Act*

The *Clean Air Act*, the basis for federal air quality regulations, was passed in 1967 and had comprehensive amendments in 1970, 1977, and 1990. In accordance with Section 112 of the *Clean Air Act*, the EPA established the "National Emissions Standards for Hazardous Air Pollutants" (40 CFR 61). The DOE and the EPA signed the *Federal Facility Compliance Agreement for Radionuclides NESHAP, for the U.S. Department of Energy, Richland Operations Office, Richland, Washington* (EPA 1994). The agreement provides a 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 sources of airborne emissions. Scheduled agreement milestones were completed during 2006, and Hanford Site radiological air emissions remained well below the levels that approach the EPA offsite emission standard of 10 mrem (100 μSv) per year (40 CFR 61.92) (see Section 10.1). The requirements for flow and emissions measurements, quality assurance, and sampling documentation have been implemented at Hanford Site emission sources and/or are monitored for milestone progress in accordance with a schedule approved by the EPA and monitored by the Washington State Department of Health. Data for the emission sources are documented annually in the radionuclide air emissions report for the Hanford Site (e.g., DOE/RL-2007-01, Rev. 0).

The Washington State Department of Health's Division of Radiation Protection regulates radioactive air emissions statewide through Washington State legislative authority. The Hanford Site operates under state license FF-01 (Appendix D, Table D.1) for air emissions. Conditions specified in the license are incorporated into the Hanford Site air operating permit renewal, which was reissued by the Washington State Department of Ecology on December 29, 2006. The permit provides a compilation of applicable *Clean Air Act* requirements both for radioactive and nonradioactive (i.e., toxic and criteria pollutants) emissions. The permit requires the DOE Richland Operations Office to submit periodic compliance reports (e.g., DOE/RL-2007-03, Rev. 0) to the Washington State Department of Ecology.

The Washington State Department of Ecology's 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*. The EPA regulates other potential air emission sources under the *Clean Air Act* at the Hanford Site.

For the local region, the EPA delegated the Benton Clean Air Authority as the agency to establish a local oversight and compliance program for asbestos renovation and/or demolitions, adopting the EPA's regulation by reference (i.e., 40 CFR 61, Subpart M, "National Emission Standards for Asbestos"). In addition, the Benton Clean Air Authority regulates open-air burning as an extension of the Washington State Department of Ecology's open-air burning requirements (WAC 173-425).

5.2.2 *Clean Air Act* Enforcement Inspections

Hanford Site contractors and the DOE actively work towards resolution of any potential notice of correction and/or

notice of violation allegation letters from the Washington State Department of Health and/or the Washington State Department of Ecology. During 2006, 22 enforcement inspections were conducted in the *Clean Air Act* area.

5.3 Water Quality Protection

This section provides information regarding federal statutes and assessments related to water quality.

5.3.1 *Clean Water Act*

R. Ranade

The *Clean Water Act* applies to point-source discharges to surface waters in the United States. At the Hanford Site, the requirements of the act are applied through the "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System" (40 CFR 122) permits that govern effluent discharges to the Columbia River. There were no permit violations during 2006.

There is one National Pollutant Discharge Elimination System permit (Permit #WA-002591-7) issued by the EPA for the Hanford Site (Appendix D, Table D.1). The permit covers three outfalls: outfall 001 for the 300 Area Treated Effluent Disposal Facility and outfalls 003 and 004 in the 100-K Area. Fluor Hanford, Inc. is the holder of this permit.

The Hanford Site was covered by one storm water permit during 2006. The EPA's National Pollutant Discharge Elimination System Storm Water Multi-Sector General Permit (Permit #WAR05A57F) (Appendix D, Table D.1) establishes the terms and conditions under which storm water discharges associated with industrial activity are authorized. This Multi-Sector General Permit for storm water discharges, issued in October 2000, expired at midnight on October 30, 2005. A new permit to replace it has not been issued. Facilities that obtained coverage under the 2000 Multi-Sector General Permit prior to its expiration are automatically granted an administrative continuance of permit coverage. Fluor Hanford, Inc. is the holder of this permit.

There are numerous sanitary wastewater discharges to the ground throughout the Hanford Site. Sanitary wastewater from the 400 Area is discharged to a treatment facility at Energy Northwest's Columbia Generating Station (Figure 1.0.1). Sanitary wastewater from the 300 Area, the former 1100 Area, and other facilities north of and in the city of Richland is discharged to the city's treatment facility. Sanitary wastewater in the 100 and 200 Areas is primarily treated in a series of onsite sewage systems. The placement of these systems is based on population centers and facility locations. In recent years, extensive efforts have been made to regionalize the onsite sewage systems. Many of the small onsite sewage systems have been replaced with larger systems. These larger systems (with design capacities of 13,300 to 55,000 liters [3,500 to 14,500 gallons] per day) operate under permits issued by the Washington State Department of Health and treat wastewater from several facilities rather than a single facility (Appendix D, Table D.1). Holding tank sewage systems are also used for disposal of sanitary wastewater. The Washington State Department of Health issues annual permits for the onsite sewage systems, including holding tank sewage systems.

The Washington State Department of Ecology has a State Wastewater Discharge Permit Program that regulates the discharge or disposal of wastewater to groundwater. During 2006, the Hanford Site had five state waste discharge permits issued by the Washington State Department of Ecology (ST-4500, ST-4501, ST-4502, ST-4507, and ST-4511). There were no permit violations in 2006.

5.3.2 *Safe Drinking Water Act*

L. M. Kelly

In 1974, Congress passed the *Safe Drinking Water Act*. The act set up a cooperative program among local, state, and federal agencies to establish drinking water regulations applicable to all public water systems in the United States. States were granted primary responsibility, known as primacy, for administering and enforcing the *Safe Drinking Water Act*. To obtain primacy, states had to meet certain criteria, including adoption of regulations equal to or more stringent than the EPA regulations.

Washington State was awarded primacy in 1978. The State Board of Health and the Washington State Department of Health became partners in developing and enforcing state drinking water regulations. Hanford Site water systems were designated as public water systems in 1986 and became formally registered as public systems under the jurisdiction of the Washington State Department of Health in 1987.

The *Safe Drinking Water Act* was amended in 1986 to strengthen the act, and amended again in 1996 (*Safe Drinking Water Act Amendments*). The 1996 amendments represent a national commitment to 1) prepare for future drinking water challenges and assure the sustainable availability of safe drinking water; 2) increase state flexibility; 3) provide for more efficient investments by water systems; 4) give better information to consumers; and 5) strengthen the EPA's scientific work, including the use of risk and cost-benefit analysis in establishing drinking water standards. The amendments include development of several new drinking water regulations to be published over the next several years.

A series of these EPA regulations—known as the Microbial and Disinfection Byproduct Rules—address acute threats from microbial contamination and chronic threats from disinfectant residuals and byproducts. Two of the rules incorporated into the state drinking water regulations, WAC 246-290, "Public Water Supplies," became effective in January 2004 ("Stage 1, Disinfectants and Disinfection Byproducts Rule") and January 2005 ("Long Term 1 Enhanced Surface Water Treatment Rule"), impacting Hanford Site water systems. These rules limit disinfectant residuals and disinfection byproducts in the distribution systems while improving particle removal in the drinking water treatment plants. In 2006, the affected Hanford Site systems were tested and complied with rules and limits for disinfectant residuals and disinfection byproducts.

To protect the health of workers using public water supplies at the Hanford Site, the water systems were monitored during 2006 for microbiological, chemical, physical, and radiological constituents. There were three total coliform (broad class of bacteria common in the environment) detections during the 2006 monitoring cycle. Follow-up sampling yielded satisfactory results as reported by the state-accredited laboratory performing the analyses. Analytical results for 2006 radiological monitoring are summarized in Section 10.6. All chemical concentrations in Hanford Site drinking water were well below the maximum contaminant levels established by the EPA.

5.4 Natural and Cultural Resources

This section provides information about federal statutes and assessments related to ecological compliance and cultural resources at the Hanford Site.

5.4.1 Ecological Compliance

M. R. Sackschewsky

DOE policies require that all projects with the potential to adversely affect biological resources have an ecological compliance review performed prior to project initiation. This review determines if the project complies with the *Endangered Species Act* and the *Migratory Bird Treaty Act*. It also examines whether 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 actions are prescribed; these actions can include avoidance of the area, minimization of activities, rectification, or compensation.

There were 188 reviews performed during 2006, including 95 ecological compliance reviews to support general Hanford Site activities and 93 reviews for environmental restoration activities. Because many projects occur during periods of the year when plants are not growing and are difficult to identify or evaluate, each of the operational areas (the 200-East and 200-West Areas, the 100-K Area, and the 300 Area) are surveyed each spring. All habitat areas within these areas are surveyed and each building is inspected for the nests of migratory birds. These baseline visual surveys provide information about habitat types, and species inventories and abundances that can be used throughout the rest of the year to assess potential impact. These data are also used to support ecological inventory and data requirements for ecological risk evaluations. Examples of the baseline survey maps are available at the following website: http://www.pnl.gov/ecomon/Compliance/comp.html.

5.4.1.1 *Endangered Species Act*

Several protected species of plants and animals exist on the Hanford Site and in the Hanford Reach of the Columbia River. Steelhead trout (*Oncorhynchus mykiss*) and spring-run Chinook salmon (*Oncorhynchus tshawytscha*) are listed under the *Endangered Species Act* as either threatened or endangered (50 CFR 17, Subpart B) and occur onsite. The bald eagle (*Haliaeetus leucocephalus*), which occurs on the Hanford Site, was previously listed as a federal-threatened species but was delisted in June 2007. The DOE has management plans in place for each of these species (DOE/RL-94-150, Rev. 0; DOE/RL-2000-27). Other species at the Hanford Site are listed by the Washington Department of Fish and Wildlife as endangered, threatened, or sensitive (see Section 10.12).

Two informal consultations under Section 7 of the *Endangered Species Act* occurred during 2006. The first was with the National Marine Fisheries Service regarding remediation impacts of the 128-F-2 burn pit on steelhead and spring-run Chinook salmon. The second informal consultation was with the U.S. Fish and Wildlife Service regarding impacts on the bald eagle from environmental sampling activities in the White Bluffs Slough.

5.4.1.2 *Migratory Bird Treaty Act*

The *Migratory Bird Treaty Act* prohibits taking or disturbing specified migratory birds or their feathers, eggs, or nests. Over 100 species of birds that regularly occur on the Hanford Site are protected by the *Migratory Bird Treaty Act*. All Hanford Site projects with a potential to affect federal- or state-listed species of concern complied with the requirements

of this act by using the ecological compliance review process described in the *Hanford Site Biological Resources Management Plan* (see Section 5.5.1 in DOE/RL-96-32, Rev. 0). When applicable, the ecological reviews produced recommendations to minimize adverse impacts to migratory birds, such as performing work outside of the nesting season and minimizing the loss of habitat; otherwise, there were no significant issues with *Migratory Bird Treaty Act* compliance.

5.4.2 Cultural Resources

E. P. Kennedy

The DOE's policy is to comply with all cultural resources-related laws and regulations (DOE P 141.1). At the Hanford Site, cultural resources are subject to the provisions of the following laws, regulations, executive orders, and proclamations. Laws include the *American Indian Religious Freedom Act*; *Antiquities Act*; *Archaeological and Historic Preservation Act*; *Archaeological Resources Protection Act*; *Historic Sites, Buildings and Antiquities Act*; *National Environmental Policy Act*; *National Historic Preservation Act*; and *Native American Graves Protection and Repatriation Act*. Regulations applicable to cultural resources include "Curation of Federally-Owned and Administered Archaeological Collections" (36 CFR 79); "National Historic Landmarks Program" (36 CFR 65); "National Register of Historic Places" (36 CFR 60); "Determinations of Eligibility for Inclusion in the National Register of Historic Places" (36 CFR 63); "Native American Graves Protection and Repatriation Act: Final Rule" (43 CFR 10); "Protection of Archaeological Resources" (43 CFR 7); and "Protection of Historic Properties" (36 CFR 800). Executive Orders include Executive Order 11593, "Protection and Enhancement of the Cultural Environment" (36 FR 8921); Executive Order 13007, "Indian Sacred Sites" (61 FR 26771-26772); Executive Order 13287, "Preserve America" (68 FR 10635); and Proclamation 7319, "Establishment of the Hanford Reach National Monument" (65 FR 37253).

See Section 10.15 for details regarding the cultural resources programs on the Hanford Site.

5.5 National Environmental Policy Act

M. T. Jansky

The *National Environmental Policy Act* (NEPA) requires preparation of an environmental impact statement for major federal actions that have the potential to significantly affect the quality of the human environment. An environmental assessment is prepared when it is uncertain if a proposed action would require the preparation of an environmental impact statement. A supplement analysis is prepared to consider new information developed since issuance of an environmental impact statement and record of decision. The supplement analysis would determine 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 the DOE and determined to not normally result in a significant environmental impact. These actions are called categorical exclusions, and, if eligibility criteria are met, they are exempt from NEPA 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 Hanford Site contractors. In addition, site-wide categorical exclusions are applied to routine, typical actions conducted daily on the Hanford Site. In 2006, there were 20 NEPA site-wide categorical exclusions at the Hanford Site.

Hanford Site NEPA documents are prepared and approved in accordance with the Council on Environmental Quality National Environmental Policy Regulations for Implementing the Procedural Provisions of the *National Environmental Policy Act* (40 CFR 1500-1508), DOE NEPA implementation procedures (10 CFR 1021), and DOE Order 451.1B Change 1, "National Environmental Policy Act Compliance Program – Change 1." In accordance with the Order, the DOE documents prepared for CERCLA projects incorporate NEPA values such as analysis of cumulative, offsite, ecological, and socioeconomic impacts to the extent practicable in lieu of preparing separate NEPA documentation.

5.5.1 Recently Issued Environmental Impact Statements

In February 2006, the DOE announced its intention to prepare a new environmental impact statement titled "Notice of Intent to Prepare the Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, WA" (71 FR 5655). The Washington State Department of Ecology will be a cooperating agency in preparing this environmental impact statement. This environmental impact statement will revise, update, and re-analyze groundwater impacts previously addressed in the *Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington* (DOE/EIS-0286F). The *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, WA* will 1) include a re-analysis of onsite disposal alternatives for the Hanford Site's low-level radioactive waste and mixed low-level radioactive waste, and low-level radioactive waste and mixed low-level radioactive waste from other DOE sites; 2) revise and update other potential impact areas previously addressed in DOE/EIS-0286F; and 3) incorporate existing analyses from DOE/EIS-0286F that do not affect and are not directly affected by the waste-disposal alternatives after review or revision, as appropriate. The DOE will continue its ongoing analysis

of alternatives for the retrieval, treatment, storage, and disposal of underground tank wastes and closure of underground single-shell tanks. In addition, the scope of the ongoing *Fast Flux Test Facility Decommissioning Environmental Impact Statement* (DOE/EIS-0364, Notice of Intent issued in 69 FR 50178) was also included in 71 FR 5655. The DOE extended the scoping period for the *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, WA* and rescheduled the public scoping meetings (71 FR 8569). Four public scoping meetings were held in March 2006. Projected issuance of the draft environmental impact statement is 2008.

A draft comprehensive conservation plan and environmental impact statement for the Hanford Reach National Monument/Saddle Mountain National Wildlife Refuge was being prepared by the U.S. Fish and Wildlife Service to evaluate management alternatives for the monument and including the units of the monument that comprise the national wildlife refuge (Fitzner/Eberhardt Arid Lands Ecology Reserve, Saddle Mountain, and Wahluke Units) (67 FR 40333). As co-manager of the monument, the DOE Richland Operations Office is a cooperating agency. The draft document, titled *Draft Hanford Reach National Monument Comprehensive Conservation Plan and Environmental Impact Statement* was issued for review in December 2006 (U.S. Fish and Wildlife Service 2006). The public comment period ended March 10, 2007. Projected issuance of the final environmental impact statement is late 2007 to early 2008.

5.5.2 Recent Environmental Assessments

An environmental assessment titled *Environmental Assessment for the Sodium Residual Reaction/Removal and Other Deactivation Work Activities, Fast Flux Test Facility Project, Hanford Site, Richland, Washington* (DOE/EA-1547F) was prepared in March 2006. A Finding of No Significant Impact was issued on March 31, 2006.

5.6 *Atomic Energy Act*

W. M. Glines

The *Atomic Energy Act* was promulgated to assure the proper management of radioactive materials. The act and its amendments have delegated the roles and responsibilities for the control of radioactive materials and nuclear energy primarily to the DOE, the Nuclear Regulatory Commission, and the EPA. Under the act, the DOE regulates the control of radioactive materials under its authority including the treatment, storage, and disposal of low-level radioactive waste from its operations. Sections of the act authorize the DOE to set radiation protection standards for itself and its contractors. Accordingly, the DOE promulgated a series of regulations (e.g., 10 CFR 820, 10 CFR 830, and 10 CFR 835) and Orders (e.g., DOE Order 435.1 and DOE Order 5400.5) to protect public health and the environment from potential risks associated with radioactive materials. Hanford Site operations are subject to the requirements in these regulations and Orders. In 2006, the following DOE manual and guidance document were issued that potentially impact the management and control of radioactive materials:

- DOE Manual 450.4-1. 2006. "Integrated Safety Management System Manual."
- DOE/EH-0697. 2006. *Control and Release of Property: A Guide to Good Practices for the Control and Release of Property*.

In addition, the following DOE Technical Standard pertaining to the management and control of radioactive materials underwent significant revision in 2006:

- DOE-HDBK-1188-2006. 2006. *Glossary of Environment, Safety and Health Terms*. U.S. Department of Energy, Washington, D.C.

These 2006-issued documents may be accessed on the DOE Directives, Regulations, and Standards website at http://www.directives.doe.gov/.

The DOE also issued proposed amendments to 10 CFR 820, "Procedural Rules for DOE Nuclear Activities," and 10 CFR 835, "Occupational Radiation Protection," on August 10, 2006 (71 FR 45996-46025).

5.7 References

10 CFR 820. "Procedural Rules for DOE Nuclear Activities." *Code of Federal Regulations*, U.S. Department of Energy.

10 CFR 830. "Nuclear Safety Management." *Code of Federal Regulations*, U.S. Department of Energy.

10 CFR 835. "Occupational Radiation Protection." *Code of Federal Regulations*, U.S. Department of Energy.

10 CFR 1021. "Compliance with the National Environmental Policy Act." *Code of Federal Regulations*, U.S. Department of Energy.

29 CFR 1910.1200(c). "Hazard Communication"; Subsection C, "Definitions." *Code of Federal Regulations*, Occupational Safety and Health Administration.

36 CFR 60. "National Register of Historic Places." *Code of Federal Regulations*, U.S. Department of Labor.

36 CFR 63. "Determinations of Eligibility for Inclusion in the National Register of Historic Places." *Code of Federal Regulations*, U.S. Department of Labor.

36 CFR 65. "National Historic Landmarks Program." *Code of Federal Regulations*, U.S. Department of Labor.

36 CFR 79. "Curation of Federally-Owned and Administered Archaeological Collections." *Code of Federal Regulations*, U.S. Department of Labor.

36 CFR 800. "Protection of Historic Properties." *Code of Federal Regulations*, U.S. Department of Labor.

40 CFR 61. "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 61.92. "Standard." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 61, Subpart H. "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 61, Subpart M. "National Emission Standard for Asbestos." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 122. "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 264.73. "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities; Manifest System, Recordkeeping, and Reporting; Operating Record." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 300. "National Oil and Hazardous Substances Pollution Contingency Plan." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 355, Appendices A and B. "Emergency Planning and Notification; The List of Extremely Hazardous Substances and Their Threshold Planning Quantities." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 761. "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 761.61(a) and (c). "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions; PCB Remediation Waste." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 761.180. "General Records and Reports." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 1500-1508. "Protection of Environment." *Code of Federal Regulations*, National Environmental Policy Act.

43 CFR 7. "Protection of Archaeological Resources." *Code of Federal Regulations*, U.S. Department of Interior.

43 CFR 10. "Native American Graves Protection and Repatriation Act: Final Rule." *Code of Federal Regulations*, U.S. Department of Labor.

50 CFR 17, Subpart B. "Endangered and Threatened Wildlife and Plants; Lists." *Code of Federal Regulations*, U.S. Department of Interior.

36 FR 8921, May 13, 1971. Executive Order 11593, "Protection and Enhancement of the Cultural Environment." *Federal Register*.

61 FR 26771-26772, May 24, 1998. Executive Order 13007, "Indian Sacred Sites." *Federal Register*.

65 FR 37253. 2000. "Establishment of the Hanford Reach National Monument." Proclamation 7319 of June 9, 2000, by the President of the United States of America. *Federal Register*.

67 FR 40333, June 12, 2002. "Notice of Intent to Prepare a Comprehensive Conservation Plan and Associated Environmental Impact Statement for Hanford Reach National Monument/Saddle Mountain National Wildlife Refuge." *Federal Register*.

68 FR 10635, March 3, 2003. Executive Order 13287, "Preserve America." *Federal Register*.

69 FR 50178, August 13, 2004. "Notice of Intent to Prepare an Environmental Impact Statement for the Decommissioning of the Fast Flux Test Facility at the Hanford Site, Richland, Washington." *Federal Register*.

71 FR 5655, February 2, 2006. "Notice of Intent to Prepare the Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington." *Federal Register*.

71 FR 8569, February 17, 2006. "Extension of Scoping Period and Rescheduled Scoping Meetings for the Notice of Intent to Prepare the Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington." *Federal Register*.

71 FR 45996-46025, August 10, 2006. "10 CFR Parts 820 and 835; Procedural Rules for DOE Nuclear Activities and Occupational Radiation Protection; Proposed Rule." *Federal Register*.

American Indian Religious Freedom Act. 1978. Public Law 95-341, as amended, 42 USC 1996.

Antiquities Act. 1906. 34 Stat. 225, 16 USC 431-433.

Archaeological and Historic Preservation Act. 1974. Public Law 93-291, as amended, 16 USC 469-469c-2.

Archaeological Resources Protection Act. 1979. Public Law 96-95, as amended, 16 USC 470-470aa-mm.

Atomic Energy Act. 1954. Chapter 1073, 68 Stat. 919, 42 USC 2011 et seq.

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.

Comprehensive Environmental Response, Compensation, and Liability Act. 1980. Public Law 96-150, as amended, 94 Stat. 2767, 42 USC 9601 et seq. Accessed May 1, 2007, at http://www.epa.gov/region5/defs/html/cercla.htm.

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DOE Order 451.1B, Change 1. 2001. "National Environmental Policy Act Compliance Program – Change 1." U.S. Department of Energy, Washington, D.C.

DOE Order 5400.5. 1990. "Radiation Protection of the Public and the Environment." U.S. Department of Energy, Washington, D.C.

DOE P 141.1. 2001. "Department of Energy Management of Cultural Resources." U.S. Department of Energy, Washington, D.C.

DOE/RL-91-27, Rev. 1. 2000. *Hanford Facility Dangerous Waste Permit Application, 222-S Laboratory Complex*. U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-94-150, Rev. 0. 1994. *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington*. RE Fitzner and SG Weiss, Pacific Northwest Laboratory and CH2M HILL Hanford, Inc. for the U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-32, Rev. 0. 2000. *Hanford Site Biological Resources Management Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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6.0 Environmental Restoration and Waste Management Operations

J. P. Duncan

This section describes ongoing Hanford Site environmental cleanup and decommissioning activities. Included are discussions of cleanup operations, facility decommissioning activities, underground waste storage tanks, the construction of the Hanford Waste Treatment and Immobilization Plant, and research activities related to waste cleanup. Activities, accomplishments, and relevant issues are presented and resolutions are described.

6.1 Cleanup Operations

This section describes ongoing cleanup and remediation activities at the Hanford Site.

6.1.1 Soil and Groundwater Remediation Project

B. H. Ford

The U.S. Department of Energy (DOE) established the Groundwater/Vadose Zone Integration Project in 1997. On July 1, 2002, the project was transferred from the environmental restoration contractor, Bechtel Hanford, Inc., to Fluor Hanford, Inc. and designated as the Groundwater Remediation Project (now known as the Soil and Groundwater Remediation Project). The Soil and Groundwater Remediation Project team includes staff from Fluor Hanford, Inc.; CH2M HILL Hanford Group, Inc.; and Pacific Northwest National Laboratory, as well as support staff from other national laboratories and universities. The purpose of the Soil and Groundwater Remediation Project is to coordinate all projects at the Hanford Site involved in characterization, monitoring, and remediation of groundwater and vadose zone contamination, with the overall objective of protecting the Columbia River. Information on groundwater and vadose zone remediation systems in use in 2006 is summarized in Section 10.7.

6.1.2 Waste Site Investigations and Remediation Activities in the 200 Areas

L. R. Fitch

Remedial investigation/feasibility study activities continued during 2006 at waste sites in the 200 Areas. Work was performed within the characterization and regulatory framework defined in the *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program* (DOE/RL-98-28, Rev. 0). Work was performed at a number of operable unit groups, which were at various stages of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) remedial investigation/feasibility study process. The following summary provides a description of activities performed in 2006.

200-CW-1 Operable Unit. The 200-CW-1 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 cooling water from facilities such as the Plutonium-Uranium Extraction (PUREX) Plant and B Plant. In 2006, the 200-CW-1 Operable Unit was included in a Central Plateau soil-sites supplemental characterization activity. This activity was conducted by the Tri-Party agencies (Washington State Department of Ecology, U.S. Environmental Protection Agency [EPA], and the DOE). Data quality objectives workshops were conducted to determine specific additional characterization activities. Several supplemental remedial investigation activities are planned for fiscal year 2007, including using direct-push technology to install test pits and a borehole. Direct-push technology advances a hollow rod directly into the soil, allowing soil sample collection and/or monitoring.

Strontium-90, cesium-137, cadmium, mercury, lead, silver, and polychlorinated biphenyls (PCBs) were the major risk contributors identified for human and ecological receptors. Data from this supplemental investigation will be incorporated into Draft B of the feasibility study report (DOE/RL-2002-69, Draft A) and proposed plan (DOE/RL-2003-06,

Draft A) to be submitted per the *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement; Ecology et al. 1989) Interim Milestone M-015-38B, by May 31, 2009.

200-CS-1 Operable Unit. The 200-CS-1 Operable Unit consists of waste sites that received sewer wastewater containing chemicals from major plant facilities in both the 200-West and 200-East Areas. A remedial investigation/feasibility study work plan (DOE/RL-99-44, Rev. 0) was approved in 2000 that defines planned remedial investigation activities at four representative waste sites of the operable unit: the 216-S-10 pond, 216-S-10 ditch, 216-B-63 trench, and 216-A-29 ditch. Fiscal year 2005 activities focused on preparing a feasibility study and proposed plan that was issued to the Washington State Department of Ecology and the EPA in March 2006 (Tri-Party Agreement Milestone M-015-39B). A closure plan for the 216-A-29 ditch, closure/post-closure plans for the 216-S-10 pond and ditch and the 216-B-63 trench treatment, storage, and disposal facilities were submitted in fiscal year 2006 under Tri-Party Agreement Milestone M-020-39, in conjunction with the feasibility study and proposed plan. Draft B of the feasibility study for this operable unit is planned for submittal in fiscal year 2007.

200-CW-2, 200-CW-4, 200-CW-5, and 200-SC-1 Operable Units. The 200-CW-2, 200-CW-4, 200-CW-5, and 200-SC-1 consolidated operable unit group consists of waste sites that received cooling water, steam condensate, and chemical sewer waste from facilities in the 200-West Area, including the U Plant; powerhouse and laundry facilities; 242-S evaporator; Plutonium Finishing Plant and associated facilities; Reduction Oxidation (REDOX) Plant; T Plant; Plutonium-Uranium Extraction (PUREX) Plant; and the Waste Encapsulation and Storage Facility. The remedial investigation included pipeline sampling, geophysical logging of shallow drive-point casings, and characterization drilling to the water table to determine vadose zone contamination. Primary contaminants of concern identified included strontium-90, technetium-99, cesium-137, americium-241, plutonium isotopes, uranium, selenium, PCBs, magnesium, and nitrite. A feasibility study (DOE/RL-2004-24, Draft A) and proposed plan (DOE/RL-2004-26, Draft A) were issued to the regulatory agencies in October 2004 (Tri-Party Agreement Milestone M-015-40C). Revisions to the feasibility study and proposed plan will be initiated in fiscal year 2007. Discussions with the Tri-Party agencies are underway to determine what additional characterization information is required at this operable unit group. Feasibility study revisions are underway with a Draft B version due to the agencies on April 30, 2008 (Tri-Party Agreement Milestone M-015-40D).

200-TW-1, 200-TW-2, and 200-PW-5 Operable Units. The 200-TW-1 Operable Unit consists of waste sites, which are mostly cribs and trenches, that received waste associated with uranium recovery activities at the U Plant. The 200-TW-2 Operable Unit also consists of waste sites (mostly cribs and trenches) that received waste from decontamination processes at the B and T Plants. The 200-PW-5 Operable Unit waste sites received fission-product-rich wastes that were generated during the fuel-rod enrichment cycle and then released when the fuel elements were decladded or dissolved in sodium hydroxide or nitric acid. All activities in the 200-TW-1, 200-TW-2, and 200-PW-5 Operable Units were on hold in fiscal year 2006 because of continued emphasis on the remediation of the BC cribs and trenches area (the BC cribs and trenches area is included in the 200-TW-1 Operable Unit). The Tri-Party agencies felt the feasibility study for the 200-TW-1, 200-TW-2, and 200-PW-5 Operable Units was too complex and wanted to address a smaller subset of sites through the BC cribs and trenches area accelerated remediation project. The BC cribs and trenches area activity included conducting high-resolution resistivity geophysical characterization to better understand the extent of the mobile technetium-99 and nitrate contamination. Revisions to the 200-TW-1, 200-TW-2, and 200-PW-5 Operable Units feasibility study and proposed plan are scheduled to be initiated in fiscal year 2007.

200-PW-1, 200-PW-3, and 200-PW-6 Operable Units. The 200-PW-1 Operable Unit contains waste sites that received significant quantities of carbon tetrachloride and plutonium, as well as other contaminants associated with process waste from the Plutonium Finishing Plant. The 200-PW-3 Operable Unit waste sites received organic-rich waste from other separation facilities such as S Plant (reduction and oxidation separation process), A Plant (plutonium-uranium extraction process), U Plant (uranium recovery process), and the 201-C Building (hot semi-works

process). The 200-PW-6 Operable Unit waste sites received plutonium-rich waste from the Plutonium Finishing Plant complex. This operable unit group also includes the carbon tetrachloride in the vadose zone that has migrated beyond the boundaries of the waste sites. The work plan for the plutonium/organic-rich operable unit (200-PW-1, 200-PW-3, and 200-PW-6 Operable Units) was approved in 2004 (DOE/RL-2001-01, Rev. 1).

During 2003 and 2004, a borehole was installed at the 216-Z-9 trench (200-PW-1 Operable Unit); high levels of plutonium and carbon tetrachloride were found in the upper vadose zone at this borehole. The borehole was drilled to basalt and completed as a groundwater monitoring well. Characterization of carbon tetrachloride in the vadose zone was initiated in 2002, and work continued through 2006. Activities included passive vapor sampling, sampling of waste burial ground vent riser vapors, numerical simulations of carbon tetrachloride migration, assessment of carbon tetrachloride groundwater hot spots for potential sources, vapor and water sampling in existing wells, and soil-vapor sampling at waste sites or hot spot areas using direct pushes for vadose zone access. Highest carbon tetrachloride concentrations, located near known disposal sites (216-Z-1A and 216-Z-9), are being reduced by the interim-action soil-vapor extraction. Concentrations detected in areas away from known sites are considered to have no significant current or future groundwater impacts. In fiscal year 2006, a slant borehole was drilled under the 216-Z-9 trench and was completed as a soil-vapor extraction well; high levels of plutonium and carbon tetrachloride were found in the upper vadose zone at this borehole. A remedial investigation report (DOE/RL-2006-51, Draft A) was delivered to the Washington State Department of Ecology and the EPA for review in October 2006 (Tri-Party Agreement Milestone M-015-45A).

Field activities to evaluate whether carbon tetrachloride is present in the subsurface as a dense, nonaqueous phase liquid were initiated in 2004 for the DOE Richland Operations Office by Vista Engineering Technologies LLC and completed in 2006. Activities included drilling and sampling fine-grained subsurface layers, cross-well geophysical surveys, passive soil-vapor sampling, and soil-vapor sampling at the 216-Z-9 and 216-Z-1A waste sites (200-PW-1 Operable Unit) using direct pushes for vadose zone access. Fluor Hanford, Inc. and Vista Engineering Technologies LLC worked closely to coordinate field activities for the carbon tetrachloride investigation. The final report on the dense, nonaqueous phase liquid investigation was completed in October 2006 (DOE/RL-2006-58, Rev. 0).

200-PW-2 and 200-PW-4 Operable Units. Waste sites in the 200-PW-2 Operable Unit received uranium-rich condensate and process waste, primarily from waste streams generated at the U Plant, Reduction and Oxidation (REDOX) Plant, Plutonium-Uranium Extraction (PUREX) Plant, B Plant, and semi-works facilities. Waste sites in the 200-PW-4 Operable Unit received mostly process drainage, process distillate discharge, and miscellaneous condensates from the same facilities, including condensates from the S and A Tank Farms and 242-A evaporator. In 2006, data from the remedial investigation activities were incorporated into the feasibility study (DOE/RL-2004-85, Draft A) and proposed plan (DOE/RL-2004-86, Draft A), which were submitted to the Washington State Department of Ecology and the EPA in May 2006 (Tri-Party Agreement Milestone M-015-43C). Closure plans for several treatment, storage, and disposal units in these operable units were also submitted along with the feasibility study and proposed plan (Tri-Party Agreement Milestone M-020-33). During 2006, data quality objectives workshops were conducted to determine specific future characterization strategies. Direct pushes and three boreholes are planned for fiscal years 2008 and 2009. Draft B of the feasibility study is planned for December 2010.

200-LW-1 and 200-LW-2 Operable Units. Waste sites in the 200-LW-1 and 200-LW-2 Operable Units received two types of waste: 1) liquid waste resulting from 300 Area process laboratory operations that supported radiochemistry metallurgical experiments, and 2) liquid waste resulting mainly from laboratory operations in the 200 Areas that supported the major chemical processing facilities and equipment decontamination at T Plant. Field work was completed in fiscal year 2005 and consisted of installation of boreholes at three waste sites (216-T-28, 216-S-20, and 216-Z-7). The remedial investigation report (DOE/RL-2005-61, Draft A) was submitted to the regulatory agencies in February 2006 (Tri-Party Agreement Milestone M-015-46A). Drafts of the feasibility study and proposed plan were completed in fiscal year 2006, but were not submitted to the Washington State

Department of Ecology and the EPA because of the decision to perform additional characterization (Tri-Party Agreement Change Number M-15-06-02).

200-MW-1 Operable Unit. The waste sites in the 200-MW-1 Operable Unit consist mainly of cribs, French drains, and trenches that received moderate- to low-volume equipment decontamination waste and ventilation system waste, plus small-volume waste streams commonly disposed to French drains. The work plan for the 200-MW-1 Operable Unit was approved in 2002 (DOE/RL-2001-65, Rev. 0). Field work was initiated in 2004 and consisted of installing boreholes at two sites (216-U-3 and 216-T-33), installing an auger hole at one site (200-E-4), and excavating two test pits at one site (216-T-13). High contamination levels caused a borehole installation to be discontinued at the 216-A-4 crib in 2004. In 2006, a replacement borehole was drilled at the 216-A-4 crib and will be completed as a groundwater monitoring well in 2007. A direct push at the 200-E-102 trench was completed in 2006 and a remedial investigation report (DOE/RL-2005-62, Draft A) was submitted to the Washington State Department of Ecology and the EPA in April 2006 (Tri-Party Agreement Milestone M-015-44A). Contamination levels for the sites, with the exception of the 216-A-4 crib, were very low. Contaminants at the 216-A-4 crib included plutonium, americium-241, cesium-137, and strontium-90.

200-SW-1 and 200-SW-2 Operable Units. The remedial investigation/feasibility study work plan for the 200-SW-1 and 200-SW-2 Operable Units was initiated in 2003 and submitted to the regulatory agencies for review in December 2004 (Tri-Party Agreement Milestone M-013-00O). Following review, the Washington State Department of Ecology and the DOE entered into collaborative discussions on the path forward for the work plan, in an effort to address Washington State Department of Ecology's comments. An agreement was reached for the work plan revision that included two data quality objectives processes, research of historical information, and non-intrusive field activities prior to completing the next draft of the document. In fiscal year 2005, research of the historical information was initiated, a data quality objectives process that focused on further non-intrusive characterization activities was initiated, and surface geophysical surveys of eight burial grounds were completed. In fiscal year 2006, the data quality objectives process for non-intrusive work was completed (D&D-27257), and a sampling and analysis instruction was issued (D&D-28283). Non-intrusive characterization field work was completed in fiscal year 2006, including geophysical investigation, passive organic-vapor sampling, radiation surveys, and additional research of historical information. Conceptual site models are being revised based on historical and non-intrusive information, a second data quality objectives process was initiated in early fiscal year 2007 to identify intrusive data collection needs, and the 200-SW-1 and 200-SW-2 Operable Units work plan revision was initiated.

200-IS-1 and 200-ST-1 Operable Units. The 200-IS-1 Operable Unit consists primarily of pipelines, diversion boxes, catch tanks, and related structures used to transfer single-shell tank waste within and between the 200 Areas. These facilities are the responsibility of the tank farms (groupings of underground waste-storage tanks) contractor, CH2M HILL Hanford Group, Inc. Five *Resource Conservation and Recovery Act* (RCRA) treatment, storage, and disposal unit tanks belonging to Fluor Hanford, Inc. are also included in this operable unit: the 241-CX-70, 241-CX-71, 241-CX-72, 276-S-141, and 276-S-142 tanks. The 200-ST-1 Operable Unit consists of septic tanks and tile fields that potentially received minor quantities of radioactively contaminated liquid waste from showers, floor drains, and janitor sinks. A data quality objectives process was initiated in 2005 to identify characterization needs for completing the remedial investigation/feasibility study process for the 200-IS-1 Operable Unit pipelines. Planning for field work will be initiated in 2007 for the six process waste bins identified in the data quality objective process. A phased characterization approach using direct-push techniques or test pits, followed by boreholes if deeper contamination is found, is planned for fiscal year 2008. The phased approach will be documented in DOE/RL-2002-14, Rev. 1B (Tri-Party Agreement Milestone M-013-27).

BC Cribs and Trenches Area. The BC cribs and trenches area was identified for accelerated closure during 2003. Two boreholes were drilled in this area in fiscal year 2004. Evaluations of these boreholes were included in a feasibility study (DOE/RL-2004-66, Draft A) and proposed plan (DOE/RL-2004-69, Draft A) that were submitted to the Tri-Party agencies in May 2005. Comment resolution

was initiated in fiscal year 2005 and continued in fiscal year 2006. Geophysical characterization (high-resolution resistivity) was conducted to delineate the extent of anomalous soil conductivity believed to result from deep, mobile contamination that is primarily nitrate, sodium, and technetium-99. Preparations to "ground-truth" the high-resolution resistivity characterization data were initiated. Also, plans for an excavation-based treatability test were initiated, focusing on the near-surface contamination comprised primarily of cesium-137 and strontium-90.

Central Plateau Ecological Risk Assessment. Initiated in 2002, the Central Plateau Ecological Risk Assessment task is designed to evaluate the potential ecological risks associated with Central Plateau waste sites. The information obtained from this assessment will be used to support CERCLA decision making. The task includes compiling existing data and four phases of data collection and evaluation. In fiscal year 2002, a data evaluation report was initiated. In fiscal year 2004, an initial phase of data-quality objectives development and sample planning was conducted, followed by a second phase in fiscal year 2005. Sampling for Phases I and II was conducted in fiscal year 2005 and focused on characterizing background sites, a subset of CERCLA waste sites, and the BC Controlled Area. Phase III data-quality objectives development and sample planning activities were conducted in fiscal year 2006, along with the associated sampling in the non-waste site areas around the 200-East and 200-West Areas. Additional Phase III sampling was performed to fill data gaps observed in the Phase I and II characterization efforts and in two offsite reference site characterizations. Data from Phases I, II, and III will be compiled and evaluated in fiscal years 2007 and 2008 in the Final Ecological Risk Assessment report. This report will support the remedial investigation/feasibility study process for the Central Plateau.

6.1.3 Cleanup and Remediation Activities in the 100 Areas

This section describes cleanup and remediation activities occurring in the 100 Areas.

6.1.3.1 Remediation of Waste Sites in the 100 Areas

J. W. Golden and A. K. Smet

Full-scale remediation of waste sites in the 100 Areas began in 1996. Figure 1.0.1 shows the 100 Areas former-reactor region along the Columbia River. Remediation activities in 2006 were performed in multiple locations in the 100 Areas, including in the 100-B/C, 100-K, 100-N, 100-D, and 100-F Areas. Remediation activities included sampling to determine if suspected waste sites exceeded cleanup objectives, sampling to confirm that cleanup objectives had been met, physical excavation operations, waste sorting and segregation, waste sampling, waste treatment, waste disposal, backfill, and revegetation.

Waste sites vary in complexity and types of waste. Typical waste sites include waste burial grounds, liquid effluent waste sites, burn pits, retired septic systems, piping systems, and miscellaneous waste sites. The primary focus early in the cleanup process was to address waste sites receiving liquid waste because those sites generally contain significant quantities of contaminants and serve as potential sources for groundwater contamination.

Waste burial grounds and miscellaneous waste sites were the focus in 2006. Waste burial grounds require cleanup but also present a significant health and safety risk to workers due to incomplete disposal records, and the potential for discovering unknown material from past disposal practices. For example, unknown materials or containers with no marking or labeling could be discovered during cleanup that would require further characterization. Characterization of the unknown material is critical to ensure worker safety and the proper management of the waste for potential treatment and disposal. Discovery of an unknown material requires additional time and planning to ensure proper protective gear is used in the field when characterizing the material, and to verify that limits and controls identified in approved authorization documents—required by the DOE—are adequate for the work scope. If authorization documents do not adequately cover the material discovered, work is stopped until documentation can be revised and work safely restarted. Based on characterization results, additional waste treatment may be required before disposal.

Miscellaneous waste sites vary in the nature and extent of contamination and are generally smaller-sized areas compared to liquid-waste disposal sites and waste burial grounds. Sampling requirements for determining if a miscellaneous waste site requires cleanup or is in compliance with post-cleanup goals can vary significantly from one waste site to another. Therefore, each site requires a specific sampling instruction. Many of the miscellaneous liquid effluent waste sites and waste burial grounds are similar and can use a template sampling plan or instructions.

The waste sites in the 100 Areas are authorized for remediation activities through the issuance of records of decision that have been approved by the EPA, the DOE, and the Washington State Department of Ecology. Additionally, a few waste sites are authorized for closure (i.e., cleanup) through issuance of a closure plan approved by the DOE and the Washington State Department of Ecology if the action is performed under RCRA regulations and in accordance with the Hanford Facility RCRA Permit (Ecology 1994). Waste generated from the cleanup of these waste sites is disposed of in Hanford's Environmental Restoration Disposal Facility located in the 200 Areas. This centralized disposal facility is the primary disposal pathway, but other disposal options are available, if necessary, should the material not meet the waste acceptance criteria for the facility.

During 2006, a total of 356,947 metric tons (393,548 tons) of contaminated soil from the 100 Areas remediation activities were disposed of at the Environmental Restoration Disposal Facility. Quantities and respective locations are as follows:

- 122,115 metric tons (134,637 tons) from the 100-B/C Area
- 53,587 metric tons (59,082 tons) from the 100-K Area
- 74 metric tons (82 tons) from the 100-N Area
- 180,947 metric tons (199,501 tons) from the 100-F Area
- 223 metric tons (246 tons) from the 100-D Area.

6.1.3.2 K Basins Closure Activities

M. S. Gerber

Cleanout of the K Basins was managed in 2006 by Fluor Hanford, Inc. in the K Basins Closure Project. The K Basins are two indoor, concrete pools attached to the now-closed K-East and K-West Reactors (Figure 6.1.1). For nearly

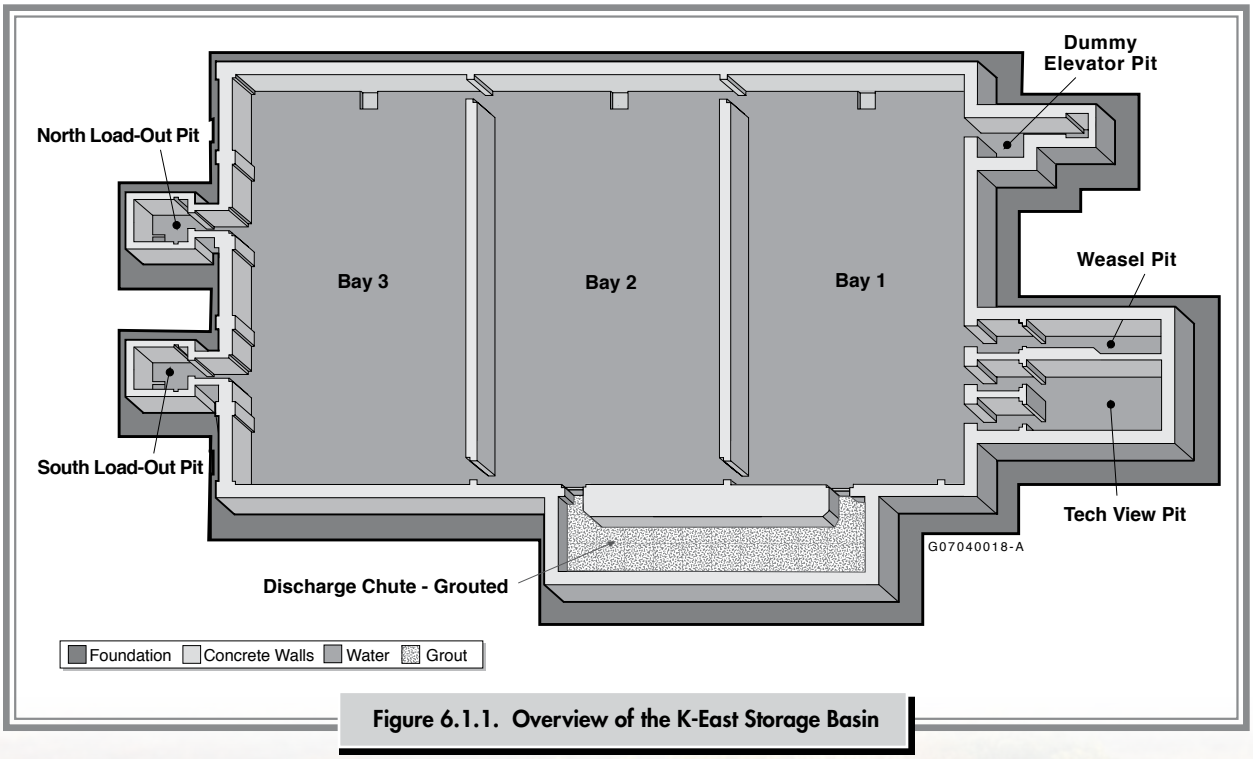

Figure 6.1.1. Overview of the K-East Storage Basin

30 years, the basins stored 2,100 metric tons (2,300 tons) of Hanford N Reactor spent fuel and a small quantity of slightly irradiated single-pass reactor fuel (fuel from older Hanford Site reactors). The fuel was removed in a major cleanup project that ended in October 2004.

Corrosion of the fuel during storage left behind up to 53.8 cubic meters (70.35 cubic yards) of sludge. There were up to 11.2 cubic meters (14.65 cubic yards) in the K-West Basin and 42.6 cubic meters (55.7 cubic yards) in the K-East Basin. Sludge is a non-homogeneous mixture of debris such as windblown sand and environmental particulates, fragments of concrete from the basin walls, corrosion products from fuel canisters and fuel racks, fuel cladding pieces, tiny bits of corroded uranium fuel (uranium oxides, hydrates, and hydrides), ion-exchange resin beads, PCBs, and fission products. Several different forms of sludge exist in the K Basins, based on the basin, canister type, and pit location where the particular sludge was found. For the purposes of differentiating spent nuclear fuel and debris from sludge, any material that is less than or equal to 0.64 centimeter (0.25 inch) in diameter is considered to be sludge.

In addition, the K Basins contained more than 272 metric tons (300 tons) of debris (solid nuclear waste) when the fuel removal project ended. The debris included over 200 fuel racks—weighing at least 136 kilograms (300 pounds) apiece—in each basin. It also included extensive lengths of hoses, hundreds of pieces of large and small equipment and tools, thousands of canisters and lids that formerly held the fuel, and a variety of other miscellaneous debris. The K-West Basin held more debris than the K-East Basin, both because the fuel canisters and lids from the K-East Basin had all been transferred there, and because much of the fuel retrieval system installed in the K-West Basin in the late 1990s to handle and process the fuel is now debris.

During 2006, the Fluor Hanford, Inc. K Basins Closure Project made the following progress in cleaning out the K Basins:

- Grappled, washed, and loaded out more than 272 metric tons (300 tons) of debris and fuel racks from both K Basins. The debris and fuel racks were packaged and readied for shipment to the Hanford Site's Environmental Restoration Disposal Facility as low-level nuclear waste. Waste shipments from the K Basins to the Environmental Restoration Disposal Facility were ongoing throughout the year.
- Completed pumping and containerizing bulk sludge in the K-East Basin, finishing the last 18% of sludge collection in 2006.
- Completed installing, testing, and starting up a special Hose-in-Hose Transfer System to transfer sludge collected in tanks in the K-East Basin to the K-West Basin. By the end of 2006, about 4 cubic meters (6 cubic yards) of sludge had been transferred to K-West Basin through the system.
- Worked with a subcontractor to complete the design for the main portion of the Sludge Treatment System that will treat the bulk of the K Basins sludge, and began procuring fabrication of some system components.
- Began modifications to the Cold Vacuum Drying Facility in the 100-K Area to prepare for sludge treatment.
- Completed readiness and started operating the Floor and Pit Sludge Retrieval System in the K-West Basin.
- Completed treatment of a small, distinct subset of sludge from one area of the K-East Basin – the North Load-Out Pit – at T Plant.

6.1.3.3 DOE Richland Operations Office Progress on Defense Nuclear Facilities Safety Board Recommendations

S. M. Hahn

The DOE Richland Operations Office made progress in 2006 on recommendations from the Defense Nuclear Facilities Safety Board.

The Defense Nuclear Facilities Safety Board Recommendation 2000-1 (DNFSB 2001) has four open commitments related to the K Basins. These include 1) completing containerization of the bulk sludge from the K Basins by July 2007; 2) completing sludge transfer from the K-East Basin by May 2007; 3) removing containerized sludge from the K-West Basin and treating it to meet applicable waste acceptance criteria by November 30, 2009; and 4) completing the removal of back-flushed filter sludge from the K-East North Load-Out Pit by May 2007.

The DOE Richland Operations Office made progress on its commitments for Defense Nuclear Facilities Safety Board 2004 recommendations (DNFSB 2004a, 2004b) by completing feedback, improvement, and work planning assessments. In addition, the DOE Richland Operations Office and its prime contractors implemented DOE Order 226.1, "Implementation of Department of Energy Oversight Policy" in September 2006. The open DOE Richland Operations Office commitment to complete Defense Nuclear Facilities Safety Board Recommendation 2004-2 requires a review of the safety classification of confinement ventilation systems and their safety functions, and an assessment of the feasibility of upgrading those systems to current codes and standards (DNFSB 2004b). During 2006, the DOE Richland Operations Office completed a review of the proposed confinement ventilation systems at the Cold Vacuum Drying Facility, T Plant, Waste Receiving and Processing Facility, and Waste Encapsulation Storage Facility. An assessment on the need and feasibility of upgrading these confinement ventilation systems will follow in 2007.

The open DOE Richland Operations Office commitment to complete Defense Nuclear Facilities Safety Board Recommendation 2002-3 requires review of current administrative controls to determine the need for specific controls (DNFSB 2002). Training was completed in late 2005. Review of the Plutonium Finishing Plant and Waste Management Documented Safety Analyses and Controls was completed in 2006, and example specific administrative controls were developed and reviewed by the DOE Richland Operations Office. Final development of a complete set of specific administrative controls will be included in the next annual update to both documented safety analyses.

6.1.3.4 DOE Office of River Protection Progress on Defense Nuclear Facilities Safety Board Recommendations

C. M. Fetto

The DOE Office of River Protection made progress on its commitments related to recommendations from the Defense Nuclear Facilities Safety Board. Throughout the year, DOE and Bechtel National, Inc. staff met with Defense Nuclear Facilities Safety Board representatives regarding the following topics for the Waste Treatment and Immobilization Plant:

- Waste treatment and immobilization plant construction status
- Cost, schedule, and baseline revisions
- Authorization basis maintenance activities
- Integrated Safety Management System implementation and federal oversight
- Implementation of revised ground-motion spectra in seismic analysis
- Borehole project
- Industry external flow sheet review team activities
- Hydrogen accumulation in pipes and ancillary vessels
- Anti-foam agents effect on hydrogen generation
- Fire coatings on the Waste Treatment and Immobilization Plant structural steel
- Ultrafiltration system design
- Alternative ion-exchange resin development for removal of cesium from tank waste.

DOE and CH2M HILL Hanford Group, Inc. staff met with Defense Nuclear Facilities Safety Board representatives throughout 2006 to discuss the following topics:

- Retrieval of wastes from single-shell tanks
- Double-shell waste tank integrity
- Demonstration bulk vitrification system
- Vapor issue resolution
- Tank farm Integrated Safety Management System
- Authorization basis maintenance activities
- Integrated Disposal Facility construction
- Tank farm RCRA corrective action project.

In 2006, the DOE Office of River Protection made progress on its commitments for the Defense Nuclear Facilities Safety Board 2004 recommendations (DNFSB 2004a, 2004b). As part of the DOE's response to Defense Nuclear Facilities Safety Board Recommendation 2004-1, *Oversight*

of Complex, High-Hazard Nuclear Operations (DNFSB 2004a), the DOE committed to improving the effectiveness of Integrated Safety Management Systems at all sites. The DOE Office of River Protection submitted to the DOE Office of Environmental Management, and received approval of, a quality assurance plan consistent with the requirements of DOE Order 414.1C, "Quality Assurance." In addition, an improvement initiative was undertaken to incorporate the human-performance principles developed by the Institute of Nuclear Power Operations for the nuclear industry into the DOE's Integrated Safety Management Systems. At the Hanford Site, the DOE Office of River Protection, the DOE Richland Operations Office, and the prime contractors have taken the DOE Office of Environmental Management complex lead to pilot the human-performance initiative, and to subsequently share the results and lessons learned with other DOE sites. The goal of this initiative is to improve key safety culture approaches; e.g., "investigations focus on organization processes, not persons" and using a "no-fault approach to error" such that adversarial barriers are not created and, instead, safety becomes a *shared* experience between labor and management.

In response to Defense Nuclear Facilities Safety Board recommendation 2004-2, *Active Confinement Systems* (DNFSB 2004b), the DOE committed to review the safety classification of current confinement ventilation systems and their safety functions, and assess the feasibility of upgrading those systems to current codes and standards. During 2006, the DOE Office of River Protection completed a review of the proposed confinement ventilation systems at the tank farms and the Waste Treatment and Immobilization Plant.

6.1.3.5 Revegetation of Washington Closure Hanford LLC's Remediated Waste Sites in the 100 Areas

A. L. Johnson

Washington Closure Hanford LLC's Field Remediation project revegetated several remediated and backfilled waste sites in the 100-B/C, 100-K, and 100-N Areas. The remediated sites in the 100-B/C and 100-K Areas were revegetated in the spring of 2006 while the 100-N Area site was planted in the winter of 2006. The 100 Areas sites were planted with native grass seed and sagebrush seedlings propagated from seed collected at the Hanford Site.

6.1.4 Remediation of Waste Sites in the 300 Area

M. L. Proctor, S. Parnell, and A. K. Smet

Full-scale remediation work began in the 300 Area in 1997 and focused on the 300-FF-1 Operable Unit waste sites and several 300-FF-2 Operable Unit waste sites. Remediation of the 300-FF-1 Operable Unit waste sites was completed in February 2004, including backfill and revegetation.

Remediation efforts in 2006 focused on the 300-FF-2 Operable Unit waste sites. The 300-FF-2 Operable Unit record of decision (EPA 2001) authorized remediation activities for the 300-FF-2 Operable Unit. Remediation for the 300-FF-2 Operable Unit began in September 2002. Remediation activities included sampling to determine if suspected waste sites exceeded cleanup objectives; sampling to confirm that cleanup objectives were met; conducting physical excavation operations; sorting and segregating waste; sampling, treating, and disposing of waste; and backfilling and revegetating affected sites.

Waste burial grounds require cleanup but also present a significant health and safety risk to workers due to incomplete waste-disposal records and the potential for discovering unknown material from past disposal practices. This unknown material may require further characterization. Characterization is critical to ensure worker safety and proper management of waste for potential treatment and disposal. Discovery of unknown material requires additional time and planning to ensure proper protective gear is utilized in the field when characterizing the material, and to verify that limits and controls identified in approved work authorization documents (as required by the DOE) are adequate for the work scope. If work authorization documents do not adequately cover the material discovered, work is stopped until the documents can be revised and work can be safely restarted. Based on the characterization results, additional waste treatment may be required before disposal.

The 300-FF-2 Operable Unit waste sites are authorized for remediation activities through a record of decision

approved by the EPA, the DOE, and the Washington State Department of Ecology (EPA 2001). Waste generated from the cleanup of these waste sites is disposed of at the Hanford Site's Environmental Restoration Disposal Facility located in the 200 Areas; the Waste Isolation Pilot Plant in Carlsbad, New Mexico; and other disposal facilities approved by the EPA. The Environmental Restoration Disposal Facility is discussed in Section 6.3.3.6.

A total of 49,035 metric tons (54,063 tons) of contaminated soil from the 300-FF-2 Operable Unit was disposed of at the Environmental Restoration Disposal Facility in 2006. No waste was shipped to the Waste Isolation Pilot Plant.

The 618-10 burial ground, located just west of Route 4 South, operated from 1954 to 1963 and is approximately 2.1 hectares (5.2 acres) in size. The 618-11 burial ground, located close to the Energy Northwest nuclear power plant, was operated from 1962 to 1967 and is approximately 3.5 hectares (8.6 acres) in size. Both burial grounds received waste including transuranic material from the 300 Area laboratory facilities. The burial grounds consist of multiple trenches, vertical pipe units, and caissons.

Significant challenges for remediation are present at the 618-10 and 618-11 burial grounds. In August 2005, responsibility for remediating these two waste sites was transferred from Fluor Hanford, Inc. to Washington Closure Hanford LLC. After the transfer, Washington Closure Hanford LLC began developing a design solution for the sites, evaluating waste removal and packaging technologies and disposal pathways to determine the most cost-effective methods. The design solution was submitted to the DOE on December 31, 2006. The DOE will evaluate the design solution and make a determination within 90 days of submittal whether to proceed with the remediation.

Revegetation of Remediated Waste Sites in the 300 Areas

A. L. Johnson

Washington Closure Hanford LLC's Field Remediation project staff revegetated several remediated and backfilled waste sites in the 300 Area in the winter of 2006. The 300 Area sites are within a portion of the 300 Area that has been designated for future industrial use, and were planted with a mix of crested and bluebunch wheatgrasses.

6.2 Facility Decommissioning Activities

This section provides information about the transition of Hanford Site facilities from operation to stabilization, surveillance and maintenance, and decommissioning. Decommissioning activities include the interim safe storage of plutonium-production reactors and the decommissioning of ancillary reactor facilities.

6.2.1 Facility Decommissioning in the 200 Areas (Central Plateau)

This section provides information about the transition and decommissioning of facilities in the 200 Areas.

6.2.1.1 Plutonium Finishing Plant

M. S. Gerber

During 1949, the Plutonium Finishing Plant began processing plutonium nitrate solutions into metallic plutonium for shipment to nuclear weapons-production facilities. Operation of this plant continued into the late 1980s. In 1990, the DOE issued a shutdown order for the Plutonium Finishing Plant, and in 1996, authorized deactivation and transition of the plutonium-processing portions of the facility in preparation for decommissioning.

In 2004, Fluor Hanford, Inc. workers at the Plutonium Finishing Plant complex completed a large and multifaceted effort to stabilize, immobilize, re-package, and/or properly dispose of nearly 18 metric tons (19.8 tons) of plutonium-bearing materials in the plant. The workers then turned their full energies to decontaminating and deactivating the processing facilities, while still providing for the safe and secure storage of nuclear materials until final disposition.

Significant accomplishments achieved by Fluor Hanford, Inc. at the Plutonium Finishing Plant during 2006 included the following:

- Cleaned out contaminated equipment from 19 plutonium processing gloveboxes and "hoods" (open-faced enclosures used for working with plutonium). This downgraded them to low-level waste status.
- Completed cleanout of four of the five cells and tanks beneath the 241-Z Liquid Waste Treatment Facility.
- Completed cleanout and demolition of the 232-Z Incinerator Building (in July 2006).
- Decontaminated and packaged for shipment all of the "product solution containers" (highly contaminated drums that once held plutonium nitrate) stored beneath the 234-5Z Facility. A total of 294 out of 644 product solution containers were decontaminated and packaged in 2006. All containers were shipped out of the Plutonium Finishing Plant complex as waste. A total of 326 containers were shipped out in 2006, and 318 containers were shipped out prior to 2006.
- Removed five non-contaminated ancillary buildings within the Plutonium Finishing Plant complex.
- Re-surfaced and repaired the 8,360-square-meter (90,000-square-foot) roof of the main 234-5Z Building.
- Completed other facility "life-extension" upgrades, including fire system improvements, replaced or refurbished large supply and exhaust fans in the 234-5Z Building, and improved electronic controls in other facilities.
- Vented the major process vacuum system in the 234-5Z Building to prevent hydrogen buildup.

- Installed more than 1,400 "pie-plates" (metal and plastic covers) to contain contamination in 100 glove-boxes in Plutonium Finishing Plant facilities until decontamination and dismantlement occurs.
- Packed and disposed of nearly 800 fuel pins as waste and shipped 87 sodium-bonded fuel pins to the Fast Flux Test Facility (for trans-shipment to the Idaho National Laboratory). Fuel pins are tubes of zirconium alloy that contain fuel pellets of enriched uranium. Several fuel pins are bundled together to form a fuel rod. Fuel rods exposed in a sodium-cooled reactor can bond and the bonding must be treated and stabilized before the rods can be disposed of.
- Completed calibrations of and placed into service a large "Super High Efficiency Neutron Counter" to accurately measure large shipments of highly contaminated materials leaving the Plutonium Finishing Plant.
- Completed an engineering evaluation/cost analysis for all waste sites and structures in the ground below the Plutonium Finishing Plant.

6.2.1.2 Surveillance, Maintenance, and Deactivation Activities in the 200 Areas and on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit

G. J. LeBaron

Disposition of 200 Areas facilities includes the surveillance, maintenance, and deactivation of buildings and waste sites in the 200-East, 200-West, and 200-North Areas, and on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit. Facilities include interim-status RCRA treatment, storage, and disposal units awaiting closure, the canyon facilities (Plutonium-Uranium Extraction [PUREX] Plant, B Plant, Reduction Oxidation [REDOX] Plant, and U Plant), two operating major air emission stacks, and three operating minor emission stacks.

Surveillance, maintenance, and decontamination or stabilization of over 500 waste sites, including former waste-disposal cribs, ponds, ditches, trenches, unplanned release sites, and waste burial grounds continued in 2006. Periodic surveillances, radiation surveys, and herbicide applications were performed at these sites and timely responses to identified problems were initiated. The overall objective was to maintain these sites in safe and stable configurations and prevent contaminants at these sites from spreading in the environment.

6.2.1.3 Investigating the Potential for Using the 200 Areas Chemical Separations Plants as Waste-Disposal Facilities

J. R. Robertson

The Canyon Disposition Initiative was created to investigate the potential for using the five canyon buildings (B Plant, T Plant, U Plant, Plutonium-Uranium Extraction [PUREX] Plant, and the Reduction Oxidation [REDOX] Plant) at the Hanford Site as disposal facilities for Hanford Site remediation waste, rather than demolishing the structures. The U Plant was selected as the pilot project for the Canyon Disposition Initiative. The remaining canyon buildings are to be addressed on a case-by-case basis, building on previous canyon disposition work.

Planning and sampling activities to support preparation of a CERCLA feasibility study for implementation of the Canyon Disposition Initiative at U Plant began in the mid-1990s. In December 2004, the Canyon Disposition Initiative (221-U Facility) final feasibility study (DOE/RL-2001-11, Rev. 1) and the associated proposed plan (DOE/RL-2001-29, Rev. 0) were released for public review. These documents examine five alternatives for the remediation of the 221-U Facility: 1) no action, 2) full removal and disposal, 3) entombment with internal waste disposal, 4) entombment with internal and external waste disposal, and 5) close in place–collapsed structure. In the fall of 2005, the EPA issued the 221-U Facility (Canyon Disposition Initiative) record of decision (DOE et al. 2005), selecting the close in place–collapsed structure alternative. In accordance with the record of decision, process equipment already in the plant will be consolidated into the below-ground plant process cells; the cells, galleries, and other void spaces will be backfilled with grout; the exterior walls and roof will be collapsed in place; and the site will be covered with a barrier.

Following issuance of the U Plant record of decision, the DOE began conceptual design work for implementation of the record of decision. A number of engineering studies to

support this undertaking have either been issued or are in the development stage. In December 2006, the DOE issued the *Remedial Design/Remedial Action Work Plan for the 221-U Facility* (DOE/RL-2006-21, Draft A) for review by the regulatory agencies.

No waste will be imported into U Plant as a part of the remedial action. While U Plant remediation is a prototype for the remaining canyon buildings, remedial action decisions will be reached independently for each of the remaining canyon buildings, taking into account the significant differences between each building. Planning to support development of a remedial decision on the Plutonium-Uranium Extraction (PUREX) Plant was initiated in the fall of 2006.

6.2.2 Decommissioning of 300 Area Facilities

D. M. Yasek

During 2006, deactivation, decontamination, decommissioning, and demolition activities in the 300 Area aggressively focused on removing physical barriers to performing remedial actions in the 300-FF-2 Operable Unit. These activities were conducted as non-time critical removal actions under CERCLA in accordance with Action Memorandum #1 for the 300 Area (DOE and EPA 2005). The following 300 Area buildings were demolished during 2006:

- 303A Storage Building
- 303B Storage Building
- 303C Material Evaluation Laboratory
- 303E Storage Building
- 303F Pump House
- 303G Storage Building
- 303J Material Storage Building
- 303M Uranium Oxide Facility
- 304/304A Uranium Concentration Facility/Change Room
- 305 Engineering Testing Facility
- 305B Hazardous Waste Storage Facility
- 305BA Boiler Annex
- 311 Tank Farm (aboveground acid waste storage tanks)
- 333 N Fuels Building
- 334 Process Sewer Monitor Facility
- 334A Waste Acid Storage Building
- 334 Tank Farm (aboveground acid waste storage tanks)
- 377 Geotechnical Engineering Laboratory
- 3225 Bottle Dock
- 3705 Photography Building
- 3707D Information Services Building
- 3708 Radio-Analytical Laboratory
- 3711 Maintenance Storage Building
- 3712 Storage Building
- 3713 Carpenter Shop
- 3715 Spare Parts Warehouse
- 3716 Storage Building
- 3717 Spare Parts Warehouse
- 3717B South Maintenance Facility
- 3722 Fabrication Shop
- 3746D Technical Services Annex
- MO-026/MO-052 Mobile Office Trailers.

In addition to field activities, several planning efforts were underway to support future removal actions in the 300 Area. Two separate engineering evaluations and subsequent action memoranda were issued to address 300 Area inactive facilities, as well as facilities that do not have long-term missions. Facility deactivation, characterization, and demolition planning is ongoing for many other buildings located in the 300 Area.

6.2.3 Deactivation of 400 Area Facilities

M. T. York

The Fast Flux Test Facility is a DOE owned, formerly operating, 400-megawatt (thermal) liquid-metal cooled (sodium) research and test reactor located in the 400 Area. Built in the late 1970s, the original purpose was to develop and test advanced fuels and materials for the Liquid Metal

Fast Breeder Reactor Program, and to serve as a prototype facility for future Liquid Metal Fast Breeder Reactor Program facilities; other missions were subsequently pursued. The Fast Flux Test Facility operated from April 1982 to April 1992 and provided the nuclear industry with significant advances in fuel performance, medical isotope production, material performance, and passive and active safety systems testing. The reactor was placed in a standby mode in December 1993. After multiple studies, a final decision was made to complete facility deactivation, including removing all nuclear fuel, draining the sodium systems, and deactivating systems and equipment to place the facility in a low-cost, long-term surveillance and maintenance condition by September 2009.

During 2006, fuel removal from the 400 Area Property Protected Area continued. The remaining mixed-oxide fuel assemblies were removed, processed, and placed in interim spent nuclear fuel storage casks. Two interim storage casks were transferred to the 200 Areas Interim Storage Area at the end of 2005, and eight interim storage casks with fuel were transferred to the 200 Areas Interim Storage Area in 2006. Three empty interim storage casks remain in storage at the 400 Area Interim Storage Area. Fuel removal has allowed the Fuel Storage Facility to be de-energized and all water sources removed and capped, placing the facility in a "cold and dark" condition. Re-certification of the T-3 shipping cask continued in 2006. The T-3 cask will be used in 2007 for transferring sodium-bonded fuel pins to the Idaho National Laboratory. These T-3 cask shipments will remove the last of the fuel pins from the Fast Flux Test Facility.

Draining of bulk-liquid sodium metal from the Fast Flux Test Facility continued in 2006. One hundred and nine core component pots (tubes used to move core components between the interim-decay storage vessel and the interim examination and maintenance cell) were removed from the interim-decay storage vessels and placed in two storage boxes. Each storage box contains about 757 liters (200 gallons) of contaminated sodium. These boxes were declared hazardous mixed-waste and required establishment of a RCRA storage unit. Temporary authorization for a greater-than 90-day storage area was issued by the Washington State Department of Ecology. An application for a RCRA Treatment, Storage, and Disposal container storage area, designated as the 400 Waste Management Unit, was submitted to the DOE in November 2006. The removal of the core component pots allowed the remaining sodium in interim-decay storage vessels to be successfully drained and transferred to the Sodium Storage Facility. Additional sodium will be removed in 2007 by draining nine main heat-transport system valves. Following drainage of the main heat-transport system valves, a total of approximately 920,000 liters (243,000 gallons) of liquid sodium will have been drained from Fast Flux Test Facility. This sodium will be converted to sodium hydroxide for later use by the DOE Office of River Protection (i.e., Waste Treatment and Immobilization Plant). The remaining residual sodium will be converted to sodium hydroxide at the Fast Flux Test Facility or removed during decommissioning.

Workers are continuing to remove and/or replace transformers containing PCBs as their need decreases. Materials were removed and equipment dismantled in the Interim Examination and Maintenance Cell Training Facility in the 309 Building in preparation for demolishing the building in the future.

6.2.4 Decommissioning of Facilities in the 100 Areas

D. M. Yasek

During 2006, 100 Areas deactivation, decontamination, decommissioning, and demolition activities focused on the 100-N Area. These activities were conducted as non-time critical removal actions under CERCLA. The following buildings in the 100 Areas were demolished during 2006:

- 108N Chemical Unloading Facility
- 119N/NA Air Sampling/Monitoring Buildings
- 151N Electrical Substation
- 153N Switchgear Building
- 163N/183N Demineralizer Plant and Water Filter Plant
- 166N Oil Storage Building
- 181NC Sampling/Skid Station
- 183NA Pump House
- 184NB Air Handler Building
- 184NC Air Handler Annex Building

- 1314N Liquid Disposal Building
- 1331N Storage Structure
- 1515N Multi-Craft Shop
- 1516N Carpenter Shop
- 1517N Painter Shop
- 1518N Electrical Shop
- 1519N Pipefitter Shop
- 1701N Gate House Trailer
- 1707N Boat House
- 1715N Oil Tank
- 1723N Warehouse
- 1723NX Laydown Storage Area
- 1802N Steam Pipe and Trestle
- MO-050/MO-200/MO-358/MO-561/MO-900/MO-913 Mobile Office Trailers.

In addition to field activities, several planning efforts were underway to support future actions in the 100 Areas. Although clean-out activities are still ongoing at the K Basins, an engineering evaluation/cost analysis was issued to address interim safe storage of the 105-KE and 105-KW Reactors and demolition of 100-K Area ancillary facilities. The action memorandum and associated CERCLA-planning documents for the 105-KE and 105-KW Reactors and the 100-K Area ancillary facilities are scheduled to be issued in 2007 to support the interim safe storage of the 105-KE and 105-KW Reactors by September 2011, in accordance with Tri-Party Agreement Milestone M-93-22. A conceptual design report for N Reactor interim safe storage was issued in August 2006 (WCH-00093) to support Tri-Party Agreement Milestone M-93-19, which required submittal of a storage design report by September 2009. Planning for N Reactor (105-N and 109-N buildings) interim safe storage continues.

6.3 Waste Management Operations

This section provides information about liquid and solid waste management at the Hanford Site.

6.3.1 Waste Classifications

D. L. Dyekman

Hanford Site cleanup operations result in the generation of non-regulated, radioactive, non-radioactive, mixed, or dangerous waste. Radioactive waste is categorized as transuranic, high-level, and low-level. Mixed waste is a radioactive waste that also has a dangerous waste component. Dangerous waste contains hazardous constituents regulated under Washington State's "Dangerous Waste Regulations" in WAC 173-303.

Radioactive and mixed waste is currently handled in several ways. High-level waste is stored in large underground single- and double-shell tanks, as well as in capsules. Low-level waste is stored in either the underground waste-storage tank system, on storage pads, or is buried. The method used to store 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 (as defined in 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-2006-13, Rev. 0). Dangerous waste is treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous waste generated at the site is also shipped offsite for disposal or destruction. Some types of dangerous waste, such as used lead-acid batteries and used aerosol products (e.g., spray paint), are shipped offsite for recycling.

Non-regulated waste is waste that does not contain hazardous or radioactive substances. Non-regulated waste generated at the Hanford Site historically was disposed of at the Hanford Site. Beginning in 1999, non-regulated waste including refuse, asbestos-containing waste, and drummed non-hazardous waste has been disposed of at municipal or commercial solid-waste disposal facilities. Since 1996, medical waste has been shipped to a commercial medical waste treatment and disposal facility.

Non-dangerous waste originates at a number of areas across the Hanford 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 Columbia River water, failed and broken equipment and tools, air filters, uncontaminated used gloves and other clothing, and certain chemical precipitates (such as oxalates). Non-dangerous demolition waste from 100 Areas decommissioning projects is buried in situ or in designated disposal sites in the 100 Areas.

6.3.2 Solid Waste Inventories

D. L. Dyekman

Solid waste program activities are regulated by RCRA and the *Toxic Substances Control Act*, as discussed in Section 5.1.

Solid waste quantities generated onsite or received from offsite sources, and disposed of at the Hanford Site from 2002 through 2006 are shown in Tables 6.3.1 and 6.3.2. Quantities of dangerous waste shipped offsite from 2002 through 2006 are shown in Table 6.3.3.

Hanford Site solid waste management is discussed in Section 6.3.3.

Table 6.3.1. Quantities of Solid Waste[a] Generated on the Hanford Site, 2002 Through 2006, kg (tons)

Waste Category	2002	2003	2004	2005	2006
Mixed	1,025,000 (1,130)	421,000 (464)	144,512 (159)	349,416 (385)	315,188 (347)
Radioactive	1,588,000 (1,750)	758,000 (836)	906,591 (999)	1,188,212 (1,310)	465,340 (513)

(a) Solid waste includes containerized liquid waste.

Table 6.3.2. Quantities of Solid Waste[a] Received on the Hanford Site from Offsite Sources, 2002 Through 2006, kg (tons)

Waste Category	2002	2003	2004	2005	2006
Mixed	112,000 (123)	667,000[b] (735)	255,690[b] (282)	190,020[b] (209)	152,487[b] (168)
Radioactive	1,517,000 (1,670)	407,000 (449)	519,609 (573)	83,123 (92)	71,244 (79)

(a) Solid waste includes containerized liquid waste. Solid waste quantities do not include U.S. Navy reactor compartments.
(b) Total includes Hanford-generated waste treated by an offsite contractor and returned as newly generated waste.

Table 6.3.3. Quantities of Dangerous Waste[a] Shipped Off the Hanford Site, 2002 Through 2006, kg (tons)

Waste Category	2002	2003	2004	2005	2006
Containerized	78,400[b] (86)	83,500[b] (92)	75,296[b] (83)	71,601[b] (79)	18,700[b] (21)
	3,500[c] (4)	91,800[c] (101)	49,560[c] (55)	61,422[c] (68)	33,285[c] (37)
Bulk Solids	0	0	0	0	0
Bulk Liquids	50,700 (56)	48,400 (53)	35,057 (39)	49,154 (54)	917 (1)
Total	132,500 (146)	224,000 (247)	159,913 (176)	182,177 (201)	52,902 (58)

(a) Does not include *Toxic Substances Control Act* waste.
(b) Dangerous waste only.
(c) Mixed waste (radioactive and dangerous).

6.3.3 Solid Waste Management

Solid waste management includes the treatment, storage, and/or disposal of solid waste produced as a result of Hanford Site operations or received from offsite sources authorized by the DOE to ship waste to the site. The following sections contain information regarding specific waste treatment, storage, or disposal locations at the Hanford Site.

6.3.3.1 Central Waste Complex

D. E. Faulk

Waste is received at the Central Waste Complex in the 200-West Area from sources at the Hanford Site and any offsite sources that are authorized by the DOE to ship waste to the Hanford Site for treatment, storage, and disposal. Ongoing cleanup, research, and development activities on the Hanford Site 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 PCBs. Current volume of wastes stored totals approximately 6,950 cubic meters (9,100 cubic yards).

The Central Waste Complex can store as much as 20,796 cubic meters (27,200 cubic yards) of low-level mixed waste and transuranic waste. This capacity is adequate to store the projected volumes of low-level, transuranic, and mixed waste, and radioactively contaminated PCBs to be generated from the activities identified above, 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 is established at the point of origin based on process knowledge or sample analysis.

6.3.3.2 Waste Receiving and Processing Facility

H. C. Boynton

Waste destined for the Waste Receiving and Processing Facility includes stored waste as well as newly generated waste from current Hanford Site cleanup activities. The waste consists primarily of contaminated cloth, paper, rubber, metal, and plastic. Processed waste that qualifies as low-level radioactive waste and meets disposal requirements is buried onsite. Low-level radioactive waste not meeting 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 determined 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.

The Waste Receiving and Processing Facility, which began operating in 1997, analyzes, characterizes, and prepares drums and boxes of waste for disposal. The 4,800-square-meter (52,000-square-foot) facility, along with two 2,000-square-meter (21,900-square-foot) storage buildings is located north of the Central Waste Complex in the 200-West Area. The facility dispositioned and shipped offsite 586 cubic meters (767 cubic yards) of waste during calendar year 2006.

6.3.3.3 T Plant Complex

P. W. Martin

The T Plant complex in the 200-West Area provides waste treatment, storage, and decontamination services for the Hanford Site as well as for offsite facilities. The T Plant complex currently operates under RCRA interim status. In 2006, the following activities occurred at the T Plant complex:

- Numerous containers and boxes of waste were repackaged, treated, sampled, and characterized to meet waste acceptance criteria and land-disposal restrictions requirements.
- Treatment of K-East Basin North Load-Out Pit sludge began in October 2005 and concluded in June 2006. As of June 9, 2006, three hundred and thirty-two 208-liter (55-gallon) containers of grouted sludge were generated.
- Three new work stations were set up in the 221-T Canyon Building in 2005 to repackage transuranic drums and/or process legacy waste. In 2006, five hundred and sixty-eight 208-liter (55-gallon) drum equivalents of

transuranic waste were repackaged to meet offsite waste acceptance criteria and eventual disposal at the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

- T Plant completed operations in July 2006 to create a new access to the 221-T Canyon Building via the "head end" facility located at the northern endpoint of the Canyon Building. This second access point facilitates waste movements into the canyon portions of the building and speeds entry and exit of personnel.

A new Notice of Construction for the 2706-T Building was received from the Washington State Department of Health on October 5, 2006. This Notice of Construction allows radioactive air emissions from work conducted in the 2706-T Building, which can include drum venting, container repackaging, and container sampling.

A revised Notice of Construction for the 221-T Canyon Building was received on October 5, 2006, from the Washington State Department of Health. This Notice of Construction removed references to general conditions that were already addressed in the Hanford Site-Wide Air Operating Permit. The 221-T Canyon Building Notice of Construction is now more streamlined in terms of the conditions and limitations specific to T Plant operations.

6.3.3.4 Mixed Low-level Waste Treatment and Disposal Facility

D. E. Nester

During 2006, 988 cubic meters (1,292 cubic yards) of mixed low-level waste were treated and/or directly disposed of at the Radioactive Mixed Waste Disposal Facility:

- 670 cubic meters (876 cubic yards) of mixed low-level waste were treated and disposed of in support of treatment objectives in Tri-Party Agreement Milestone M-91-42.
- 154 cubic meters (201 cubic yards) of mixed low-level waste, or approximately 740 drum equivalents (based on a standard 208-liter [55-gallon] drum), were shipped from the Hanford Site and non-thermally treated to RCRA land-disposal restriction standards by offsite commercial waste processors. The treated waste was returned to the Hanford Site and disposed of in trenches 34 and 31 at the Radioactive Mixed Waste Disposal Facility.
- 516 cubic meters (675 cubic yards) of mixed low-level waste, or approximately 2,481 drum equivalents, were shipped from the Hanford Site and non-thermally treated to RCRA land-disposal restriction standards by offsite commercial waste processors. The treated waste was returned to the Hanford Site and disposed of at the Environmental Remediation Disposal Facility.
- 239 cubic meters (313 cubic yards) of mixed low-level waste, or approximately 1,149 drum equivalents, were treated and disposed of in support of treatment objectives in Tri-Party Agreement Milestone M-91-12. This waste was shipped from the Hanford Site and thermally treated to RCRA land-disposal restriction standards by offsite commercial waste processors. The treated waste was returned to the Hanford Site and disposed of in trenches 34 and 31 at the Radioactive Mixed Waste Disposal Facility.
- 79 cubic meters (103 cubic yards) of mixed low-level waste, or approximately 380 drum equivalents, were directly disposed of at the Radioactive Mixed Waste Disposal Facility. This waste came from various Hanford Site generators and was either treated offsite by commercial waste processors, onsite by the generator, or was not treated because it met land-disposal restriction standards in the "as-generated" state.

6.3.3.5 Disposal of U.S. Navy Reactor Compartments

S. G. Arnold

One disposal package containing a defueled U.S. Navy reactor compartment was received and placed in trench 94 of the 218-E-12B burial ground in 2006. This brings the total number of reactor compartments received to 115. All U.S. Navy reactor compartments shipped to the Hanford Site for disposal have originated from decommissioned nuclear-powered submarines or cruisers. Decommissioned submarine reactor compartments are approximately 10 meters (33 feet) in diameter, 14.3 meters (47 feet) long, and weigh between 908 and 1,362 metric tons (1,000 and 1,500 tons). Decommissioned cruiser reactor compartments are approximately 10 meters (33 feet) in diameter, 12.8 meters (42 feet) high, and weigh approximately 1,362 metric tons (1,500 tons).

6.3.3.6 Environmental Restoration Disposal Facility

M. A. Casbon

The Environmental Restoration Disposal Facility is located near the 200-West Area. The facility began operations in July 1996 and serves as the central disposal site for contaminated waste removed during Hanford Site cleanup operations conducted under CERCLA regulations.

To provide a barrier to prevent contaminant migration from the in-ground facility, the Environmental Restoration Disposal Facility was constructed to RCRA Subtitle C Minimum Technology Requirements, which included a double liner and leachate collection system. Remediation waste disposed of in the facility includes soil, rubble, or other solid waste materials contaminated with hazardous, low-level radioactive, or mixed (combined hazardous and radioactive) low-level waste.

There are currently six waste cells within the Environmental Restoration Disposal Facility. Initially, cells 1 and 2 were constructed and waste placement in these cells is nearly complete. Interim covers have been placed over the parts of cells 1 and 2 that have been brought up to grade. Cells 3 and 4 have reached their operational capacity. Construction of cells 5 and 6 has been completed; the cells began receiving waste in January 2005. All six cells are roughly equal in size, each holding approximately 1.27 metric tons (1.4 million tons) or approximately 0.61 million cubic meters (0.8 million cubic yards).

In 2006, approximately 475,792 metric tons (524,474 tons) of remediation waste were disposed of at the facility. A total of approximately 6.2 million metric tons (6.8 million tons) of remediation waste have been placed in the Environmental Restoration Disposal Facility from initial operations start-up through 2006. The total available expansion area of the Environmental Restoration Disposal Facility site was authorized in a 1995 record of decision (EPA/ROD/R10-95/100) to cover as much as 4.1 square kilometers (1.6 square miles).

6.3.3.7 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. Disposal to trench 34 began in September 1999.

Currently, there are approximately 4,010 cubic meters (5,244 cubic yards) of waste disposed of in 3,553 waste packages in trench 34. During summer 2004, the first operational layer of waste packages was covered with compacted gravel and soil. The second waste layer was started and continues to be filled; it is currently approximately half filled.

Trench 31 became operational for disposal in July 2004. Currently, there are approximately 293 cubic meters (383 cubic yards) of waste disposed in 429 waste packages in trench 31.

The current combined packaged waste volume in trenches 31 and 34 is 4,301 cubic meters (5,626 cubic yards); however, some of the waste in these trenches has been radiologically stabilized in grout monoliths, which take up additional disposal space. Taking these monoliths into account, the current realized disposal volume in trenches 31 and 34 is approximately 5,620 cubic meters (7,348 cubic yards).

Trenches 31 and 34 are rectangular landfills, with approximate base dimensions of 76 by 30 meters (250 by 100 feet). The bottom of the excavation slopes 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 (3.3 feet) deep 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.

These disposal units were originally designated for disposal of mixed low-level waste only; however, beginning in July 2004, disposal of low-level waste in unlined trenches ceased at the Hanford Site. Low-level waste is currently being disposed of in trenches 31 and 34.

6.3.3.8 Low-Level Burial Grounds

D. E. Faulk

The low-level burial grounds consist of eight burial grounds located in the 200-East and 200-West Areas that are used for the disposal of low-level waste and mixed waste (i.e., low-level radioactive waste with a dangerous waste component regulated by WAC 173-303). The low-level burial grounds have been permitted under a RCRA Part A permit since 1985.

Three trenches receive mixed waste regulated by WAC 173-303. Trenches 31 and 34 in burial ground 218-W-5 are lined trenches with leachate collection and removal systems (see Sections 6.3.3.4 and 6.3.3.7). Trench 94 in burial ground 218-E-12B is used for disposal of defueled U.S. Navy reactor compartments (Section 6.3.3.5). Low-level waste and transuranic waste have been placed in the other burial grounds. Transuranic waste has not been placed in the low-level burial grounds without specific DOE approval since August 19, 1987. Soil is placed over some of the waste containers to provide radiological protections. The transuranic waste was placed in a manner that allows for retrieval and/or removal in the future.

On June 23, 2004, the DOE issued a record of decision (69 FR 39449) for the Solid Waste Program at the Hanford Site. Part of the record of decision stated that the DOE will dispose of low-level waste in lined disposal facilities. Only two of the low-level burial ground trenches are lined (trenches 31 and 34); therefore, since that date, all low-level waste, as well as mixed low-level waste, is being disposed in these two trenches (Section 6.3.3.7). Disposal of U.S. Navy reactor compartments (Section 6.3.3.5) in the low-level burial grounds is not affected by this record of decision.

Retrieval of suspect-transuranic retrievably stored waste in the 218-W-4C burial ground was initiated in October 2003 in accordance with the Tri-Party Agreement (Change Number M-91-03-01). Retrieval of suspect-transuranic retrievably stored waste continues in accordance with Tri-Party Agreement Milestone M-91-40.

A draft revision to the RCRA Part B permit application for the low-level burial grounds was submitted to the Washington State Department of Ecology in June 2002. Discussions between the DOE and the state concerning the permit application are ongoing. In addition, the low-level burial grounds are included in a draft remedial investigation/feasibility study work plan completed in December 2004 (DOE/RL-2004-60, Draft A). The plan outlines possible characterization and remediation activities for specified landfills at the Hanford Site.

6.3.4 Liquid Waste Management

Facilities are operated on the Hanford Site to store, treat, and dispose of various types of liquid effluent generated by site cleanup activities. These facilities are operated and maintained in accordance with state and federal regulations and facility permits.

6.3.4.1 Liquid Effluent Retention Facility

M. D. Guthrie

The Liquid Effluent Retention Facility in the 200-East Area consists of three RCRA-compliant surface basins to temporarily store process condensate from the 242-A evaporator and other aqueous waste. The Liquid Effluent Retention Facility provides for a steady flow and consistent 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 each basin in the event a leak should develop in an operating 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 and bentonite clay barrier, should both the primary and secondary liners fail. Each basin has a floating membrane cover constructed of very low-density polyethylene to keep out windblown soil and weeds, and to minimize evaporation of small amounts of organic compounds and tritium that may be present in the basin contents. The facility began operating in April 1994 and receives liquid waste from both RCRA- and CERCLA-regulated cleanup activities.

The volume of wastewater received for interim storage in 2006 was approximately 7.08 million liters (1.87 million

gallons). This included approximately 3.90 million liters (1.03 million gallons) of RCRA-regulated wastewater (primarily 242-A evaporator process condensate and mixed-waste trench leachate) and approximately 3.19 million liters (843,000 gallons) of CERCLA-regulated wastewater (primarily Environmental Restoration Disposal Facility leachate). The majority of the wastewater was received via pipeline direct from the originating facility. Approximately 1.77 million liters (468,000 gallons) of wastewater were received from various facilities by tanker trucks. The wastewater volume transferred to the Effluent Treatment Facility for treatment and disposal in 2006 was 15.6 million liters (4.13 million gallons).

The volume of wastewater being stored in the Liquid Effluent Retention Facility at the end of 2006 was 31.42 million liters (8.30 million gallons). This included 8.10 million liters (2.14 million gallons) of RCRA-regulated wastewater and 23.32 million liters (6.16 million gallons) of CERCLA-regulated wastewater.

6.3.4.2 Effluent Treatment Facility

M. D. Guthrie

The Effluent Treatment Facility (200-East Area) treats liquid effluent to remove toxic metals, radionuclides, and ammonia, and destroy organic compounds. The treatment process constitutes best available technology and includes pH adjustment, filtration, ultraviolet light and peroxide destruction of organic compounds, reverse osmosis to remove dissolved solids, and ion exchange to remove the last traces of contaminants. The facility began operating in December 1995. Treatment capacity of the facility is a maximum of 570 liters (150 gallons) per minute.

The treated effluent is stored in tanks, sampled and analyzed, and discharged via a dedicated pipeline to the State-Approved Land Disposal Site (also known as the 616-A crib). This disposal site is located just north of the 200-West Area and is an underground drain field. The percolation rates for the field have been established by site testing and evaluation of soil characteristics. Tritium in the liquid effluent from the Effluent Treatment Facility cannot be practically removed, and the location of the disposal site maximizes the time for migration of the tritium to the Columbia River to allow for radioactive decay (the half-life of tritium is 12.35 years).

The volume of wastewater treated and disposed of in 2006 was approximately 15.6 million liters (4.13 million gallons). This was primarily CERCLA-regulated wastewater (groundwater from the 200-UP-1 Operable Unit in the 200-West Area and Environmental Restoration Disposal Facility leachate).

6.3.4.3 200 Area Treated Effluent Disposal Facility

M. D. Guthrie

The 200 Area 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 and all known available and reasonable treatment in accordance with "Submission of Plans and Reports for Construction of Wastewater Facilities" (WAC 173-240), which is the responsibility of the generating facilities. The 200 Area Treated Effluent Disposal Facility consists of approximately 18 kilometers (11 miles) of buried pipelines connecting three pumping stations, the 6653 Building (known as the disposal sample station), and two 2-hectare (5-acre) disposal ponds located east of the 200-East Area. The facility began operating in April 1995 and has a capacity of 12,900 liters (3,400 gallons) per minute. The volume of unregulated effluent disposed of in 2006 was 765.3 million liters (202.2 million gallons). The major source of this effluent was uncontaminated cooling water and steam condensate from the 242-A evaporator, with a variety of other uncontaminated waste streams received from other Hanford Site facilities.

6.3.4.4 300 Area Treated Effluent Disposal Facility

D. L. Halgren

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

the nearby 307 retention basins where it is monitored and released to the 300 Area process sewer for treatment by the 300 Area Treated Effluent Disposal Facility.

This facility has a storage capacity of up to 5 days at the design flow rate of 1,100 liters (300 gallons) per minute. The treatment process includes iron co-precipitation to remove heavy metals, ion exchange to remove mercury, and ultraviolet light and hydrogen-peroxide oxidation to destroy organics and cyanide. The treated liquid effluent is monitored and discharged through an outfall to the Columbia River under a National Pollutant Discharge Elimination System permit. The volume of industrial wastewater treated and disposed of during 2006 was 139.5 million liters (36.87 million gallons).

6.3.4.5 242-A Evaporator

T. L. Faust

The 242-A evaporator in the 200-East Area concentrates dilute liquid tank waste by evaporation. This reduces the volume of liquid waste sent to double-shell waste storage tanks for storage and reduces the potential need for additional double-shell tanks. The 242-A evaporator completed a cold-run campaign for training purposes and a readiness review, and one waste campaign during calendar year 2006. The volume of waste treated was 2.095 million liters (553,400 gallons), reducing the waste volume by 901,682 liters (238,200 gallons), or approximately a 43% reduction of the total volume. The volume of process condensate transferred to the Liquid Effluent Retention Facility for subsequent treatment in the Effluent Treatment Facility was 1,249 million liters (330,000 gallons).

6.3.5 Washington State Initiative 297, The *Cleanup Priority Act*

M. K. Marvin

Initiative 297, known as the *Cleanup Priority Act*, was passed by Washington State voters in November 2004. The *Cleanup Priority Act* adds a new chapter to the *Mixed Radioactive and Hazardous Waste* (RCW 70.105E) law and addresses a variety of Hanford Site operations. Among other restrictions, the act seeks to restrict importing offsite waste to the Hanford Site, establish cleanup standards for radioactive releases, and require the DOE to pay a new mixed-waste surcharge. In December 2004, the U.S. Department of Justice sought and received a temporary restraining order from the U.S. District Court that enjoined application or enforcement of the act at the Hanford Site or Pacific Northwest National Laboratory, except to the extent it prohibited the import of mixed waste to the Hanford Site. The U.S. Department of Justice filed a motion for summary judgment arguing the *Cleanup Priority Act* is preempted by federal law, violates the principle of sovereign immunity, and burdens the flow of interstate commerce in violation of the U.S. Constitution. In February 2005, Washington State officials asked the federal court to certify five issues for interpretation by the Washington State Supreme Court. The federal court agreed and then prohibited application of the entire initiative, including waste importation prohibitions, until all claims have been resolved in both federal and state courts. The Washington State Supreme Court provided the requested interpretation of the act in July 2005. After receiving briefs and hearing oral arguments regarding the act, U.S. District Court Judge Alan McDonald in June 2006 granted the United States' motion for summary judgment. The court ruled the initiative was "invalid in its entirety" because it violated the U.S. Constitution in several areas. Washington State subsequently appealed the ruling. The parties submitted briefs to the Ninth Circuit Court of Appeals in late 2006 through early 2007; no date for oral argument had been set as of April 2007.

6.4 Underground Waste Storage Tanks

M. E. Cole

Most of the waste stored at the Hanford Site is contained in large underground single-shell (one wall) and double-shell (two walls) tanks. These tanks are located in the 200 Areas; a grouping of tanks is referred to as a tank farm. The single-shell tanks are older, and some are known to have leaked. Liquid in the single-shell tanks is being transferred to double-shell tanks to prevent additional environmental releases. The following sections summarize waste-tank-related activities that occurred in 2006.

6.4.1 Waste Tank Status

This section provides information about the 149 single-shell and 28 double-shell tanks on the Hanford Site and activities related to their closure. Quantities of liquid waste generated in 2006 and stored in underground storage tanks are included in an annual dangerous waste report (e.g., DOE/RL-2006-13, Rev. 0). Table 6.4.1 is a summary of the liquid waste generated from 2001 through 2006 and stored in underground storage tanks.

6.4.1.1 Single-Shell Tanks

The Tri-Party Agreement (Ecology et al. 1989) formally establishes a schedule for interim stabilization, retrieval, and closure of the Hanford Site 200 Areas waste-storage tanks. Interim stabilization was achieved several years ago by transferring pumpable liquid from single-shell tanks to double-shell tanks to assure the tanks would no longer leak their contents to the environment.

CH2M HILL Hanford Group, Inc. completed waste retrieval of three single-shell tanks in 2006. A vacuum system was used to retrieve 87,000 liters (23,000 gallons) of residual solids, including water from tank 241-C-201.

Table 6.4.1. Quantities of Liquid Waste[a] Generated and Stored Within the Tank Farm System on the Hanford Site During 2006 and the Previous 5 Years, L (gal)

Type of Waste	2001[b]	2002[b]	2003	2004	2005	2006
Volume of waste added to double-shell tanks	2,980,000 (788,000)	9,280,000 (2,452,000)	9,710,000 (2,565,000)	3,316,000 (876,000)	3,668,000 (969,000)	3,547,000 (937,000)
Total volume in double-shell tanks (year end)	79,980,000 (21,131,000)	87,683,000 (23,166,000)	92,693,000 (24,487,000)	95,275,000 (25,169,000)	98,943,000 (26,138,000)	101,411,000 (26,790,000)
Volume evaporated at 242-A evaporator	2,580,000 (682,000)	1,578,000 (417,000)	4,720,000 (1,247,000)	734,000 (194,000)	706,700 (186,700)	1,052,000 (278,000)
Volume pumped from single-shell tanks[c]	590,000[c] (155,000)	5,288,000[c] (1,397,000)	6,185,000[c] (1,634,000)	2,778,000[c] (734,000)	888,000[c] (234,714)	2,953,000[d] (780,000)

(a) Quantity of liquid waste is defined as liquid waste sent to double-shell underground storage tanks during these years, rounded to the nearest 1,000. This does not include containerized (e.g., barreled) waste 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 (e.g., barreled) waste included in the solid waste category.
(c) Volume does not include dilution or flush water.
(d) Volume does include dilution or flush water.

The amount retrieved exceeded the Tri-Party Agreement (Ecology et al. 1989) cleanout goal and left the tank clean enough to expose weld seams on the bottom of the tank.

The vacuum system was also used to retrieve 174,000 liters (46,000 gallons) of water and solids from tank 241-C-204. This tank is the last in a grouping of four tanks known as the C-200 series tanks to be emptied under terms of the Tri-Party Agreement. Waste in tanks 241-C-202 and 241-C-203 was retrieved in 2005.

In 2006, a total of 488,000 liters (129,000 gallons) of waste and water was retrieved from tank 241-C-103 using a modified sluicing system, thereby completing tank waste retrieval.

Waste retrieval is currently underway in tank 241-C-108, which was approximately 25% complete at the end of 2006; waste retrieval in tank 241-S-102 was approximately 70% complete; and waste retrieval in tank 241-S-112 was approximately 99% complete at the end of 2006.

CH2M HILL Hanford Group, Inc. transferred over 2,950,000 liters (780,000 gallons) of radioactive and hazardous waste (including the water used in waste retrieval activities) from single-shell tanks to safer double-shell tanks. The waste material contained over 111,000 terabecquerels (3 million curies) of radioactivity.

6.4.1.2 Single-Shell Tank Farm Vadose Zone Program

The CH2M HILL Vadose Zone program is actively working to understand the radioactive and chemical contaminants in the soil around the Hanford Site's underground radioactive waste storage tanks.

Using a variety of technologies, CH2M HILL Hanford Group, Inc. is investigating contaminant plumes from prior tank leaks or process discharges to determine what the contaminants are, where they are, and where they are going. Knowledge gained by these activities will be integrated into the site-wide Vadose Zone Project to help guide future decisions.

Because water provides the primary force that drives contaminants down to the water table, CH2M HILL Hanford Group, Inc. has taken a number of measures to minimize and control rainwater and snow runoff that may result in surface flooding, as well as preventing leaks from pressurized water lines. CH2M HILL Hanford Group, Inc. has installed berms, curbs, culverts, and gutters around all 12 single-shell tank farms to prevent the flow of surface water onto the farms. Water lines serving the single-shell tank farms were leak-tested, repaired or cut-and-capped, and waterproof caps were installed on 998 dry wells.

CH2M HILL's Vadose Zone project is expanding the knowledge of subsurface conditions in the tank farms. The studies and activities are significantly improving the understanding of contaminant waste plumes, the plumes' content, and plume migration through the vadose zone. In July 2006, an initial performance assessment (DOE/ORP-2005-01, Rev. 0) was issued and sent to the regulatory agencies for review. In September 2006, the near-surface vadose zone characterization was completed at T Tank Farm using the hydraulic hammer/direct-push technology. This technology advances a hollow rod directly into the soil, vertically or at an angle, allowing the targeted collection of soil samples or monitoring of soil moisture and radiation, but does not bring contaminated soils to the ground surface.

Surface geophysical exploration, a technique that uses the electrical properties in the soil to map potential contamination plumes, was completed at S and T Tank Farms in 2006 (RPP-RPT-30976; RPP-RPT-28955). In addition, the technique was applied in a reconnaissance mode to aid further characterization in the C and U Tank Farms (RPP-RPT-31558; RPP-RPT-31557).

6.4.1.3 Double-Shell Tanks

The tank farms contain 28 double-shell tanks. Current fill limits give the double-shell tank system a storage capacity of approximately 126 million liters (33 million gallons). This storage space is being managed to store waste pending treatment by the Waste Treatment and Immobilization Plant or a supplemental treatment process (i.e., bulk vitrification). At the end of 2006, there were 101 million liters (27 million gallons) of waste in the double-shell tanks. During 2006, 2.9 million liters (780,000 gallons) of waste were transferred from the single-shell tank system into the double-shell tank system. Waste was received from single-shell tanks 241-C-103, 241-C-108, 241-C-201, 241-C-204, 241-S-102, and 241-S-112. Ultrasonic testing of all 28 double-shell tanks was also completed in 2006, verifying

their soundness for safe waste storage and meeting the Tri-Party Agreement M-48 milestone.

6.4.2 Demonstration Bulk Vitrification System

The Demonstration Bulk Vitrification System will be a full-scale test facility that will receive waste from single-shell tank 241-S-109, mix the waste with glass-forming materials, and feed it into a metal container lined with a refractory and sand. The blended material will then be heated to approximately 1300°C (2372°F) to produce a vitrified waste product. The waste product will then be sampled and tested to verify that it is suitable for near-surface land disposal at the Integrated Disposal Facility. The Demonstration Bulk Vitrification System will treat the process off-gas to ensure it is compliant with applicable state and federal regulations, and is protective of human health and the environment. Secondary liquid wastes will be sent to the Effluent Treatment Facility for proper treatment and disposal.

The Demonstration Bulk Vitrification System design was approved by the Washington State Department of Ecology under a Research Development and Demonstration Permit in July 2006. CH2M HILL Hanford Group, Inc. commissioned a panel of 16 independent experts and consultants to review the approved design to help ensure facility construction and operations will be successful. The design will undergo some modifications during fiscal year 2007 to incorporate recommendations from the expert panel. The Demonstration Bulk Vitrification System project has conducted supporting activities that have focused on glass formulation and performance of the melter system. Project personnel have also conducted an extensive set of process tests ranging from crucible melts of both simulants and radioactive tank wastes, cold (non-radioactive) and hot (radioactive) engineering scale melts, and a series of full-scale tank waste simulant tests.

Containers of low-activity waste produced by the Demonstration Bulk Vitrification System will be placed in Hanford's new Integrated Disposal Facility, which was completed in 2006. The facility is located in the 200-East Area near the center of the Hanford Site. It is the site's first permitted disposal facility that meets RCRA requirements. This means that the Integrated Disposal Facility meets a DOE commitment to Washington State that wastes will be disposed of only in a facility that is fully lined and has a leachate collection system to intercept any liquids that percolate through the waste before they reach the groundwater.

6.5 Hanford Waste Treatment and Immobilization Plant

J. F. Brown

The Waste Treatment and Immobilization Plant is being built on 26 hectares (65 acres) located on the Central Plateau at the 200-East Area to treat radioactive and hazardous waste currently stored in 177 underground tanks. Four major facilities are being constructed: a pretreatment facility, a high-level waste vitrification facility, a low-activity waste vitrification facility, and an analytical laboratory, along with supporting facilities.

The technical challenges of designing and building a first-of-its-kind project, coupled with overcoming stagnation of the U.S. nuclear industry, led to major changes in the project's execution plan in 2006. The project is poised to move forward on a new schedule. The major challenges faced over the past year included the following:

- The Waste Treatment and Immobilization Plant's cost and schedule were revised to account for changes in the project's work scope, new seismic design criteria, technical modifications, and funding limitations. The new estimate at completion, which calls for the project to be completed in 2019 at a cost of $12.26 billion, has been reviewed and validated by independent experts and approved by the Under Secretary for Energy. A certified Earned Value Management System will track the project's progress against this validated cost and schedule baseline.
- A team of 50 independent experts in chemical and nuclear operations reviewed the project's technical baseline. This review team identified issues that could prevent the plant from operating at its design capacity or impact its reliability and operations. The most significant issues were the potential for pipe plugging, the effectiveness of ultra-filters for removing radioactive solids from tank waste, mixing of tank waste in vessels, and the effectiveness of chemically leaching metals from the waste. The cost of these solutions has been accounted for in the updated cost and schedule baseline and they are being incorporated in the plant design.
- The seismic design criteria for the Pretreatment and High-Level Waste Vitrification Facilities are nearly final. Design methodology for incorporating new ground-motion estimates is in place and was approved by the Defense Nuclear Facilities Safety Board and the U.S. Army Corps of Engineers. Already-constructed work was evaluated using this methodology that determined the work meets the new criteria. Four deep boreholes were drilled at the construction site to study how shock waves move through rock and sediment layers beneath the site. Data analysis is underway and the DOE expects a report summarizing results from Pacific Northwest National Laboratory in spring 2007. Finalizing the seismic criteria will allow construction to resume on the Pretreatment and High-Level Waste Vitrification Facilities.

Considerable progress continued on the construction of the Low-Activity Waste Vitrification Facility, Analytical Laboratory, and dozens of support facilities in 2006.

The Low-Activity Waste Vitrification Facility was "closed in," therefore providing a weather-proof work environment; all structural work on the facility was completed; a 40-meter- (130-foot-) tall emissions stack was erected; and the $2-million low-activity waste tower crane, which was no longer needed for construction, was dismantled and shipped to the DOE's Savannah River Site in South Carolina.

The concrete foundation was completed on the Analytical Laboratory and structural steel is being erected. Of the support facilities, the Simulator Facility, Cooling Towers, and Electrical Switchgear Building were completed, while

the Chiller-Compressor Building and the Water Treatment Facility are nearing completion.

In 2006, the Waste Treatment and Immobilization Plant placed 7,646 cubic meters (10,000 cubic yards) of concrete; erected 1,361 metric tons (1,500 tons) of steel; installed 9,144 meters (10,003 yards) of pipe, 1,067 meters (1,167 yards) of cable tray, 4,877 meters (5,335 yards) of conduit, and 4,572 meters (5,002 yards) of wire and cable; and committed over $200 million to materials and services to assure a backlog of construction work in 2007 and 2008.

6.6 Scientific and Technical Contributions to Hanford Cleanup

T. Walton

In 2006, Pacific Northwest National Laboratory and Battelle, which the Laboratory for the DOE, provided scientific support to the DOE and its contractors. With the primary focus on subsurface and radiochemical processing, Pacific Northwest National Laboratory researchers provided analyses, reviews, tests, and new tools to assist the DOE in solving its complex scientific issues.

Waste Treatment and Immobilization Plant construction was impacted when the design basis for a seismic event changed. Pacific Northwest National Laboratory researchers are leading the Waste Treatment Plant Seismic Boreholes Project to reduce the uncertainty associated with shear-wave velocities of sediments and basalts below the Waste Treatment and Immobilization Plant. This uncertainty has called into question the adequacy of the current seismic design criteria. Efforts in 2006 focused on installing the deep boreholes and gathering initial geophysical data from the subsurface.

In support of Bechtel National, Inc., Pacific Northwest National Laboratory researchers performed scaled and prototypic testing of Waste Treatment and Immobilization Plant process components, including tank mixers and piping systems, to resolve technical uncertainties related to the adequacy of mixing, pipe plugging, and the potential for gas generation. In addition, Pacific Northwest National Laboratory researchers provided glass chemistry data that increased the plant's production assumptions through a better understanding of sulfate-loading parameters in the glass waste form and additional efforts to test the effectiveness of the high-level waste pretreatment processes, such as the caustic leaching process and the ultrafiltration system.

In support of the DOE Richland Operations Office, Pacific Northwest National Laboratory researchers provided additional scientific understanding of the behavior of contaminants in the subsurface, and developed technologies and approaches to treat chromium, strontium, uranium, and carbon tetrachloride in the groundwater, reducing the risk of further contaminating the Columbia River. These successes were achieved through projects funded by the DOE Office of Science (Office of Basic Environmental Research) and the DOE Office of Environmental Management (Office of Engineering and Technology).

Efforts include examining methods to halt a uranium plume moving towards the Columbia River. Researchers are investigating the underlying science of creating a subsurface barrier containing a long-chain polyphosphate that would convert uranium to autunite (a mineral), which sequesters uranium in place. Other work involves providing the scientific underpinnings to place a long-lasting apatite barrier near the river to sequester strontium from contaminated groundwater until it decays. In addition to in-situ remedies for strontium, Pacific Northwest National Laboratory researchers are addressing alternatives for treating chromium, nitrate, and other soil materials. Researchers are investigating the efficacy of native microbes in this treatment in conjunction with a downstream in-situ reduction and oxidation manipulation barrier to convert remaining chromium to a less soluble form. The microbes' actions upstream could increase the existing in-situ reduction and oxidation manipulation barrier's longevity, and protect shoreline vegetation and the downstream human population.

To help resolve "issues of scale" (different subsurface models that focus on different scales), the Pacific Northwest

National Laboratory received a Scientific Discovery Through Advanced Computing grant to develop a computer model that can simulate biogeochemical processes on multiple scales. This computational advancement will enable researchers to make more accurate predictions of the movement and fate of contaminants in groundwater so that appropriate cleanup and human safety measures can be applied to the problem.

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7.0 Site Closure Activities

This section provides information about activities to support Hanford Site cleanup as the U.S. Department of Energy (DOE) progresses toward site closure and possible transfer of land to other entities.

7.0.1 Radiological Release of Property from the Hanford Site

W. M. Glines

Principal requirements for the control and release of DOE property containing residual radioactivity are in DOE Order 5400.5, "Radiation Protection of the Public and the Environment." These requirements are designed to ensure the following:

- Property is evaluated, radiologically characterized, and where appropriate decontaminated before release.
- The level of residual radioactivity in property to be released is as near background levels as is reasonably practicable, as determined through the DOE's as low as reasonably achievable process requirements, and meets DOE authorized limits.
- All property releases are appropriately certified, verified, documented, and reported; public participation needs are addressed; and processes are in place to appropriately maintain records.

No property with detectable residual radioactivity was released from the Hanford Site in 2006.

Radiological Clearance for Personal Property Potentially Contaminated with Hard-to-Detect Radionuclides

W. M. Glines

Washington Closure Hanford LLC, the prime contractor for the River Corridor Closure Contract, is tasked with decontamination and decommissioning activities at the Hanford Site. In the process of performing these activities, Washington Closure Hanford LLC encounters a wide variety of contaminated personal property including consumables, office items, tools and equipment, and debris. Final disposition of these materials depends on whether the property is considered radiologically contaminated, and whether the disposal of such property is subject to *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) requirements. Radiologically contaminated property is disposed of at the Environmental Restoration Disposal Facility if subject to CERCLA requirements and at the Central Waste Complex if not. Personal property that has contamination levels below approved DOE control and release guidelines are considered for release if the property can be reused. Washington Closure Hanford LLC routinely encounters a wide variety of radionuclide mixtures, ranging from essentially pure plutonium to fission and activation products. Included in these fission and activation products are low-energy beta emitters, such as carbon-14, iron-55, nickel-59, nickel-63, selenium-79, technetium-99, palladium-107, and europium-155 that are difficult or impossible to detect with routine field-survey methods; i.e., hard-to-detect radionuclides.

Traditionally, field detectable or easy-to-detect radionuclides have been used as an analog for the entire mixture

of radionuclides encountered, and the control and release criteria have been adjusted downward to account for the portion of the activity that is not detectable by field survey methods. As the ratio of hard-to-detect radionuclides to easy-to-detect radionuclides increases, the criteria are reduced to a point where the adjusted limits are difficult or impossible to verify with field survey instruments. Decades of radioactive decay have reduced the contributions of easy-to-detect radionuclides to such low levels that current control and release methodologies are no longer sufficient for verifying that contaminant levels comply with the existing, approved DOE property release guidelines in DOE Order 5400.5, "Radiation Protection of the Public and the Environment."

Accordingly, in 2006, Washington Closure Hanford LLC submitted a request to increase the release criteria (authorized limits) for hard-to-detect radionuclides (Table 7.0.1). The requested authorized limits will apply only to beta-gamma surface contamination on potentially contaminated equipment and materials, and excludes volumetric contamination (contamination that is distributed throughout the volume of the property), contamination in or on persons, unrestricted release of metals, and alpha-surface contamination. Detailed radiological analyses were performed to demonstrate that these authorized limits would be protective of human health and the environment. Based on these analyses, the requested authorized limits would result in a dose of less than 1 mrem (10 μSv) in any year to the maximally exposed individual and a collective dose of less than 10 person-rem (0.1 person-Sv) to any exposed population. These requested authorized limits have been reviewed by the DOE Richland Operations Office and DOE Headquarters personnel and are expected to be approved for implementation in early 2007.

Table 7.0.1. Requested Authorized Limits for Select Hard-to-Detect Radionuclides[a] for Residual Beta-Gamma Surface Contamination

Average (dpm/100 cm²)	Maximum (dpm/100 cm²)	Removable (dpm/100 cm²)
50,000	150,000	10,000

(a) Carbon-14, iron-55, nickel-59, nickel-63, selenium-79, technetium-99, palladium-107, and europium-155.
dpm = Disintegrations per minute.

7.0.2 River Corridor Baseline Risk Assessment and Long-Term Stewardship

E. T. Feist

The Hanford Site's River Corridor includes the 100 and 300 Areas, which border the Columbia River shoreline. The 100 and 300 Areas include hundreds of contaminated excess facilities, 9 deactivated plutonium-production reactors, and nearly 600 liquid- and solid-waste disposal sites. The DOE's award of the River Corridor Closure Contract to Washington Closure Hanford LLC in 2005 has allowed cleanup actions to continue in the 100 and 300 Areas with completion in mind. The principal goals of the DOE's River Corridor Closure Contract are to complete the following:

- Deactivate, decontaminate, decommission, and demolish excess facilities
- Place former production reactors in an interim safe and stable condition
- Remediate liquid- and solid-waste disposal sites
- Meet all regulatory requirements
- Determine the adequacy of the current cleanup criteria in protecting human health and the environment
- Obtain a proposed "finding of suitability" to transfer the Hanford Site's River Corridor to long-term stewardship.

The last two bullets, which focus on site closure and possible transfer of land to other entities, are being addressed under the River Corridor Closure Contract by the River Corridor Baseline Risk Assessment and Long-Term Stewardship tasks. Ongoing, open communication among the many parties interested in Hanford Site cleanup continued in 2006 as work progressed under the River Corridor Baseline Risk Assessment and Long-Term Stewardship tasks. An Internet website (http://www.washingtonclosure.com/Projects/endstate.html) provides current information on these associated activities. The website includes the planned dates of public involvement opportunities, documents available for review and comment, administrative information, and links to related projects.

7.0.2.1 River Corridor Baseline Risk Assessment

J. E. Thomson

The DOE's cleanup plans for the Columbia River corridor are based on CERCLA requirements. In 1991, the DOE, U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (the Tri-Parties) agreed that interim remedial actions in the 100 Areas and 300 Area could be implemented by relying on streamlined qualitative risk assessments rather than a quantitative baseline risk assessment. Waste-site cleanup under interim action records of decision was initiated during the mid-1990s and is planned for completion by Washington Closure Hanford LLC by 2013. The current focus of Washington Closure Hanford LLC is on completing the remedial actions so the Tri-Party agencies can proceed to final CERCLA closeout of the 100 Areas and 300 Area. A critical step in proceeding toward final CERCLA closeout is a baseline risk assessment, which is now being performed by Washington Closure Hanford LLC as the River Corridor Baseline Risk Assessment. The River Corridor Baseline Risk Assessment task consists of the following:

- A baseline risk assessment for the 100 Areas and 300 Area Component, which includes former operational areas (primarily former reactor areas).
- A baseline risk assessment for the Inter-Areas Component, which includes reaches of the Columbia River shoreline area between the former operational areas in the 100 Areas and 300 Area.
- Risk-assessment planning efforts for the Columbia River Component, which includes the Hanford Reach of the Columbia River, as well as downstream reaches of the river to a boundary that has not yet been determined.

The results of these assessments will be used to evaluate the adequacy of cleanup actions within the Columbia River corridor.

The River Corridor Baseline Risk Assessment uses a multi-step process. The process begins by compiling and summarizing the existing data, then using the data quality objectives process to identify both data gaps and unresolved issues through open workshops, and by soliciting and incorporating input from regulatory agencies, the Natural Resources Trustees Council, affected Indian tribes, and stakeholders. Based on these discussions, sampling analysis plans will be developed to collect the data needed to fill the gaps and address the issues. After all necessary data are collected, the risks to human health and the environment will be assessed.

Risk assessment sampling of upland, riparian, and near-shore environments for the 100 Areas and 300 Area Component was initiated in 2005 and completed in 2006. Sampling included collecting nearly 1,100 Columbia River water, biota, and near-shore sediment samples; terrestrial soil and biota samples; and groundwater samples. Laboratory analysis of collected samples was performed during 2006. Results are being used in the preparation of a draft risk assessment report for the 100 Areas and 300 Area Component of the River Corridor Baseline Risk Assessment, which is scheduled for regulatory and stakeholder review in 2007.

Adapting methods developed and agreed to by the Tri-Party agencies and stakeholders for the 100 Areas and 300 Area Component risk assessment, the Inter-Areas Component risk assessment was initiated in 2006 for the riparian and near-shore environments of the river corridor between reactor/operational areas. This risk assessment effort will supplement results from the 100 Areas and 300 Area Component to provide a more complete analysis of residual human health and ecological risk in the river corridor. Results from these baseline risk assessments will be used to develop a source unit remedial investigation report. Recommendations for final cleanup decisions at source units within the river corridor, based in part on the risk assessment results, will be presented by the Tri-Party agencies to the public for consideration in a river corridor source unit proposed plan in the future.

The third element of the River Corridor Baseline Risk Assessment is the Columbia River Component. The purpose of this component is to identify whether there are areas beyond the boundaries of the Hanford Site that may require additional information to proceed with making risk management decisions. In 2006, work included compilation and evaluation of existing information. Planning is

underway by the DOE Richland Operations Office for Washington Closure Hanford LLC to complete a work plan report that will be provided to the DOE Richland Operations Office and the regulatory agencies for review and approval. Implementation of this work plan is not included in the scope of the River Corridor Closure contract.

7.0.2.2 River Corridor Long-Term Stewardship

J. A. Lerch

The long-term stewardship task focuses on achieving end-state closure and transition of the river corridor to long-term stewardship. Within the River Corridor Closure Contract, key elements of the long-term stewardship work include the preparation of remedial actions reports for each CERCLA operable unit and development of a draft long-term stewardship plan. Preparation for transition to long-term stewardship includes "orphan site" evaluations. These evaluations include a systematic approach to review land parcels and identify potential waste sites (orphan sites) in the river corridor that are not currently listed in existing CERCLA decision documents. Orphan site evaluations consist of comprehensive reviews of historical documentation, field investigations, and geophysical surveys.

In 2006, a draft for a long-term stewardship plan report was prepared and reviewed by the DOE. The report will be provided to regulatory agencies in 2007. Also in 2006, orphan site evaluations were completed in the 100-D Area in response to a regulatory agency request to perform this work sooner than had been originally planned. In addition, work started on orphan site evaluations for the 100-IU-2 and 100-IU-6 Operable Units (located between the 100-F and 100-H Areas) and the Inter-Areas.

Results of risk assessment activities, orphan site evaluations, remedial actions reports, and long-term stewardship plans will provide a basis for closure reviews of the 100 Areas and 300 Area by independent experts. The independent closure reviews will assure that implemented remedies meet the required action objectives established in the source operable unit records of decision and that no further action is needed to protect human health and the environment. These activities will culminate in development of a final long-term stewardship plan that will contain a proposed finding of suitability to transfer in accordance with CERCLA Section 120(h) and the final criteria for long-term stewardship.

7.0.3 References

Comprehensive Environmental Response, Compensation, and Liability Act. 1980. Public Law 96-510, as amended, 94 Stat. 2767, 42 USC 9601 et seq. Accessed May 1, 2007, at http://www.epa.gov/region5/defs/html/cercla.htm.

DOE Order 5400.5. 1990. "Radiation Protection of the Public and the Environment." U.S. Department of Energy, Washington, D.C.

8.0 Environmental Occurrences

B. G. Fritz

Releases of radioactive and regulated materials to the environment are reported to the U.S. Department of Energy (DOE) and other federal and state agencies as required by law. The specific agencies notified depend on the type, amount, and location of each release event. This section addresses releases or potential releases to the environment that may not be documented by other reporting mechanisms. All occurrences at the Hanford Site are reported to the Occurrence Notification Center, the home of the Occurrence Reporting and Processing System. This system is a DOE electronic database that tracks occurrence reports across the DOE complex (DOE M 231.1-2). The following sections summarize occurrences that took place during 2006 that could have impacted the Hanford Site environment. The occurrences are arranged according to significance category. Significance categories are assigned based on the nature and severity of the occurrence. The categories include operational emergency, recurring, category 1 (significant impact); category 2 (moderate impact); category 3 (minor impact); and category 4 (some impact). In 2006, there were no Hanford Site environmental occurrences ranked as operational emergency, recurring, or category 1.

8.0.1 Category 2 – Moderate Impact

Category 2 occurrences are defined as having a moderate impact on safe facility operations, worker or public safety and health, regulatory compliance, or public and business interests. A single Category 2 occurrence with potential environmental implications occurred on the Hanford Site in 2006.

Radioactive Contamination Found at Offsite Location. On August 8, 2006, the DOE requested Fluor Hanford, Inc. to assist with a radiological survey of material owned by a member of the general public. The material was 86 metal canisters (known as 'birdcages') purchased as Hanford Site excess in 1985. Results of the survey identified contamination as high as 1,400 dpm/100 cm^2 fixed alpha. Three of the canisters were identified as having detectable levels of contamination. The canisters were recovered by Fluor Hanford, Inc. and disposed of properly.

8.0.2 Category 3 – Minor Impact

Category 3 occurrences are defined as having a minor impact on safe facility operations, worker or public safety and health, regulatory compliance, or public and business interests. One Category 3 occurrence with potential environmental implications occurred on the Hanford Site in 2006.

Contaminated Burial Box Shipped to Fluor Hanford Low-Level Burial Grounds. On February 16, 2006, a mixed-waste metal burial box (MW06700076) was shipped from Pacific EcoSolutions Inc. (now Perma-Fix Northwest, Inc.), in north Richland, to the Hanford Site's low-level burial grounds. Personnel identified removable contamination of 650,000 dpm/100 cm^2 beta-gamma (no alpha). Contamination was also discovered on a second box (MW06700036) at a maximum of 5,000 dpm/100 cm^2 beta-gamma (no alpha). It was later concluded that the contamination on the second box was a result of transfer from box MW06700076. Upon discovery of the contamination, the boxes were covered in plastic to prevent further spread of contamination. This incident could have potentially resulted in the spread of contamination to the environment

as the burial boxes were shipped over public roads from Pacific EcoSolutions, Inc. (now Perma-Fix Northwest, Inc.) to the low-level burial grounds.

8.0.3 Category 4 – Some Impact

Category 4 occurrences are defined as having some impact on safe facility operations, worker or public safety and health, regulatory compliance, or public and business interests. Three Category 4 occurrences with potential environmental implications occurred on the Hanford Site in 2006.

1. On May 19, 2006, a grass fire occurred on the Hanford Site east of the Energy Northwest compound. The fire was caused by a lightning strike and burned approximately 2.4 hectares (6 acres).
2. On May 29, 2006, a grass fire occurred on the Hanford Site near mile post 42 of State Highway 24. The fire was caused by a lightning strike and burned approximately 10 hectares (25 acres).
3. On August 10, 2006, a grass fire occurred on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit of the Hanford Reach National Monument. The fire occurred approximately 3.2 kilometers (2 miles) west of State Highway 240 near mile post 2. The fire was caused by U.S. Department of Fish and Wildlife grass-mowing activities and burned approximately 0.8 hectare (2 acres).

Discovery of Legacy Contamination. Each year on the Hanford Site, legacy contamination is spread as a result of biological activity. Some of this contamination is discovered each year during routine survey work. Biological vectors that can result in the spread of contamination include tumbleweeds, rabbits, and mud daubers (wasps). Tumbleweeds have a deep taproot that can sequester contamination from below the soil surface into the plant body. Rabbits can eat vegetation located in contaminated areas, and then deposit contaminated feces outside of the contaminated area. Mud daubers build nests from mud and occasionally use mud from contaminated areas, resulting in the transfer of contamination to uncontaminated areas. Of these three biological vectors, contaminated tumbleweeds are the most frequent occurrence and have the potential to transfer contamination the farthest distance from the original location. There were 11 Category 4 occurrences in 2006 where biological activities resulted in the spread of radiological contamination.

8.0.4 Reference

DOE M 231.1-2. 2003. "Occurrence Reporting and Processing of Operations Information." Office of Environment Safety and Health, U.S. Department of Energy, Washington, D.C.

9.0 Pollution Prevention and Waste Minimization

This section provides information about Hanford Site policies regarding pollution prevention and waste minimization.

9.0.1 Pollution Prevention Program

C. E. Marple

The DOE Richland Operations Office is responsible for the Hanford Site pollution prevention program and provides program guidance to Hanford Site contractors.

U.S. Department of Energy (DOE) Order 450.1, Change 2, "Environmental Protection Program," established new pollution prevention and environmental stewardship goals that enhanced the pollution prevention and environmental management system provisions in DOE Order 450.1 and Executive Orders 13148, "Greening the Government Through Leadership in Environmental Management" (65 FR 24595), and 13101, "Greening the Government Through Waste Prevention, Recycling and Federal Acquisition" (63 FR 49643). These goals are implemented by Hanford Site contractors.

In 2006, the Hanford Site recycled 1,115 metric tons (1,230 tons) of sanitary and hazardous waste (Table 9.0.1). Affirmative procurement—the purchase of environmentally preferable products containing recycled material—at the Hanford Site achieved 100% of the 2006 goal.

The Hanford Site generated 4,278 cubic meters (5,595 cubic yards) of cleanup and stabilization goal waste (i.e., low-level waste, mixed low-level waste, and hazardous waste).

One notable achievement in 2006 was the Hanford Site's Centralized Consolidated Recycling Center, which received the DOE Office of Environmental Management High Achievement Pollution Prevention Award for the Aerosol

Table 9.0.1. Hanford Site Sanitary and Hazardous Waste Recycled in 2006

Waste	Metric Tons (tons)	
Sanitary Waste		
Appliances and furniture	38.81	(42.78)
Computers and electronics	81.61	(89.96)
Computer software	5.45	(6.01)
Copper	5.11	(5.63)
Engine oils	39.58	(43.63)
Fire extinguishers	6.32	(6.97)
Iron and steel	413.15	(455.42)
Light ballasts	1.88	(2.07)
Mixed office paper and cardboard	127.26	(140.28)
Non-ferrous metal	53.77	(59.27)
Tires	39.32	(43.34)
Toner cartridges	8.07	(8.90)
Hazardous Waste		
Antifreeze	0.64	(0.71)
Batteries	39.27	(43.29)
Excess chemicals	0.89	(0.98)
Lamps (fluorescent, sodium, mercury vapor, incandescent)	2.55	(2.81)
PCB oil[(a)]	251.01	(276.69)
Shop towels	0.8	0.88

(a) Less than 50 ppm polychlorinated biphenyl oil burned for energy recovery.

Can Puncturing Project. The project was designed to safely control aerosol product removal at the Centralized Consolidated Recycling Center. Personnel are trained in the proper and safe way of removing products from the aerosol cans. Each aerosol can is monitored to ensure accountability before and after the recovery process is performed. Emptied aerosol cans are then recycled and the hazardous materials are consolidated in 208-liter (55-gallon) drums for proper disposal. Cost avoidance was approximately $60,000, with waste avoidance of 3,350 aerosol cans.

CH2M HILL Hanford Group, Inc. received two Best-in-Class Pollution Prevention Awards in 2006. One award involved the successful pursuit of a "contained-in" determination (no longer considered a hazardous waste) from the Washington State Department of Ecology for soils excavated during construction at Clean-Out Box A-30. A sampling and analysis plan was developed to support a contained-in determination request from the Washington State Department of Ecology for "F-Listed" soils (a *Resource Conservation and Recovery Act* waste from a non-specific industrial source). As a result, the excavated soil was disposed of as low-level radioactive waste, ensuing a cost savings of approximately $200,000.

A second Best-in-Class Pollution Prevention Award involved the use of direct-push drilling technology to understand the extent of tank waste contaminants in the vadose zone. In comparison to conventional drilling techniques, direct-push drilling does not generate waste, is faster, less expensive, and fewer workers are required. In 2006, the direct-push drilling technology saved over $1 million in disposal costs.

9.0.2 References

63 FR 49643. September 14, 1998. Executive Order 13101, "Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition." *Federal Register*, U.S. Department of Energy.

65 FR 24595. April 21, 2000. Executive Order 13148, "Greening the Government Through Leadership in Environmental Management." *Federal Register*, U.S. Department of Energy.

DOE Order 450.1. 2003. "Environmental Protection Program." U.S. Department of Energy, Washington, D.C.

DOE Order 450.1, Change 2. 2005. "Environmental Protection Program." U.S. Department of Energy, Washington, D.C.

Resource Conservation and Recovery Act. 1976. Public Law 94-580, as amended, 90 Stat. 2795, 42 USC 6901 et seq. Accessed May 1, 2007, at http://www.epa.gov/region5/defs/html/rcra.htm.

10.0 Environmental and Resource Protection Programs

R. W. Hanf

U.S. Department of Energy (DOE) Orders 450.1 and 5400.5 require that environmental monitoring programs be conducted at the Hanford Site to verify protection of the site's environmental and cultural resources, the public, and workers on the site. The monitoring activities support the site's integrated "Safety Management System Policy" (DOE P 450.4) and its component Environmental Management System (see Section 4.0.1). Component systems are tools for achieving site and contractor compliance with environmental, public health, and resource protection laws, regulations, and DOE Orders.

The *Environmental Monitoring Plan, United States Department of Energy, Richland Operations Office* (DOE/RL-91-50, Rev. 3) provides the implementation guidance for the monitoring programs and projects at the Hanford Site. The plan contains the rationale for the required programs and projects, including design criteria, sampling locations and schedules, quality assurance requirements, program and project implementation procedures, analytical procedures, and reporting requirements. The early identification of, and appropriate response to, potentially adverse environmental and resource effects associated with DOE operations are confirmed by the following:

- Routinely conducting pre-operational environmental characterization and assessment activities
- Monitoring effluent and emissions
- Performing environmental monitoring and surveillance (as defined in DOE Order 5400.5 and in Appendix B, Glossary)
- Monitoring cultural resources
- Performing periodic sampling of Hanford Site drinking water
- Monitoring and controlling contaminated and undesirable biota.

The objectives of the monitoring programs include the following:

- Detecting, characterizing, and responding to contaminant releases from Hanford Site DOE facilities and operations
- Providing data to assess the human health and ecological impact of Hanford Site-produced contaminants
- Estimating contaminant dispersal patterns in the environment
- Characterizing the pathways of exposure to members of the public and biota
- Characterizing the exposures and doses to individuals, the nearby population, and biota
- Evaluating potential impact to biota (and the Columbia River) in the vicinity of DOE Hanford Site activities
- Verifying that environmental monitoring programs are conducted in an integrated fashion to preclude collection of duplicative environmental data
- Ensuring early identification of, and appropriate response to, the potentially adverse environmental impact associated with DOE operations
- Promoting long-term stewardship of the Hanford Site's natural and cultural resources
- Protecting natural and cultural resources

There are other important reasons for conducting these monitoring activities:

- Complying with local, state, and federal laws and regulations and DOE Orders

- Confirming site compliance with local, state, and federal laws and regulations, and DOE Orders
- Verifying the efficacy of waste-management practices on the Hanford Site
- Providing information to assure the public that facilities and operations are not adversely affecting people or the environment
- Answering questions or providing information to stakeholders, activist organizations, and the public
- Supporting DOE decisions
- Providing information to support the DOE in environmental litigations.

Brief summaries of DOE environmental monitoring programs and projects, the Drinking Water Monitoring Project, the Biological Control Program, and the Washington State Department of Health Oversight Monitoring Program are provided in the following sections.

10.0.1 Effluent and Near-Facility Environmental Monitoring Programs

Effluent and near-facility environmental monitoring at the Hanford Site consists of 1) liquid effluent and airborne emissions monitoring at site facilities and operations; and 2) environmental monitoring near facilities and operations that have the potential to discharge, or have discharged, stored, or been a disposal site for, radioactive and hazardous materials. Categories of effluent that normally or potentially contain radionuclides or hazardous materials include cooling water, steam condensates, process condensates, and wastewater from laboratories and chemical sewers. Airborne emissions can include both radioactive and non-radioactive particulate, gaseous, and volatilized materials from facility stacks and vents.

10.0.1.1 Liquid Effluent and Airborne Emissions Monitoring

Hanford Site contractors perform real-time monitoring of liquid effluent and airborne emissions at each facility to assess the effectiveness of effluent and emissions treatment and control systems, as well as pollution-management practices, and to determine facility and site compliance with state and federal regulatory requirements. Information on effluent discharged from site facilities in 2006 is summarized in Section 10.3 and in an annual environmental release report (e.g., HNF-EP-0527-16). Emissions data for 2006 are summarized in Section 10.1 and in other reports (e.g., DOE/RL-2007-01).

10.0.1.2 Near-Facility Environmental Monitoring

Near-facility environmental monitoring is conducted near DOE facilities and operations on the Hanford Site that have the potential to discharge, or have discharged, stored, or been a disposal site for radioactive or hazardous contaminants. Monitoring locations are associated with nuclear facilities such as the Canister Storage Building and the 100-K Area fuel storage basins; inactive nuclear facilities such as N Reactor and the Plutonium-Uranium Extraction (PUREX) Plant; and active and inactive waste storage or disposal facilities such as burial grounds, cribs, ditches, ponds, underground waste storage tanks, 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 sites, and detect and monitor unusual conditions. The program implements applicable portions of DOE Orders 435.1, 450.1, and 5400.5; DOE M 231.1-1A; 10 CFR 835 and 40 CFR 61; and WAC 246-247.

Several types of environmental media are routinely sampled near Hanford Site facilities, and various radiological and non-radiological measurements are taken. The media sampled include air, soil, and vegetation. In addition, surface contamination and external radiation levels are monitored. Media samples are collected from known or expected emissions and effluent pathways, which 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 former waste-disposal cribs and trenches, retention-basin 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.

Investigations of contaminated biota, soil, and other materials are conducted in the operational 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 (e.g., cleanup or construction) sites. Investigations for contaminants are conducted for at least one of the following reasons:

- To follow up surface radiological surveys that had indicated radioactive contamination was present.
- To conduct pre-operational surveys to characterize the radiological and 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.

Contamination incidents investigated in 2006 focused on soil, vegetation, wildlife, and wildlife-related materials (e.g., bird nests, feces). Most materials were surveyed in the field to detect radioactive contamination. Some materials were sampled, and the samples were submitted to an analytical laboratory for analysis. Methods for surveying and sampling these contaminated materials are described in *Operational Environmental Monitoring* (DTS-OEM-001). Laboratory-analysis results and field-survey readings for contamination incidents investigated in 2006 are provided in a separate appendix (PNNL-16623, APP. 2).

Information on contaminant concentrations or radiation levels measured onsite near facilities and operations during 2006 is summarized in Sections 10.2, 10.9, 10.10, 10.11, 10.13, and 10.14. Additional data may be found in PNNL-16623, APP. 2. The type and general locations of samples collected for near-facility monitoring during 2006 are summarized in Table 10.0.1. Information on contamination incidents investigated during 2006 is summarized in Sections 10.9, 10.10, and 10.11.

10.0.2 Public Safety and Resource Protection Projects

The Public Safety and Resource Protection Program at Pacific Northwest National Laboratory manages projects for the DOE Richland Operations Office. These projects are designed to monitor the Hanford Site environment, provide assurance to the public that the site operates in compliance with applicable environmental regulations, and conduct impact assessments to protect public and worker safety, as well as the Hanford Site's significant ecological and cultural resources. The projects obtain environmental information related to public health and environmental effects that is necessary for the DOE to manage environmental risks at the Hanford Site. Whereas effluent and near-facility environmental monitoring are conducted by the

Table 10.0.1. Routine Environmental Monitoring Samples and Locations Near Hanford Site Facilities and Operations, 2006

Sample Type	Number of Sampling Locations	Operational Area								
		100-B/C	100-D	100-F	100-H	100-K	100-N	200/600	300/400	ERDF[a]
Air	77	5	0	5	2	10	3	46	3	3
Soil	89	0	4	4	0	2	4	57	17	1
Vegetation	69	0	0	0	0	0	4	49	16	0
External radiation	137	4	0	0	0	23	14	68	25	3

(a) Environmental Restoration Disposal Facility in the 200-West Area.

facility operating contractor or designated subcontractor, environmental surveillance is conducted independent of the operating contractors and subcontractors.

The projects include the following:

- Meteorological and Climatological Services Project
- Surface Environmental Surveillance Project
- Ecological Monitoring and Compliance Project
- Cultural Resources Project.

Brief overviews of these projects are provided in the following sections.

10.0.2.1 Meteorological and Climatological Services Project

The Meteorological and Climatological Services Project provides information to help assure the public that DOE activities on the Hanford Site that could be affected by adverse meteorological conditions (e.g., thunderstorms, strong winds, blowing dust, dense fog, and snowstorms) operate in as safe and efficient a manner as possible. Meteorological data are important for planning day-to-day work activities. The project also provides meteorological response in the event of a suspected or actual release of radioactive or hazardous material to the atmosphere so that personnel involved in responding to the event can make appropriate and timely decisions. Meteorological data are also integral to the annual estimates of potential public radiation exposure. Comprehensive climatological data records are maintained for use in a variety of other applications, such as post-accident analysis, dose reconstruction, building designs, and environmental impact assessments. Summary meteorological monitoring data for 2006 and some historical climatological information are provided in Section 10.16.

10.0.2.2 Surface Environmental Surveillance Project

The Surface Environmental Surveillance Project is responsible for measuring the concentrations of radiological and non-radiological contaminants in environmental media onsite in the 600 Area (site-wide) and offsite at perimeter, community, and distant locations as well as assessing the potential effects of these materials on the environment and the public. Samples of agricultural products, air, fish and wildlife, soil, surface water and sediment, Columbia River shoreline springs water and sediment, and vegetation are collected routinely. The samples are analyzed for radionuclides and chemicals, including metals, organics, and anions.

Project monitoring activities focus on routine releases from DOE facilities on the Hanford Site; however, the project also conducts sampling and analysis in response to known unplanned releases and releases from non-DOE operations on and near the site. Monitoring results are provided to the DOE and the public annually through this Hanford Site environmental report series. Unusually high contaminant concentrations, should they occur, are reported to the DOE Richland Operations Office and the appropriate facility managers on a timely basis.

The general requirements and objectives for the Surface Environmental Surveillance Project are to monitor routine and non-routine contaminant releases to the environment from DOE facilities and operations, to assess doses to members of the public, to monitor potential impacts of contaminants on other biota, and to alert the DOE to the possible need for corrective action (DOE Orders 450.1 and 5400.5; DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*). The specific objectives of the monitoring activities include the following:

- Collecting and analyzing samples, reviewing and interpreting analytical data, and maintaining a long-term computer database for trend analysis
- Determining 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
- Conducting pre-operational assessments
- Assessing radiological doses to the public and environment
- Assessing doses from other local sources

- Reporting alarm levels and potential doses exceeding reporting limits
- Determining contaminant background levels and site contributions of contaminants in the environment
- Determining long-term accumulations of site-related contaminants in the environment and predicting trends
- Characterizing and defining trends in the physical, chemical, and biological conditions of environmental media
- Determining the effectiveness of treatments and controls in reducing effluents and emissions
- Determining the validity and effectiveness of models to predict concentrations of pollutants in the environment
- Detecting and quantifying unplanned releases
- Identifying and quantifying new environmental quality problems
- Maintaining the capability to assess the consequence of accidental contaminant releases
- Providing public assurance and addressing issues of concern to the public, stakeholders, regulatory agencies, and business community
- Enhancing public understanding of site environmental issues, primarily through public involvement and by providing environmental information to the public
- Providing environmental data and assessments to assist the DOE and its contractors in environmental management of the site.

Annual project reviews are performed to verify that the project is 1) aligned with current operations and missions, 2) focused on those contaminants having the greatest contribution to the potential offsite dose, and 3) providing the greatest amount of useful information for the waste management, cleanup, and environmental assessment activities planned or ongoing at the Hanford Site. Site-wide and offsite surveillance is closely related to and coordinated with the Near-Facility Environmental Monitoring Program described in Section 10.0.1.2 and the Soil and Groundwater Remediation Project (Section 10.0.3).

Information on contaminant concentrations in project samples collected at site-wide and offsite locations during 2006 is summarized in Sections 10.2, 10.4, 10.5, 10.8, and 10.11. Other project information is summarized in Sections 10.12, 10.14, and 10.17. More detailed contaminant data are provided in the *Hanford Site Environmental Surveillance Data Report for Calendar Year 2006* (PNNL-16623, APP. 1). The types and general locations of samples collected for site-wide and offsite environmental surveillance during 2006 are summarized in Table 10.0.2.

10.0.2.3 Ecological Monitoring and Compliance Project

The Ecological Monitoring and Compliance Project has multiple objectives that support both activity-specific ecological compliance requirements and site-wide requirements to make sure that the Hanford Site's natural resources are protected. Project personnel monitor the abundance, vigor, and distribution of plant and animal populations on the Hanford Site and evaluate the cumulative impact of site operations on these resources. In addition, project staff perform baseline ecological resource surveys to document the occurrence of protected resources, evaluate and document impacts to protected species and habitats as required by the *National Environmental Policy Act* and the *Endangered Species Act*, facilitate cost-effective regulatory compliance, and make sure that the DOE fulfills its responsibilities to protect natural resources. This project also supports multiple objectives for completion of the Hanford Site's waste management and environmental restoration mission through the following activities:

- Verifying Hanford Site operational compliance with laws and regulations including the *Endangered Species Act*, the *Bald and Golden Eagle Protection Act*, and the *Migratory Bird Treaty Act*
- Providing data for environmental impact and ecological risk assessments
- Providing maps and information useful for mitigating the impact on biological resources during facility expansions
- Supporting Hanford Site land-use planning and stewardship.

These activities are intended to help protect the natural resources within the DOE-operated portions of the Hanford

Table 10.0.2. Types and General Locations of Samples Collected for Site-Wide and Offsite Environmental Surveillance in 2006

Type	Total Number of Locations	Sampling Locations						
						Columbia River		
		Onsite[a]	Site Perimeter[b]	Nearby[c]	Distant[c]	Upstream[c]	Hanford Reach[b]	Downstream[c]
Air	43	24	11	7	1			
Spring water	17						16	1
Spring sediment	9						8	1
Columbia River water	47					5	31	11
Irrigation water	2			2				
Drinking water	4	4						
River sediment	8					2	3	3
Ponds	2	2						
Pond sediment	1	1						
Foodstuffs	8		1	4	3			
Wildlife	7	7						
Aquatic biota	3					1	2	

(a) Surveillance Zone 1 (between the Near-Facility Environmental Monitoring Program sampling locations and the site perimeter).
(b) Surveillance Zone 2 (near or just inside the site boundary).
(c) Surveillance Zone 3 (in and between communities within an 80-kilometer [50-mile] radius of the site's industrial areas).

Site, including the DOE-managed portion of the Hanford Reach National Monument. These activities also provide information useful to Hanford Site natural resource stakeholders and the public on the status of some of the site's most highly valued biological resources.

Ecosystem and compliance monitoring information for 2006 for Hanford Site plant and animal species and communities is summarized in Sections 10.10 and 10.11.

10.0.2.4 Cultural Resources Project

The Cultural Resources Project operates the Hanford Cultural Resources Laboratory for the DOE. Project personnel perform baseline cultural resource surveys to document the occurrences of protected resources; evaluate and document impacts to protected resources as required by federal laws; facilitate regulatory compliance; and make sure that the DOE fulfills its responsibilities to protect cultural resources. A summary of Hanford Site cultural resource monitoring activities conducted in 2006 is provided in Section 10.15.

10.0.3 Soil and Groundwater Remediation Project

The Soil and Groundwater Remediation Project is responsible for assessing the distribution and movement of existing groundwater contamination (both radiological and chemical) beneath the Hanford Site and for identifying and characterizing potential and emerging groundwater contamination problems. Monitoring activities are conducted to comply with requirements of the *Resource Conservation and Recovery Act* (RCRA), DOE Orders (e.g., 5400.5), and Washington State regulations, as well as requirements for operational monitoring around retired reactors and chemical-processing facilities and requirements for environmental surveillance. Groundwater monitoring is also performed during cleanup investigations under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). Groundwater samples were collected from 974 monitoring wells and shoreline aquifer tubes during 2006. A summary of groundwater monitoring activities and analytical results for 2006 is provided in Section 10.7.

10.0.4 Drinking Water Monitoring Project

DOE Order 5400.5 sets the radiation dose limits for persons consuming water from a public drinking water supply operated by the DOE, or by a DOE contractor, to levels equivalent to those mandated by law in 40 CFR 141, "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule" (federal drinking water standards). The U.S. Environmental Protection Agency (EPA) sets legal limits on the levels of certain contaminants in drinking water. State governments, through their health departments and environmental agencies, are expected to accept the major responsibility for administering and enforcing the limits set by the EPA. In the state of Washington, federal drinking water laws are enforced by the Washington State Department of Health through state administrative codes. The Drinking Water Monitoring Project at the Hanford Site conducts radiological monitoring of DOE-owned, contractor-operated drinking water systems. Section 10.6 provides a summary of the radiological monitoring results for 2006 for the Hanford Site drinking water systems.

10.0.5 Biological Control Program

Biological control is any activity to prevent, limit, clean up, or remediate the impact to the environment, or human health and safety, from contaminated or undesirable plants or animals. The Biological Control Program is responsible for integrating 1) expanded radiological surveillance for contaminated biota and soil, 2) control of undesirable plants and animals, 3) clean up of legacy and new contamination related to biota, and 4) remediation, following cleanup, of sites affected by radioactive contamination spread by plants and animals.

The control of weeds and pests is an important part of the Biological Control Program. Weeds on industrial sites at the Hanford Site are a threat to accumulate radionuclides, become fire hazards, and interfere with work or machinery. At the Hanford Site, the control of weeds occurs at tank farms (clusters of underground radioactive waste storage tanks), radioactive waste pumping installations, industrial sites, power stations and along transmission lines, buildings, storage and work areas, and along fence lines. Pest control prevents, limits, or removes undesirable animals by applying chemical, cultural, or mechanical methods.

Noxious weeds are controlled onsite to prevent their spread and reduce or eliminate their populations. A noxious weed is a legal and administrative category designated by federal or state regulatory agencies (e.g., U.S. Department of Agriculture or Washington State Department of Agriculture). Noxious weeds are non-native, aggressively invasive, and hard to control. Damage to natural ecosystems and loss of productive agricultural lands can occur unless control measures are taken. Control measures can be mechanical, chemical, or biological. Biological control may include preventive measures or measures in response to existing contamination spread.

Activities to prevent the spread of contamination include radiological surveys, preventive controls (e.g., herbicide spraying), and the placement of engineered barriers. If contamination has already spread, typical response measures may include posting the area with radiation signs, stabilizing the contamination to keep it from spreading, and cleaning up and removing the contamination to an approved disposal location.

In some cases, restoration is necessary following clean up and removal of contamination. Restoration is a common activity on the Hanford Site but has specific meanings and limitations when applied to biological control. Restoration may include soil removal and replacement, revegetation of the soil surface, or placement of engineered barriers to stop biological intrusion (biological barriers). Such restoration on radioactive waste sites is typically performed to prevent reoccurrence of surface radioactive contamination or colonization by unwanted biota.

Activities conducted for the Biological Control Program in 2006 are discussed in Sections 10.10 and 10.11.

10.0.6 Washington State Department of Health Oversight Monitoring

The Environmental Radiation Monitoring and Assessment Section of the Washington State Department of Health

conducts an independent oversight program on Hanford Site environmental radiation monitoring conducted by DOE contractors. The contractors are currently the Pacific Northwest National Laboratory and Energy*Solutions* Federal Services of Hanford, Inc. The main objectives of the Washington State Department of Health oversight program are to verify the quality of contractor monitoring programs and to make sure the programs are adequate to protect public health.

The objectives of the Washington State Department of Health oversight program are achieved through split sampling with the contractors and independent sampling at contractor sampling sites. Analysis of Washington State Department of Health samples is performed by the Washington State Public Health Laboratory, which provides a check on contractor analyses. Each year, the Washington State Department of Health compares the measurements of radioactivity in Washington State Department of Health and contractor samples in a quantitative manner to determine the accuracy and reliability of contractor monitoring.

The results of the Washington State Department of Health oversight program are published in the Hanford Environmental Oversight Program data summary report (e.g., DOH 320-043).

10.1 Air Emissions

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Hanford Site contractors monitor airborne emissions from site facilities to assess the effectiveness of emission treatment and control systems and pollution-management practices, and to determine compliance with state and federal regulatory requirements. Measuring devices quantify most facility emission flows, while other emission flows are calculated using process information or fan manufacturer's specifications. For most radioactive air emission units, which are primarily ventilated stacks, sampling is performed either continuously or periodically. Airborne emissions with a potential to contain radioactive materials at prescribed threshold levels are measured for gross alpha and gross beta concentrations, and, as warranted, specific radionuclides. Non-radioactive constituents and parameters are monitored directly, sampled, and analyzed, or estimated based upon inventory usage.

Emissions release data are documented in several reports besides this one, all available to the public. For instance, the DOE annually submits to the EPA and the Washington State Department of Health a report of radionuclide air emissions from the site (DOE/RL-2007-01), in compliance with 40 CFR 61, Subpart H, and with WAC 246-247.

10.1.1 Radioactive Airborne Emissions

Small quantities of tritium (i.e., hydrogen-3), strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, americium-241, and a few other isotopes are released to the environment through state and federally permitted emission points. Distinguishing radionuclides in the environment that were released from the Hanford Site is extremely challenging because concentrations in emissions from Hanford Site stacks are comparable to background concentrations of radionuclides that originated from historical atmospheric nuclear weapons testing. Gross alpha and gross beta concentrations in these emissions are on average equivalent to concentrations in the environment, including concentrations at distant locations upwind of the Hanford Site. The cessation of nuclear materials processing operations is largely responsible for the decreasing radiological emissions from the site.

Radioactive airborne emissions from Hanford Site activities contain particulate and volatilizing forms of radionuclides. The monitoring of radioactive emissions involves analyzing samples collected at points of discharge to the environment, usually from a stack but sometimes a vent. Samples are analyzed for gross alpha and gross beta as well as for selected radionuclides. Emissions having the potential to exceed 1% of the EPA 10-mrem (100-mSv) per year standard for public dose are monitored continuously. The selection of the specific radionuclides sampled, analyzed, and reported is based on 1) an evaluation of the maximum potential public dose from unabated emissions under normal operating conditions from known radionuclide inventories in a facility, and 2) the sampling criteria given in contractor environmental-compliance manuals. Continuous air monitoring systems with alarms are used at selected emission points when the potential exists for radioactive emissions to exceed normal operating ranges to levels that require an immediate personnel alert.

Radioactive-emission points are located in the 100, 200, 300, 400, and 600 Areas of the Hanford Site. For 2006, the prime sources of emissions and the number of emission points by operating area are summarized as follows:

- In the 100 Areas, emissions originated predominately from normal evaporation and cleanup activities at two

water-filled storage basins (100-K East and 100-K West Fuel Storage Basins [also known as the K Basins], which did contain irradiated nuclear fuel), the Cold Vacuum Drying Facility, and a low-level radiological laboratory in the 1706-KE Building. In the 100 Areas, there were five radioactive-emission points.

- In the 200 Areas, the primary sources of radionuclide emissions were the Plutonium Finishing Plant, the T Plant, the Waste Encapsulation and Storage Facility, underground tanks storing high-level radioactive waste, waste evaporators, and the inactive Plutonium-Uranium Extraction (PUREX) Plant. In the 200 Areas, a majority of the 41 potential radioactive-emission points were active in 2006.
- The 300 Area primarily has laboratories and research facilities. The primary sources of airborne radionuclide emissions were the 324 Waste Technology Engineering Laboratory, the 325 Applied Chemistry Laboratory, the 327 Post-Irradiation Laboratory, and the 340 Complex Vault and Tanks. In the 300 Area, a majority of the 16 potential radioactive-emission points were active in 2006.
- The 400 Area has the Fast Flux Test Facility, the Maintenance and Storage Facility, and the Fuels and Materials Examination Facility, all shutdown facilities. Operations and support activities at the Fast Flux Test Facility and the Maintenance and Storage Facility released small quantities of radioactive material to the environment. In the 400 Area, five radioactive-emission points were active in 2006.
- The 600 Area has the Waste Sampling and Characterization Facility, at which low-level radiological and chemical analyses are performed on various types of samples (e.g., particulate air filters, liquids, soil, and vegetation). This facility has two radioactive-emission points, both of which were active in 2006. For dose-modeling purposes, emissions from the Waste Sampling and Characterization Facility, which is very close to the east entrance of the 200-West Area, were grouped with emissions reported for the 200-West Area.

A summary of Hanford Site radioactive airborne emissions in 2006 is provided in Table 10.1.1.

10.1.2 Non-Radioactive Airborne Emissions

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

In past years, gaseous ammonia has been emitted from the Plutonium-Uranium Extraction (PUREX) Plant, 242-A evaporator, AP Tank Farm, and 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. During 2006, the 200 Areas tank farms produced reportable ammonia emissions, summarized in Table 10.1.2.

Onsite diesel-powered electrical-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 "General Regulations for Air Pollution Sources" (WAC 173-400). Power plant emissions are calculated from the quantities of fossil fuel consumed using EPA-approved formulas (AP-42, *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*).

Should activities result in chemical emissions in excess of quantities reportable under CERCLA, the release totals are immediately reported to the EPA. If the emissions remain stable at predicted levels, they may be reported annually with the EPA's permission. Table 10.1.2 summarizes the emissions of non-radioactive pollutants discharged to the atmosphere at the Hanford Site during 2006 (Note: the 100, 400, and 600 Areas have no non-radioactive emission sources of regulatory concern). Table 10.1.2 also includes emission estimates from the carbon tetrachloride vapor extraction work in the 200-West Area. Those emissions are accounted for in the table category of "other toxic air pollutants" and do not require reporting because they are below respective reportable quantities.

Table 10.1.1. Radionuclides Discharged to the Atmosphere at the Hanford Site, 2006

		Release, Ci[(a)]				
Radionuclide	**Half-Life**	**100 Areas**	**200-East Area**	**200-West Area**	**300 Area**	**400 Area**
Tritium (as HT)	12.3 yr	NM	NM	NM	7.0×10^{1}	NM
Tritium (as HTO)	12.3 yr	NM	NM	NM	2.6×10^{2}	3.7×10^{-1}
Strontium-90	29.1 yr	2.3×10^{-5}[(b)]	4.3×10^{-5}[(b)]	3.2×10^{-5}[(b)]	1.2×10^{-6}[(b)]	NM
Iodine-129	16,000,000 yr	NM	1.5×10^{-3}	NM	NM	NM
Xenon-131m	11.8 d	NM	NM	NM	3.1×10^{-8}	NM
Xenon-135	9.1 h	NM	NM	NM	1.0×10^{-8}	NM
Cesium-137	30 yr	NM	1.3×10^{-5}	1.2×10^{-7}	6.0×10^{-6}[(c)]	7.2×10^{-6}[(c)]
Radon-220	55.6 s	NM	NM	NM	3.0×10^{1}	NM
Radon-222	3.8 d	NM	NM	NM	9.1×10^{-1}	NM
Plutonium-238	87.7 yr	2.2×10^{-6}	2.1×10^{-11}	6.0×10^{-7}	ND	NM
Plutonium-239/240	24,110 yr	1.5×10^{-5}[(d)]	1.3×10^{-6}[(d)]	3.2×10^{-5}[(d)]	1.1×10^{-7}[(d)]	1.2×10^{-6}[(d)]
Plutonium-241	14.4 yr	8.3×10^{-5}	ND	2.5×10^{-5}	7.4×10^{-10}	NM
Americium-241	432 yr	1.3×10^{-5}	1.8×10^{-7}	6.6×10^{-6}	4.7×10^{-7}[(e)]	NM
Americium-243	7,380 yr	NM	NM	NM	3.0×10^{-9}	NM
Curium-243/244	18.1 yr	NM	NM	NM	ND	NM

(a) 1 Ci = 3.7×10^{10} becquerels.
(b) This value includes gross beta release data, treated as strontium-90 in dose calculations.
(c) This value includes gross beta release data, treated as cesium-137 in dose calculations.
(d) This value includes gross alpha release data, treated as plutonium-239/240 in dose calculations.
(e) This value includes gross alpha release data, treated as americium-241 in dose calculations.
HT = Elemental tritium.
HTO = Tritiated water vapor.
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.

Table 10.1.2. Criteria[a] and Toxic Air Pollutants Discharged to the Atmosphere at the Hanford Site, 2006

Constituent	Release, kg (lb)	
Particulate matter-total	3,700	(8,200)
Particulate matter-10[b]	2,800	(6,200)
Particulate matter-2.5[b]	1,000	(2,200)
Nitrogen oxides	11,000	(24,000)
Sulfur oxides	2,900	(6,400)
Carbon monoxide	13,000	(28,000)
Lead	0.44	(0.97)
Volatile organic compounds[c,d]	10,000	(22,000)
Ammonia[e]	5,500	(12,000)
Other toxic air pollutants[f]	4,500	(9,900)
Total criteria pollutants[a]	**40,000**	**(89,000)**

(a) Criteria pollutants, as defined by the *Clean Air Act*, include particulate matter – total, nitrogen oxides, sulfur oxides, carbon monoxide, lead, and volatile organic compounds.
(b) Small particles with aerodynamic diameters less than or equal to 10 or 2.5 micrometers.
(c) The estimate of volatile organic compounds does not include emissions from certain laboratory operations.
(d) Produced from burning fossil fuel for steam and electrical generators and calculated estimates from the 200-East and 200-West Areas tank farms, evaporation losses from fuel dispensing, operation of the 242-A evaporator, 200 Area Effluent Treatment Facility, Central Waste Complex, T Plant complex, and Waste Receiving and Processing Facility.
(e) Ammonia releases are calculated estimates from the 200-East and 200-West Areas tank farms and operation of the 242-A evaporator and 200 Area Effluent Treatment Facility, and are produced from burning fossil fuel for steam and electrical generators.
(f) Releases are a composite of calculated estimates of toxic air pollutants, excluding ammonia, from the 200-East and 200-West Areas tank farms, operation of the 242-A evaporator, 200 Area Effluent Treatment Facility, Central Waste Complex, T Plant complex, and Waste Receiving and Processing Facility.

10.2 Ambient-Air Monitoring

B. G. Fritz and C. J. Perkins

Atmospheric releases of radioactive materials from Hanford Site facilities and operations to the surrounding region are potential sources of human exposure. At the Hanford Site, radioactive constituents in air are monitored onsite near facilities and operations, at site-wide locations away from facilities, and offsite around the perimeter of the site and in nearby and distant communities. Information about these ambient-air monitoring efforts, including detailed descriptions of air-sampling and analysis techniques, is provided in the DOE's Hanford Site environmental monitoring plan (DOE/RL-91-50, Rev. 3). Brief summaries of the ambient-air monitoring objectives and the projects that support them are provided in Section 10.0 of this report.

Comparing measured radionuclide concentrations from locations on and around the Hanford Site to concentrations measured at upwind locations assumed to be uninfluenced by Hanford Site operations provides an evaluation of the impact of radionuclide air emissions from the Hanford Site on surrounding ambient air. Complete listings of all radiological analytical results summarized in the following sections are reported separately (PNNL-16623, APP. 1; PNNL-16623, APP. 2).

In addition to the radiological monitoring networks, a small non-radiological air-monitoring system is operated onsite. This system measures concentrations of atmospheric particulate matter (dust) at a few locations on the Hanford Site. Results are primarily used for scientific studies in an attempt to better understand windblown dust on and around the Hanford Site.

10.2.1 Ambient-Air Monitoring Near Facilities and Operations

C. J. Perkins

During 2006, a network of continuously operating samplers at 77 locations across the site (Table 10.2.1) (sampling locations illustrated in PNNL-16623, APP. 2) was used to monitor radioactive materials in air near Hanford Site facilities and operations. Air samplers were located primarily at or within approximately 500 meters (1,640 feet) of sites and/or facilities having the potential for, or a history of, environmental releases. The samplers were predominantly located in the prevailing downwind direction. Samples were collected according to a schedule established before the 2006 monitoring year. Airborne particle samples were collected at each 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 the 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 composite samples for

Table 10.2.1. Monitoring Locations and Analyses for Ambient-Air Monitoring Samples Collected Near Hanford Site Facilities and Operations, 2006

Site	Number of Samplers	EDP Code[a]	Analyses	
			Biweekly	Composite[b]
100-B/C Area field remediation project	5	N464, N465, N466, N496, N497	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
100-F Area field remediation project	5	N519, N520, N521, N552, N553	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
105-H interim safe storage project (100-H Area)	2	N524, N525	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
100-K Area spent nuclear fuels	8	N401, N402, N403, N404, N476, N477, N478, N479	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso, ^{241}Pu, ^{241}Am
118-KR-1 field remediation project (100-K Area)	3	N403, N534, N535	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
100-N Area D4 project	3	N102, N103, N106	Gross alpha, gross beta	GEA, ^{90}Sr, 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, ^{90}Sr, Pu-iso, U-iso
Canister Storage Building (200-East Area)	2	N480, N481	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso,
Integrated Disposal Facility (200-East Area)	2	N532, N559	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
200-West Area	23	N155, N161, N165, N168, N200, N304, N433, N441, N442, N449, N456, N457, N554, N555, N956, N963, N964, N965, N966, N974, N975, N987, N994	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
200-UW-1 decontamination and demolition project (200-West Area)	4	N168, N550, N956, N963	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
300 Area decontamination and demolition project	1	N557	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
300-FF-2 field remediation project (300 Area)	2	N130, N527	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
Environmental Restoration Disposal Facility	4	N482, N517, N518, N963	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso
600 Area (Wye Barricade)	1	N981	Gross alpha, gross beta	GEA, ^{90}Sr, Pu-iso, U-iso

(a) Environmental data point (EDP) Code = Sampler location code. See PNNL-16623, APP. 2.
(b) GEA = Gamma spectroscopy; Pu-iso = isotopic plutonium (^{238}Pu, $^{239/240}$Pu); U-iso = isotopic uranium (^{234}U, ^{235}U, ^{238}U).

each location. Composite samples were routinely analyzed for gamma-emitting isotopes, strontium-90, plutonium-238, plutonium-239/240, uranium-234, uranium-235, and uranium-238, and at locations associated with processing spent nuclear fuel, americium-241, and plutonium-241 (Table 10.2.1).

Figure 10.2.1 shows the annual average air concentrations of selected radionuclides in the 100 and 200/600 Areas compared to EPA concentration values and air concentrations measured in distant communities. The EPA concentration values (40 CFR 61, Appendix E, Table 2) are dose-based reference values that are used as indexes of performance.

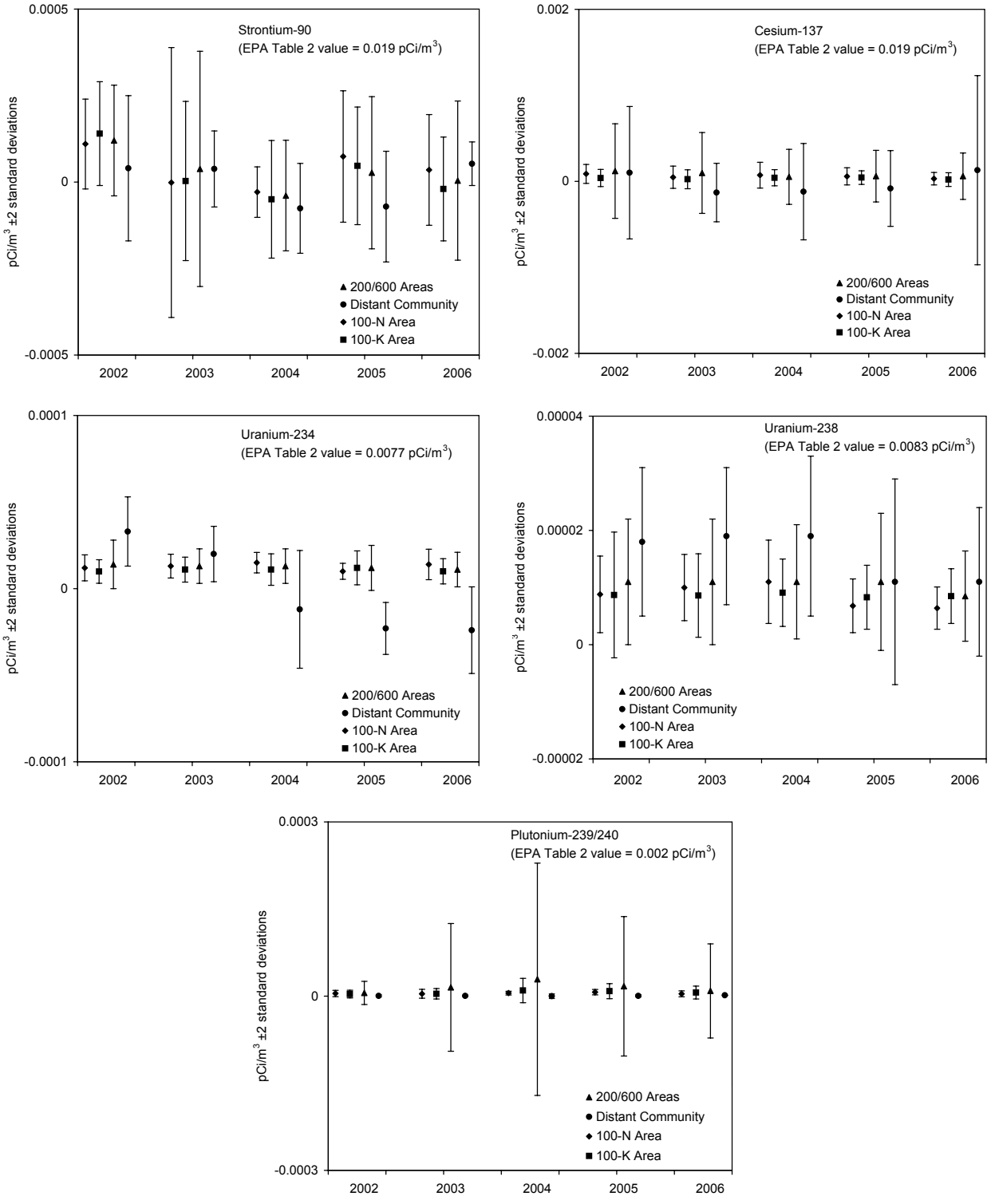


Figure 10.2.1. Average Concentrations of Selected Radionuclides in Ambient-Air Samples Collected on the Hanford Site Near Facilities and Operations Compared to Those Collected in Distant Communities, 2002 Through 2006. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol. Source: 40 CFR 61, Appendix E, Table 2.

The concentration values are concentrations that would result in a dose of 10 mrem (100 μSv) per year under conditions of continuous exposure. The 2006 data indicate a large degree of variability. Air samples collected from locations at or directly adjacent to Hanford Site facilities had higher radionuclide concentrations than did those samples collected farther away. In general, analytical results for most radionuclides were at or near Hanford Site background levels, which are much less than EPA concentration values but greater than those measured offsite. The data also show that concentrations of certain radionuclides were higher and widely variable within different onsite operational areas. Naturally occurring radionuclides beryllium-7 and potassium-40 were routinely identified. Appendix C, Table C.1 shows the annual average and maximum concentrations of radionuclides in air samples collected near facilities and operations during 2006. Concentrations of radionuclides in air in the 300 and 400 Areas, near some onsite remediation projects, and offsite at distant locations were collected by Pacific Northwest National Laboratory personnel. Results for Pacific Northwest National Laboratory air samples are summarized in Section 10.2.2.

At the remedial action project site in the 100-B/C Area, ambient-air monitoring was conducted at five locations in 2006. The radionuclides uranium-234 and uranium-238 were consistently detected, while strontium-90 and uranium-235 were detected in 15% or less of the composited samples.

Air monitoring was conducted at five locations at the 100-F Area in 2006. Similar to results observed during 2006, uranium-234 and uranium-238 were detected consistently in approximately 85% of the samples.

Through August 2006, air monitoring continued at two locations associated with the interim safe storage of the reactor buildings in the 100-H Area. The quarterly analytical results from these air samples showed radionuclide concentrations and frequencies of detection consistent with results observed over the past 6 years. Uranium-234 and uranium-238 were consistently detected (in 75% of the samples). Plutonium-239/240 and strontium-90 were not detected in 2006.

During 2006, ambient-air monitoring was conducted at eight locations in the 100-K Area (four stations each at the 100-K East and 100-K West Areas). With two exceptions, overall airborne contaminant levels in the 100-K Area were similar to those measured over the previous years. Strontium-90, historically detected in approximately 40% of the samples, was not detected during 2006. Americium-241 concentrations were somewhat higher during 2006 than in previous years, and this radionuclide was detected in 50% of the samples. During the second half of 2006, one americium-241 result (0.00044 pCi/m^3 [0.000016 Bq/m^3]) at air-sampling location N403 (100-K East) was greater than 10% of the EPA's Table 2 (40 CFR 61, Appendix E, Table 2) value (0.00019 pCi/m^3 [0.000007 Bq/m^3]) and was reported to the Washington State Department of Health. Review of the biweekly air sample results during the period did not reveal statistically elevated alpha or beta concentrations.

Air sampling to support the 118-K-1 Field Remediation Project (100-K Area) was conducted at three locations during 2006. Uranium-234 and uranium-238 were detected in approximately 90% of the samples, and plutonium-239/240 was detected in approximately 33% of the samples.

During 2006, decontamination and decommissioning activities in the 100-K Area prompted the use of air-monitoring data from three nearby existing air-sampling stations. Air-sampling results obtained from two near-facility stations and one Pacific Northwest National Laboratory air-sampling station indicated that only uranium-234, uranium-235, and uranium-238 were detected consistently, and their concentrations were similar to those measured in previous years.

Analytical results from three ambient-air sampling locations at the 100-N D4 project site (100-N Area) in 2006 were similar to those measured in previous years. Uranium-234 and uranium-238 were detected in approximately 80% of the composite samples, and plutonium-239/240 was detected in 50% of the samples.

Air sampling was conducted at 21 locations in the 200-East Area during 2006. Radionuclide levels measured in the 200-East Area ambient-air composite samples in 2006 were similar to those measured over the previous years. Uranium-234 and uranium-238 were detected in 90% of the samples, and cesium-137 and plutonium-239/240 were detected in 10% of the samples.

Air sampling was conducted at 24 locations in the 200-West Area during 2006. Generally, radionuclide levels measured in the 200-West Area were similar to results for previous years. Uranium-234 and uranium-238 were detected in approximately 85% of the samples. Plutonium-239/240 was detected in approximately 35% of the samples and uranium-235 in less than 25%. During the first half of 2006, one plutonium-239/240 result (0.00036 pCi/m^3 [0.00001 Bq/m^3]) at air-sampling location N165 (located near the 216-Z-9 trench) was greater than 10% of the EPA's Table 2 (40 CFR 61, Appendix E, Table 2) value (0.0002 pCi/m^3 [0.000007 Bq/m^3]) and was reported to the Washington State Department of Health. The elevated plutonium value may be related to (upwind) Plutonium Finishing Plant Closure Project activities that were conducted during the sampling period (e.g., 232-Z Incinerator Facility demolition and cleanout of the 241-Z Liquid Waste Treatment Facility). Review of the biweekly air-sample results during the period did not reveal statistically elevated alpha or beta concentrations.

Air sampling in support of decontamination and decommissioning activities in the 300 Area continued at one location in 2006. Results from the quarterly composited samples showed that only uranium-234 and uranium-238 were detected with any consistency (approximately 90% of the samples).

Air sampling in support of remediation work in the 300-FF-2 Operable Unit (located near the 300 Area) during 2006 was conducted at two ambient-air monitoring stations during the year. Uranium-234 and uranium-238 were detected in 100% of the samples.

The air-sampling network at the Environmental Restoration Disposal Facility (200-West Area) used two established samplers for upwind monitoring (one near-facility sampler and one Pacific Northwest National Laboratory sampler, Station #13 at the 200 W SE location) (Section 10.2.2) and three air samplers at the facility that provided downwind coverage. The 2006 analytical results were comparable to those obtained in previous years. Uranium-234 and uranium-238 were detected in approximately 90% of the near-facility composite samples, and plutonium-239/240 was detected in approximately 60% of the samples.

10.2.2 Site-Wide and Offsite Ambient-Air Monitoring

B. G. Fritz

During 2006, airborne radionuclide samples were collected by 42 continuously operating samplers. The sampling stations were grouped into four location classifications: site-wide (onsite) (23 stations), perimeter (11 stations), nearby communities (7 stations), and distant community (1 station) (Figure 10.2.2 and Table 10.2.2). Air samplers on the Hanford Site were located primarily around major operational areas to maximize the capability to detect radiological contaminants resulting from site operations. Perimeter samplers were located around the site boundary with emphasis on the prevailing downwind directions to the south and east of the site. Samplers located in Basin City, Benton City, Kennewick, Mattawa, Othello, Pasco, and Richland, Washington, provided data for the nearest population centers. A sampler in Yakima, Washington, provided background data from a community essentially unaffected by Hanford Site operations.

10.2.2.1 Collection of Site-Wide and Offsite Ambient-Air Samples and Analytes Tested

Samples were collected according to a schedule (PNNL-15618) established before the monitoring year and were analyzed for up to eight constituents (Table 10.2.2). Airborne particle samples were collected biweekly at each location by continuously drawing air through a glass-fiber filter. The filter 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 radiation. Selected filters were also analyzed for gross alpha radiation. Historically, for most radionuclides, the amount of radioactive material collected on a filter during a 2-week period has been too small for accurate analysis of individual radionuclides of concern. To increase the sensitivity and accuracy of the analysis, biweekly samples were combined

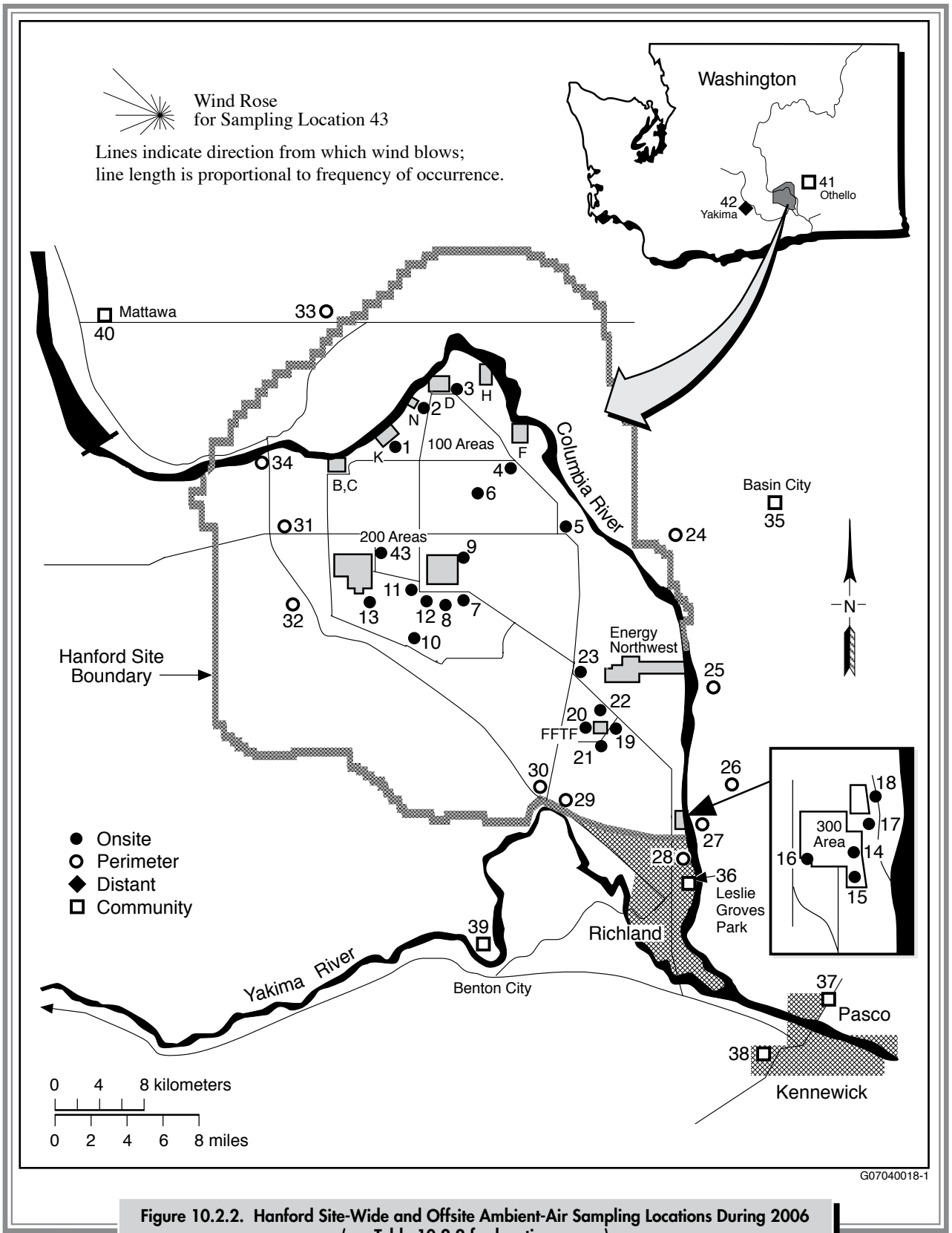


Figure 10.2.2. Hanford Site-Wide and Offsite Ambient-Air Sampling Locations During 2006 (see Table 10.2.2 for location names)

Table 10.2.2. Site-Wide and Offsite Ambient-Air Sampling Locations, Sample Composite Groups, and Analytes, 2006

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

Table 10.2.2. (contd)

Map Location[a]	Sampling Location	Analytes[b]	Composite Group	Analytes[c]
Nearby Communities				
35	Basin City School	Alpha, Beta, ^{3}H	Basin City School	Gamma, Sr, Pu, U
36	Leslie Groves-Richland	Alpha, Beta, ^{3}H	Leslie Groves-Richland	Gamma, Sr, Pu, U
37	Pasco	Beta	Tri-Cities	Gamma, Sr, Pu
38	Kennewick	Alpha, Beta		
39	Benton City	Beta	Benton City	Gamma
40	Mattawa	Beta	Mattawa	Gamma
41	Othello	Beta	Othello	Gamma
Distant Communities				
42	Yakima	Alpha, Beta, ^{3}H, ^{129}I	Yakima	Gamma, Sr, Pu, U
Non-Radiological Monitoring				
43	Hanford Meteorology Station	PM_{10}, $PM_{2.5}$[e]		

(a) See Figure 10.2.2.
(b) Alpha (gross) and beta (gross) samples were collected and analyzed every 2 weeks, ^{3}H samples were collected and analyzed every 4 weeks, and ^{129}I samples were collected every 4 weeks but were not analyzed because of an equipment problem at the analytical laboratory.
(c) Gamma spectroscopy, strontium-90, isotopic plutonium (^{238}Pu, $^{239/240}Pu$), and isotopic uranium (^{234}U, ^{235}U, ^{238}U) analyses were performed on quarterly composite samples.
(d) The N of 200 E station was moved to the top of Gable Mountain in September 2006.
(e) See Section 10.2.2.3.

into quarterly composite samples. The compositing procedure results in a 12-week-average concentration for specific radionuclides present in the atmosphere as particulates. The quarterly composite samples were analyzed for gamma-emitting radionuclides (Appendix F). Most composite samples were also analyzed for strontium-90, plutonium-238, plutonium-239/240, uranium-234, uranium-235, and uranium-238.

Samples were collected for iodine-129 analysis at four locations by drawing air through a cartridge containing a charcoal adsorbent material. Samples were collected monthly and combined to form quarterly composite samples for each location. However, in 2006, samples were collected but not analyzed because of difficulties with the analytical equipment used for iodine-129 analysis.

Atmospheric water vapor was collected for tritium analysis in 2006 at 20 locations by continuously drawing air through multi-column samplers containing adsorbent silica gel. The water-vapor samplers were exchanged every 4 weeks to prevent loss of the sample as a result of breakthrough (i.e., over saturation). 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.

10.2.2.2 Ambient-Air Monitoring Results for Site-Wide and Offsite Samples

All sample results showed very low radiological concentrations in air during 2006. All concentrations (Table 10.2.3) were below their respective DOE-derived concentration guide (Appendix D, Table D.2). The derived concentration guides are concentrations that would result in a 100-mrem (1-mSv) per year dose under conditions of continuous exposure. A more conservative dose standard is the EPA *Clean*

Table 10.2.3. Airborne Radionuclide Concentrations in the Environs of the Hanford Site, 2006 Compared to Previous Years

Radionuclide (approximate detection limit)	Location Group[a]	2006 No. of Samples	2006 No. of Detections[b]	2006 Maximum[c]	2006 Average[d]	2001-2005 No. of Samples	2001-2005 No. of Detections[b]	2001-2005 Maximum[c]	2001-2005 Average[d]	Derived Concentration Guide[e]
				pCi/m³[f]	pCi/m³[f]			pCi/m³[f]	pCi/m³[f]	pCi/m³[f]
Tritium (1.0 pCi/m³)	300 Area	78	78	52 ± 3.6	10 ± 20	457	427	23 ± 2.1	4.8 ± 7.5	100,000
	Site-wide	69	62	32 ± 2.4	3.7 ± 8.6	388	300	16 ± 2.4	2.9 ± 5.2	
	Perimeter	91	87	76 ± 10	7.6 ± 20	458	356	74 ± 10	4.4 ± 13	
	Nearby communities	26	24	160 ± 20	13 ± 59	230	184	61 ± 8.5	4.7 ± 14	
	Distant communities	13	13	5.4 ± 1.2	2.9 ± 2.5	153	82	24 ± 3.8	2.3 ± 5.8	
Gross beta (0.001 pCi/m³)	Site-wide	587	587	0.059 ± 0.0079	0.015 ± 0.016	3,626	3,617	0.14 ± 0.027	0.016 ± 0.021	No standard
	Perimeter	283	283	0.059 ± 0.0097	0.015 ± 0.015	1,692	1,690	0.075 ± 0.012	0.016 ± 0.020	
	Nearby communities	180	180	0.057 ± 0.0094	0.014 ± 0.017	1,249	1,247	0.074 ± 0.012	0.016 ± 0.020	
	Distant communities	26	26	0.029 ± 0.0049	0.013 ± 0.011	326	325	0.062 ± 0.010	0.015 ± 0.019	
				aCi/m³[g]	aCi/m³[g]			aCi/m³[g]	aCi/m³[g]	aCi/m³[g]
Gross alpha (350 aCi/m³)	Site-wide	587	472	7,200 ± 2,300	780 ± 1,000	3,601	2,451	6,300 ± 3,300	590 ± 900	No standard
	Perimeter	283	223	3,000 ± 1,000	750 ± 930	1,692	1,200	5,100 ± 1,300	590 ± 900	
	Nearby communities	79	63	3,700 ± 1,200	700 ± 970	659	495	6,300 ± 1,700	670 ± 1,100	
	Distant communities	26	22	1,500 ± 670	650 ± 550	326	208	5,500 ± 1,900	580 ± 1,100	
Strontium-90 (80 aCi/m³)	Site-wide	37	0	82 ± 71	-0.25 ± 49	247	39	1,300 ± 280	8.2 ± 210	9,000,000
	Perimeter	28	0	47 ± 54	-12 ± 67	167	10	110 ± 64	-9.3 ± 98	
	Nearby communities	12	0	13 ± 61	-15 ± 44	96	7	160 ± 62	-5.9 ± 130	
	Distant communities	4	0	-17 ± 67	-53 ± 63	48	2	300 ± 100	-16 ± 160	
Iodine-129 (0.01 aCi/m³)	Site-wide	Data not available for 2006				24	24	26 ± 2.6	19 ± 8.6	70,000,000
	Perimeter					48	48	1.2 ± 0.14	0.49 ± 0.49	
	Distant communities					24	24	0.22 ± 0.015	0.047 ± 0.084	
Plutonium-238 (3 aCi/m³)	Site-wide	44	0	1.1 ± 2.6	-0.17 ± 1.7	248	15	13 ± 3.9	0.13 ± 2.5	30,000
	Perimeter	24	0	1.3 ± 2.4	-0.16 ± 1.2	167	0	4.6 ± 4.5	-0.057 ± 1.5	
	Nearby communities	12	0	0.94 ± 2.6	-0.15 ± 1.3	96	1	3.7 ± 3.6	-0.015 ± 1.8	
	Distant communities	4	0	0.44 ± 2.7	-0.27 ± 1.1	48	0	2.0 ± 4.6	-0.37 ± 1.3	
Plutonium-239/240 (3 aCi/m³)	Site-wide	44	6	15 ± 9.1	1.4 ± 5.9	248	55	100 ± 19	2.0 ± 15	20,000
	Perimeter	24	1	4.2 ± 3.0	4.2 ± 0.62	167	6	6.7 ± 4.6	0.33 ± 2.1	
	Nearby communities	12	0	2.2 ± 3.4	2.2 ± 0.28	96	5	3.2 ± 4.6	0.42 ± 1.8	
	Distant communities	4	0	1.5 ± 1.9	1.5 ± 0.13	48	0	2.4 ± 3.0	0.22 ± 1.6	

Table 10.2.3. (contd)

Radionuclide (approximate detection limit)	Location Group[a]	2006 No. of Samples	2006 No. of Detections[b]	2006 Maximum[c] aCi/m³[g]	2006 Average[d] aCi/m³[g]	2001-2005 No. of Samples	2001-2005 No. of Detections[b]	2001-2005 Maximum[c] aCi/m³[g]	2001-2005 Average[d] aCi/m³[g]	Derived Concentration Guide[e] aCi/m³[g]
Uranium-234 (10 aCi/m³)	Site-wide	32	0	34 ± 310	-7.8 ± 33	190	136	150 ± 52	16 ± 49	90,000
	Perimeter	16	0	31 ± 240	-8.4 ± 35	96	68	140 ± 32	17 ± 55	
	Nearby communities	8	0	4.7 ± 220	-16 ± 25	72	50	58 ± 21	13 ± 48	
	Distant communities	4	0	-5.7 ± 230	-24 ± 25	48	32	34 ± 14	5.6 ± 39	
Uranium-235 (10 aCi/m³)	Site-wide	32	0	6.4 ± 16	-1.0 ± 3.9	190	2	6.5 ± 8.5	-0.062 ± 3.3	100,000
	Perimeter	16	0	2.4 ± 18	-0.98 ± 3.0	96	0	4.3 ± 4.7	0.11 ± 3.5	
	Nearby communities	8	0	0.94 ± 12	-1.2 ± 2.4	72	0	6.1 ± 8.1	-0.38 ± 4.2	
	Distant communities	4	0	0.69 ± 13	-2.1 ± 4.1	48	0	7.0 ± 9.3	-0.77 ± 4.5	
Uranium-238 (10 aCi/m³)	Site-wide	32	28	60 ± 16	17 ± 23	190	177	160 ± 37	22 ± 43	100,000
	Perimeter	16	16	57 ± 15	20 ± 25	96	90	140 ± 32	25 ± 39	
	Nearby communities	8	7	26 ± 10	15 ± 16	72	68	52 ± 16	22 ± 22	
	Distant communities	4	3	20 ± 8.8	11 ± 13	48	43	29 ± 14	16 ± 15	
Cobalt-60 (1,200 aCi/m³)	Site-wide	48	0	750 ± 810	29 ± 490	296	1	3,800 ± 2,500	75 ± 860	80,000,000
	Perimeter	32	0	530 ± 730	-1.1 ± 660	201	0	910 ± 1,700	-2.0 ± 750	
	Nearby communities	24	0	900 ± 940	130 ± 730	174	0	1,800 ± 3,600	49 ± 910	
	Distant communities	4	0	700 ± 740	460 ± 510	50	0	730 ± 1,000	66 ± 600	
Cesium-137 (1,000 aCi/m³)	Site-wide	48	0	440 ± 600	3.8 ± 460	296	3	3,500 ± 1,500	12 ± 720	400,000,000
	Perimeter	32	0	600 ± 750	-88 ± 590	201	2	4,600 ± 1,300	67 ± 930	
	Nearby communities	24	0	710 ± 1,000	8.4 ± 640	174	0	2,100 ± 3,100	38 ± 910	
	Distant communities	4	0	630 ± 970	-130 ± 1,100	50	0	530 ± 520	-27 ± 600	

(a) Location groups are identified in Table 10.2.2.
(b) Detection is defined as a value reported above the minimum detectable activity and above the total propagated analytical uncertainty.
(c) Maximum single sample result ± total analytical uncertainty. Negative concentration values are explained in Appendix A.
(d) Average of all samples ±2 times the standard deviation.
(e) DOE-derived concentration guide (see Appendix D, Table D.2).
(f) 1 pCi = 0.037 Bq.
(g) There are 1 million attocuries (aCi) in 1 picocurie (pCi).

Air Act standard of 10 mrem (100 µSv) per year from airborne radiological material. All radionuclide concentrations in air samples collected in 2006 were low enough to meet the EPA standard; no air samples were collected in 2006 with concentrations high enough to result in a 10-mrem (100-µSv) annual dose.

Gross alpha concentrations were essentially the same at site-wide and offsite locations during 2006 (Figure 10.2.3). There were no statistically significant (two-sample means t-test, 95% confidence level) differences in the average gross alpha concentrations measured at the different distant classes. The highest gross alpha concentration for 2006 was observed at a site-wide location near the 100-F Area (7,200 aCi/m^3 [270 µBq/m^3]). The average gross alpha concentrations observed in individual location groups during 2006 were slightly higher than the 5-year average concentrations observed in the groups from 2001 through 2005 (Table 10.2.3).

Gross beta concentrations in air peaked during the fall and winter months in 2006 (Figure 10.2.4), repeating a pattern of natural radioactivity fluctuations (Eisenbud 1987). The annual average gross beta concentrations at site-wide locations during 2006 were slightly higher than the concentration measured at the distant location. The differences were small and not statistically significant (two-sample means t-test, 95% confidence level). The average gross beta concentrations reported for 2006 were slightly higher than concentrations measured from 2001 through 2005 (Table 10.2.3). However, the differences were not statistically significant (two-sample means t-test, 95% confidence level).

In 2004, gross beta concentrations appeared to be inversely proportional to the average wind speed over the sampling period; i.e., as wind speed increased, concentrations decreased. This pattern was evident again in 2006 (Figure 10.2.4). Section 10.2.2.4 describes sampling done in 2006 and early 2007 to further explore this relationship.

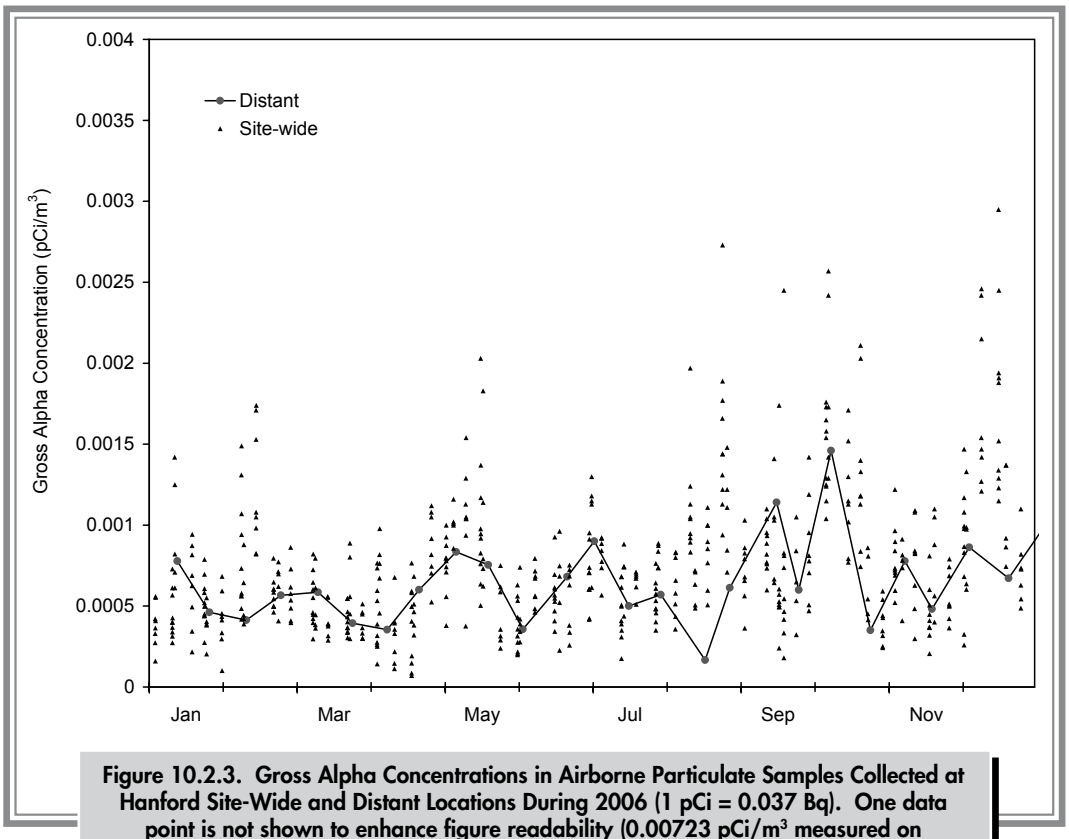


Figure 10.2.3. Gross Alpha Concentrations in Airborne Particulate Samples Collected at Hanford Site-Wide and Distant Locations During 2006 (1 pCi = 0.037 Bq). One data point is not shown to enhance figure readability (0.00723 pCi/m^3 measured on October 23, 2006, at the 100-F Area meteorology tower).

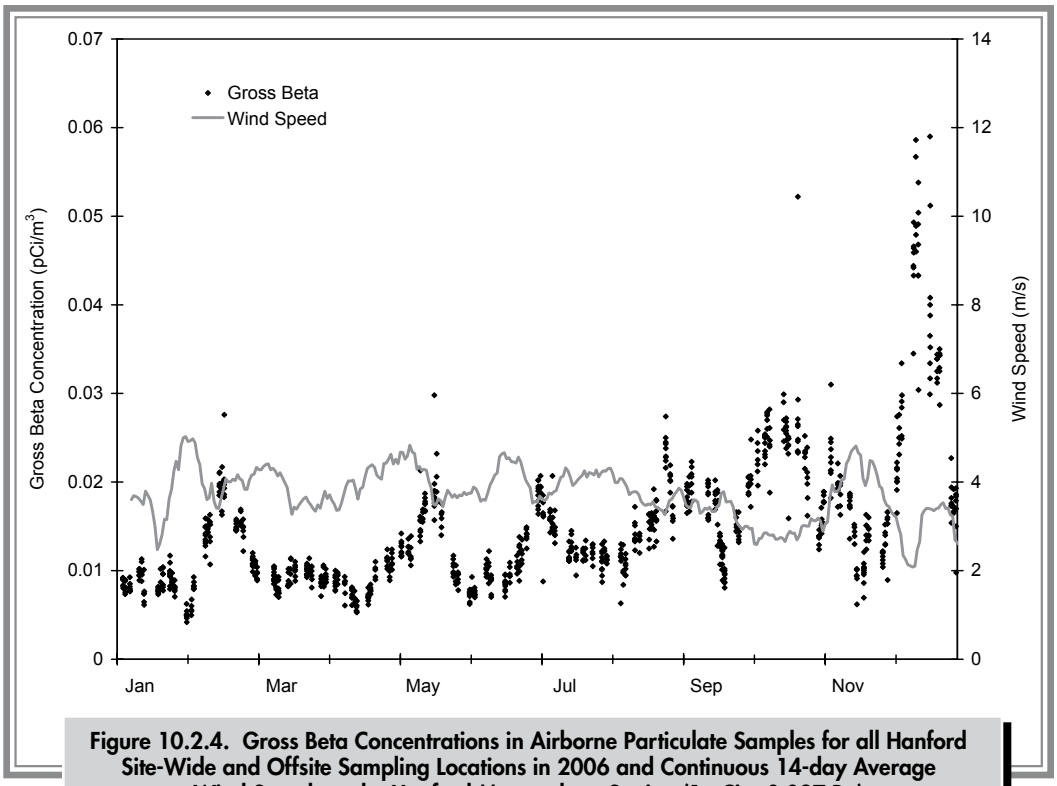


Figure 10.2.4. Gross Beta Concentrations in Airborne Particulate Samples for all Hanford Site-Wide and Offsite Sampling Locations in 2006 and Continuous 14-day Average Wind Speeds at the Hanford Meteorology Station (1 pCi = 0.037 Bq)

Tritium concentrations measured at all locations during 2006 were similar, but slightly higher than average values reported for 2001 through 2005 (Table 10.2.3). The annual average 300 Area, perimeter, and community concentrations were higher than the annual average concentration measured at the distant location, although the differences were not statistically significant (two-sample means t-test, 95% confidence level). The sample with the highest tritium concentration measured during 2006 (76 pCi/m^3 [2.8 Bq/m^3]) was collected at the Battelle complex sampling location in the city of Richland (location 28 on Figure 10.2.2) during November. This concentration was 0.076% of the DOE-derived concentration guide for tritium (Appendix D, Table D.2). The increased tritium concentrations measured in 2006 were consistent with an increase in tritium emissions from the 300 Area in 2006 (see Section 10.1.1).

Iodine-129 analyses were not performed on samples collected in 2006 (Table 10.2.2) because the mass spectrometer used to analyze samples for iodine-129 failed. However, based on trends in concentrations measured in previous years and site operations in 2006, the annual average concentrations of iodine-129 in 2006 were not expected to have been significantly different than concentrations measured in recent years (Table 10.2.2).

Plutonium-238 was not detected in any site-wide or offsite air samples collected during 2006 (Table 10.2.3). The maximum reported plutonium-238 concentration in 2006 was 1.1 aCi/m^3 (0.041 µBq/m^3), or 27,000 times below the DOE-derived concentration guide for plutonium-238 (30,000 aCi/m^3 [1,100 µBq/m^3]).

The annual average plutonium-239/240 concentration in air samples collected in 2006 at site-wide locations was 1.4 aCi/m^3 (0.052 µBq/m^3). Of the 44 site-wide samples analyzed for plutonium-239/240, 6 had detectable concentrations (Table 10.2.3). The two samples with the highest measured concentrations of plutonium-239/240 were collected at the 300 Trench sampling location (300 Area) between January and June 2006. These samples may have been affected by ongoing cleanup activities in the 300 Area. The maximum reported concentration (15 aCi/m^3 [0.56 µBq/m^3]) was 1,300 times less than

the DOE-derived concentration guide (20,000 aCi/m^3 [730 µBq/m^3]) for plutonium-239/240.

Average isotopic uranium concentrations (uranium-234, uranium-235, and uranium-238) in airborne particulate matter in 2006 were lower than average concentrations measured from 2001 through 2005 for all location groups (Table 10.2.3). The 2006 annual average uranium-238 concentration at the site perimeter was 17 aCi/m^3 (0.63 µBq/m^3), which is 0.02% of the DOE-derived concentration guide (100,000 aCi/m^3 [3,700 µBq/m^3]). The annual average site-wide and perimeter uranium-238 concentrations were not different than the concentration measured at the distant location by a statistically significant amount (two-sample means t-test, 95% confidence level). Similar to plutonium-239/240, the three highest uranium-238 concentrations measured in 2006 were for samples collected at the 300 Trench sampling location (Figure 10.2.2). The maximum measured uranium-238 concentration measured in 2006 (60 aCi/m^3 [2.2 µBq/m^3]) was only 0.06% of the DOE-derived concentration guide for uranium-238.

Eighty-one airborne-particulate samples were analyzed for strontium-90 in 2006 (Table 10.2.3). No samples had detectable concentrations.

Gamma spectroscopy was conducted on all quarterly composite samples collected in 2006. Naturally occurring beryllium-7 and potassium-40 were occasionally identified. The potential Hanford Site-origin gamma-emitting radionuclides cobalt-60 and cesium-137 were not detected in any air samples collected in 2006.

10.2.2.3 Monitoring of Airborne Particulate Matter on the Hanford Site

Airborne particulate matter (dust) is one of the EPA's criteria pollutants. The EPA classifies particulate matter by particle size. PM_{10} is an air pollutant consisting of small particles with aerodynamic diameters less than or equal to 10 micrometers. Similarly, $PM_{2.5}$ is an air pollutant consisting of small particles with aerodynamic diameters less than or equal to 2.5 micrometers (PM_{10} particles can include $PM_{2.5}$). The EPA's "National Primary and Secondary Ambient Air Quality Standards" (40 CFR 50) for PM_{10} requires a 24-hour average concentration of less than 150 µg/m^3. The newly established EPA standards for $PM_{2.5}$ are 35 µg/m^3 for a 24-hour average concentration and 15 µg/m^3 for an annual average concentration. Health-risk studies have shown a positive correlation between increases in concentrations of airborne particulate matter and increased hospital admissions for pulmonary and heart conditions (Schwartz 1994; Morgan et al. 1998; Ostro et al. 1999). Studies have indicated that a 100-µg/m^3 increase in PM_{10} concentrations results in a 17% increase in hospital admissions for pneumonia and chronic obstructive pulmonary disorder (Schwartz 1994). Similar relationships were found between PM_{10} concentrations and daily human mortality in areas where windblown dust was the main contributor to high PM_{10} concentrations (Ostro et al. 1999).

During February 2001, monitoring of particulate matter mass concentrations in air at the Hanford Site began. The motivation for this was the decrease in vegetative cover on a large portion of the site after the 24 Command Wildland Fire in 2000 (PNNL-13487) as well as information requests from the public. It was expected that the decrease in vegetative cover would result in increased wind erosion, and subsequently, increased particulate matter (dust) concentrations in air. Particulate monitoring occurs at the Hanford Meteorology Station (location 43, Figure 10.2.2 and Table 10.2.2) using a tapered element oscillating microbalance. This instrument measures the difference in mass collected on a filter by measuring the change in frequency of oscillation of the filter. The instrument records an hourly average concentration, but daily average concentration data were calculated for this report. The PM_{10} concentration data have been collected at the Hanford Meteorology Station since February 2001, while $PM_{2.5}$ concentration data collection began at the Hanford Meteorology Station in October 2001.

In 2006, the tapered element oscillating microbalance PM_{10} instrument only operated 40% of the time. Although Hanford Site measurements are not used to determine compliance with air quality standards (Section 5.2.1), EPA standards were not exceeded at the measurement locations on the Hanford Site. The observed annual average PM_{10} concentration at the Hanford Meteorology Station during 2006 (12.7 µg/m^3) was well below the EPA annual average standard (50 µg/m^3) and was typical of annual average PM_{10} concentrations measured in recent years. Daily average

PM_{10} concentrations on the Hanford Site did not exceed the EPA 24-hour average standard during any of the days when monitoring occurred in 2006.

In 2006, $PM_{2.5}$ monitoring only occurred for about 2 1/2 months (January through mid-March) because of instrument problems. The average $PM_{2.5}$ concentration during this time period was 4.5 $\mu g/m^3$ or more than three times lower than the proposed EPA annual average standard of 15 $\mu g/m^3$.

10.3 Liquid Effluents from Hanford Site Facilities

D. J. Rokkan

Liquid effluents are discharged from some facilities at the Hanford Site. Effluent streams are sampled for gross alpha and gross beta concentrations as well as for concentrations of selected radionuclides.

Contaminant data from liquid effluent sampling and analyses are reported to the DOE annually in an environmental releases report (HNF-EP-0527-16). This report also includes 1) summaries of monitoring results on liquid effluents discharged to the Columbia River, which are regulated by the National Pollutant Discharge Elimination System permit and reported quarterly to the EPA; and 2) liquid-effluent discharges to the soil, which are regulated by WAC 173-216 and reported quarterly to the Washington State Department of Ecology.

10.3.1 Radionuclides in Liquid Effluents

During 2006, only facilities in the 200 Areas discharged radioactive liquid effluents to the ground at a single location, the 616-A crib, also known as the State-Approved Land Disposal Site. A summary of radioactive liquid effluent is provided in Table 10.3.1. Table 10.3.2 summarizes data on radionuclides in liquid effluent released from the 100 Areas to the Columbia River, the sources of which include secondary cooling water used at the K Basins.

Table 10.3.1. Radionuclides in 200 Areas Liquid Effluent Discharged to the State-Approved Land Disposal Site at the Hanford Site, 2006

Radionuclide	Half-Life	Release, Ci[(a)]
Tritium	12.3 yr	20

(a) 1 Ci = 3.7×10^{10} Bq.

Table 10.3.2. Radionuclides in Liquid Effluent from the 100 Areas Discharged to the Columbia River, 2006

Radionuclide	Half-Life	Release, Ci[(a)]
Strontium-90	29.1 yr	1.0×10^{-2}
Plutonium-239/240	24,110 yr	6.6×10^{-5}

(a) 1 Ci = 3.7×10^{10} Bq.

10.3.2 Non-Radioactive Hazardous Materials in Liquid Effluents

Non-radioactive hazardous materials in liquid effluent are monitored in the 100, 200, 300, and 400 Areas. The effluent is discharged to the State-Approved Land Disposal Site and to the Columbia River. Effluent entering the environment at designated discharge points is sampled and analyzed to determine compliance with the National Pollutant Discharge Elimination System permits (40 CFR 122) and the state waste discharge permits (WAC 173-216) for the site. Should chemicals in liquid effluent exceed quantities reportable under CERCLA, the release totals are immediately reported to the EPA. If chemical levels in effluent remain stable at predicted levels, they may, with the EPA's permission, be reported annually. Section 5.3.1 provides a synopsis of the National Pollutant Discharge Elimination System and state waste discharge permit.

10.4 Surface-Water and Sediment Monitoring

G. W. Patton

Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the concentrations of radiological and chemical contaminants from the Hanford Site in the aquatic environment. Surface-water bodies monitored included the Columbia River, onsite ponds, and offsite irrigation sources (Figure 10.4.1). Aquatic sediment monitoring was conducted for the Columbia River and one onsite pond. Tables 10.4.1 and 10.4.2 summarize the sampling locations, types, and frequencies and also the sample analyses included in surface-water and sediment monitoring during 2006. This section describes the monitoring efforts and summarizes the results for these aquatic environments. Detailed analytical results are reported in PNNL-16623, APP. 1.

10.4.1 Monitoring of Columbia River Water

The Columbia River is one of the largest rivers 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 was based, in part, on the abundant water supply offered by the river. The river flows through the northern portion 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 removed from the river immediately downstream of the site also is used for crop irrigation in Benton and Franklin Counties. 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 Rocky Mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of approximately 670,000 square kilometers (260,000 square miles) before discharging to the Pacific Ocean. The flow of the river is regulated by 3 dams in Canada and 11 dams in the United States; 4 of the dams are 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 downstream 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 upstream of Bonneville Dam (the first dam upstream from the ocean) that remains unimpounded.

River flow through the Hanford Reach fluctuates significantly and is controlled primarily by operations at upstream dams. The annual average flow of the Columbia River downstream of Priest Rapids Dam is approximately 3,400 cubic meters (120,000 cubic feet) per second (WA-94-1). In 2006, the Columbia River had normal flows; the average daily flow rate downstream of Priest Rapids Dam was 3,350 cubic meters (118,000 cubic feet) per second. The peak monthly average flow rate occurred during June (5,960 cubic meters [210,500 cubic feet] per second) (Figure 10.4.2). Using mean daily flows, the lowest monthly average flow rate occurred during September (1,960 cubic meters [69,200 cubic feet] per second). Daily average flow rates varied from 1,250 to 7,730 cubic meters (44,200 to 273,000 cubic feet) per second during 2006. As a result of fluctuation in discharges, the depth of the river varies significantly over time. The river stage (water-surface level) may change along the Hanford Reach by up to 3 meters (10 feet) within a few hours (see Section 3.3.7 in PNL-10698). Seasonal changes of

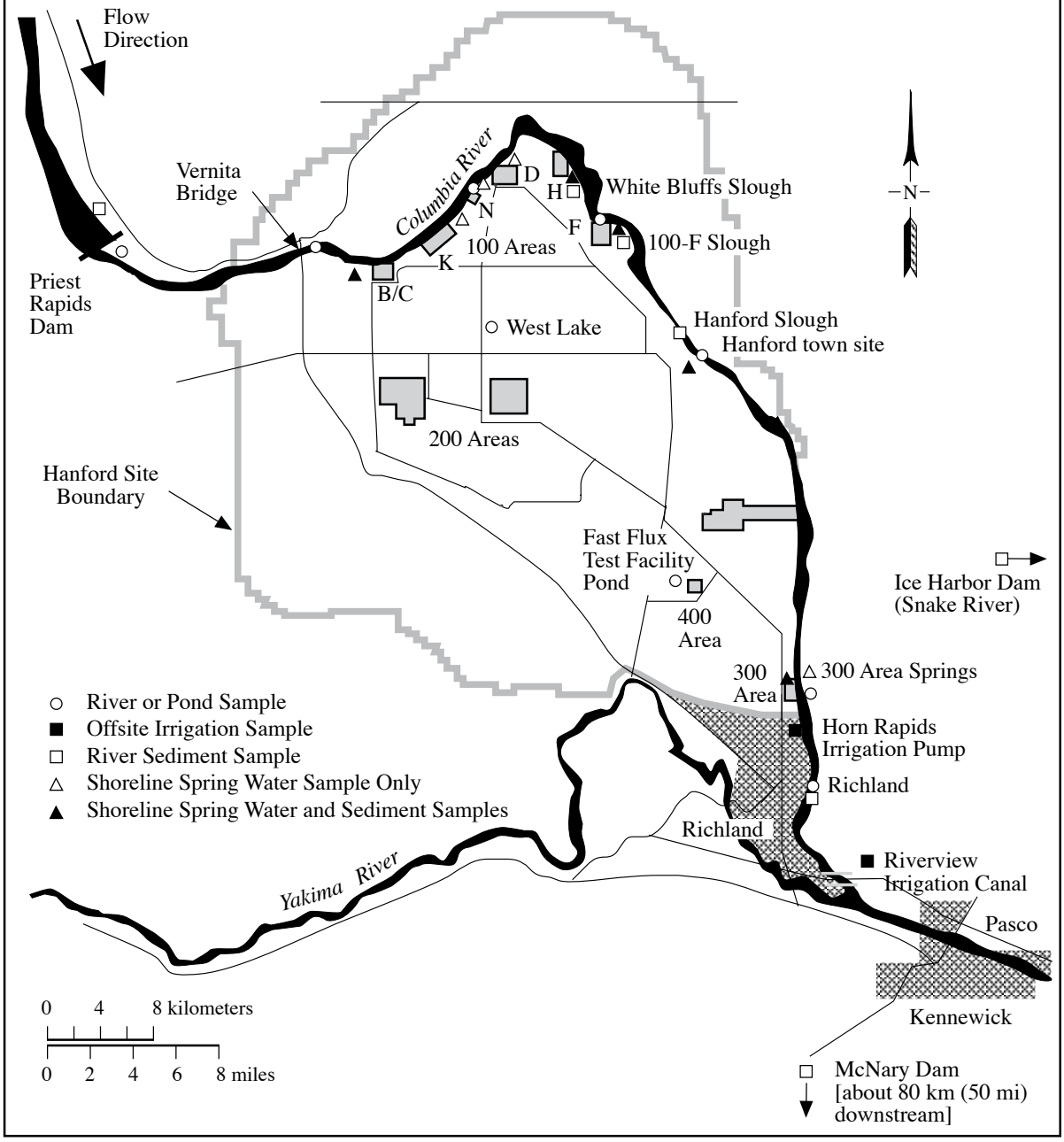


Figure 10.4.1. Surface-Water and Sediment Sampling Locations On and Around the Hanford Site, 2006

Table 10.4.1. Surface-Water Surveillance On and Near the Hanford Site, 2006

Location	Sample Type	Frequency	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland	Cumulative	M Comp[a] Q Comp[d]	Alpha, beta, low ^{3}H,[b] ^{90}Sr, ^{99}Tc, U[c] ^{129}I
	Particulate (filter)	M Cont[e] Q Cont[f]	Gamma energy analysis Pu[g]
	Soluble (resin)	M Cont Q Cont	Gamma energy analysis Pu
Vernita Bridge and Richland	Grab (transects)	Quarterly	low ^{3}H, ^{90}Sr, U
100-F, 100-N, and 300 Areas, and Hanford town site	Grab (transects)	Annually	low ^{3}H, ^{90}Sr, U
Columbia River - Chemical			
Vernita Bridge and Richland[h]	Grab	3/year	Temperature, dissolved oxygen, turbidity, pH, alkalinity, anions, suspended solids, dissolved solids, specific conductance, hardness (as $CaCO_3$), Ca, P, Cr, Mg, N, Fe, NH_3, NO_3 + NO_2
	Grab (transects)	Quarterly	Anions
	Grab (transects)	Annually	Metals (filtered and unfiltered), volatile organic compounds
100-N and 300 Areas and Hanford town site	Grab (transects)	Annually	Metals (filtered and unfiltered), anions
Onsite Ponds			
West Lake[i]	Grab	Quarterly	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U, gamma energy analysis
Fast Flux Test Facility pond	Grab	Quarterly	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	3/year	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma energy analysis

(a) M Comp indicates river water was collected hourly and composited monthly for analysis.
(b) Low ^{3}H = Low-level tritium analysis (10-pCi/L detection limit), which includes an electrolytic preconcentration.
(c) U = Isotopic uranium-234, uranium-235, and uranium-238.
(d) Collected hourly and composited for quarterly analysis.
(e) M Cont = River water was sampled for 2 weeks by continuous flow through a filter and resin column, and multiple samples were composited monthly for analysis.
(f) Q Cont = River water was sampled for 2 weeks by continuous flow through a filter and resin column, and multiple samples were composited quarterly for analysis.
(g) Pu = Isotopic plutonium-238 and plutonium-239/240.
(h) Numerous water-quality analyses are performed by the U.S. Geological Survey under contract to Pacific Northwest National Laboratory.
(i) Because of high concentrations of suspended sediment, West Lake water is analyzed for tritium; all other analytes are for sediment samples.

Comp = Composite.
Cont = Continuous.
M = Monthly.
Q = Quarterly.

approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (PNL-8580) and the relative distance of each area from Priest Rapids Dam. The width of the river varies from approximately 300 to 1,000 meters (980 to 3,300 feet) as it passes through the Hanford Site. Changing river flows result in changes in concentrations of contaminants in river water for users downstream of the Hanford Site (PNL-8531).

Pollutants from several sources enter the Columbia River as it passes through the Hanford Reach, including discharges from agricultural activities on the Grant and Franklin Counties side and from the Hanford Site (Benton County side). Hanford Site pollutants, both radiological and chemical, enter the Columbia River along the Hanford

Table 10.4.2. Columbia River Sediment Surveillance, 2006

Location[a]	Frequency	Analyses
Columbia River		River-sediment analyses included gamma energy analysis, ^{90}Sr, U,[b] Pu,[c] metals, and total organic carbon
Priest Rapids Dam: Two locations near the dam	Annually	
White Bluffs Slough	Annually	
100-F Slough	Annually	
Hanford Slough	Annually	
Richland	Annually	
McNary Dam: Two locations near the dam	Annually	

(a) See Figure 10.4.1.
(b) U = Isotopic uranium-234, uranium-235, and uranium-238 analyzed by alpha spectrometry (alpha energy analysis).
(c) Pu = Isotopic plutonium-238 and plutonium-239/240.

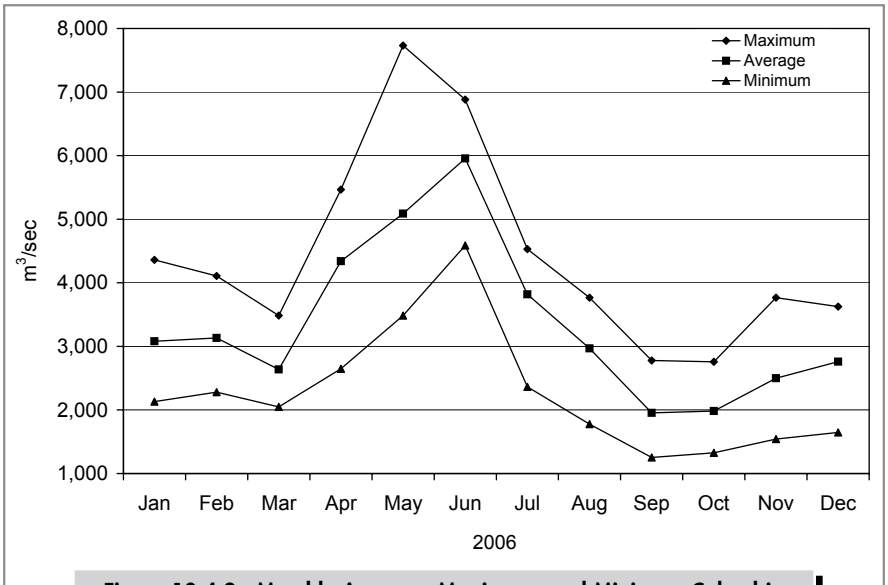


Figure 10.4.2. Monthly Average, Maximum, and Minimum Columbia River Flow Rates at Priest Rapids Dam, Washington, 2006

Reach. Effluent from each direct discharge point is monitored routinely and reported by the responsible operating contractor (Section 10.3). Direct discharges are identified and regulated for non-radiological constituents under the National Pollutant Discharge Elimination System in compliance with the *Clean Water Act* (Section 5.3.1). In addition to permitted direct discharges of liquid effluent from Hanford Site facilities, contaminants in groundwater from past operational discharges to the ground seep into the river (DOE/RL-92-12, Rev. 1; PNL-5289; PNL-7500; WHC-SD-EN-TI-006; Section 10.5 of this report). In general, groundwater discharges are considered to be the dominant pathway for Hanford Site contaminants to enter the Columbia River.

Washington State formerly classified the general water-use and water-quality criteria for 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.3). In 2003, the Washington State Department of Ecology revised the surface-water quality standards (WAC 173-201A). The Class A (Excellent) designated uses criteria were replaced with separate designations for aquatic life uses, recreational uses, water-supply uses,

and miscellaneous uses. For the Columbia River downstream from Grand Coulee Dam, the aquatic-life designation is "salmonid spawning, rearing, and migration," which provides for the protection of spawning, rearing, and migration of salmon and trout as well as other associated aquatic life. The recreational uses designation for the Columbia River downstream from Grand Coulee Dam is "primary contact," which provides for activities that may involve complete submersion by the participant. The entire Columbia River is designated as suitable for all water supply and miscellaneous uses by the state of Washington.

10.4.1.1 Collection of Columbia River Water Samples and Analytes of Interest

During 2006, Columbia River water samples were collected from fixed-location monitoring stations at Priest Rapids Dam and Richland, Washington (analyzed for radionuclides) and also from cross-river transects and near-shore locations near the Vernita Bridge, 100-N Area, Hanford town site, 300 Area, and the city of Richland, Washington (analyzed for both radionuclides and chemicals, Figure 10.4.1). Samples were collected upstream from Hanford Site facilities at Priest Rapids Dam and the Vernita Bridge to provide data from locations unaffected by site operations. Samples were collected from all other locations to identify any increase in contaminant concentrations attributable to Hanford Site operations, including a municipal drinking-water supply and points of withdrawal for irrigation water downstream of the Hanford Site. The sampling of irrigation water systems is discussed in Section 10.4.4.

The fixed-location monitoring stations at Priest Rapids Dam and Richland, Washington, consist of an automated sampler and a continuous flow system. Using the automated sampler, unfiltered samples of Columbia River water (cumulative samples) were obtained hourly and composited for a period of 7 days. These weekly samples were combined into monthly and quarterly composite samples for radiological analyses (Table 10.4.1). Using the continuous flow system, particulate and soluble constituents in Columbia River water 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 DOE/RL-91-50, Rev. 3.

Radionuclides of interest were selected for analysis based on the following criteria:

- Their presence in effluent discharged from site facilities or in near-river groundwater underlying the Hanford Site.
- Their importance in determining water quality, verifying facility effluent controls and monitoring systems, and determining compliance with applicable water-quality standards.

Constituents of interest in river water samples collected at Priest Rapids Dam and Richland, Washington, included gamma-emitting radionuclides, tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240. Water samples were collected but not analyzed for iodine-129 in 2006 because the unique instrument used for this assay was broken, and an alternative for this ultra-trace measurement capability was not available in 2006. Gross alpha and gross beta measurements were also made as indicators of the general radiological quality of the river and to provide a timely indication of change. Gamma-energy analysis provides the capability to detect numerous specific radionuclides (Appendix F). Analytical detection levels (defined as the laboratory-reported minimum detectable concentration) for all radionuclides were less than or equal to 10% of their respective Washington State water-quality criteria levels (Appendix D, Tables D.3 and D.4). Unless otherwise noted in this section, the statistical tests for differences are paired sample comparisons and two-tailed t-tests, with alpha at 5% significance level.

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 Richland. During 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 10 evenly spaced cross-river transect samples, only 6 cross-river samples were collected, and the other 4 samples were obtained at near-shore locations (typically less than 5 meters [16 feet] from shore). This sampling pattern was used during 2006 and allowed the cross-river concentration profile to be determined and also provided information over a larger portion of the Hanford Site shoreline where the highest contaminant concentrations would be expected. The Vernita Bridge and Richland transects and near-shore locations were sampled quarterly during 2006. Annual transect and near-shore sampling were conducted at the 100-N Area, the Hanford town site, and 300 Area locations in late summer when river flows were low to provide the highest probability of detecting Hanford Site contaminants (PNL-8531).

Columbia River transect water samples collected during 2006 were analyzed for both radiological and chemical contaminants (Table 10.4.1). Specific metals and anions 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, Draft B; PNL-8073; PNL-8654; PNL-10400; PNL-10535). All radiological and chemical analyses of transect samples were performed on grab samples of unfiltered water, except for metals analyses, which were performed on both filtered and unfiltered samples.

In addition to water-quality monitoring for potential Hanford Site contaminants conducted by the Pacific Northwest National Laboratory, water quality monitoring for basic parameters (e.g., pH, dissolved oxygen, turbidity) and some chemical monitoring was performed by the U.S. Geological Survey under contract to the Pacific Northwest National Laboratory. Samples were collected by the U.S. Geological Survey three times per year along Columbia River transects at the Vernita Bridge and Richland (Appendix C, Table C.2). Sample analyses were performed at the U.S. Geological Survey laboratory in Denver, Colorado, for numerous physical parameters and chemical constituents.

10.4.1.2 Radiological Results for Columbia River Water Sample Analyses

Fixed Location Samples. Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam and Richland, Washington, during 2006 are reported in PNNL-16623, APP. 1 and summarized in Appendix C (Tables C.3 and C.4). The Appendix C tables list the maximum and average concentrations of selected radionuclides detected in Columbia River water in 2006 and for the previous 5 years. All individual radiological contaminant concentrations measured in Columbia River water during 2006 were less than 1/25 of the DOE-derived concentration guides (DOE Order 5400.5, Appendix D, Table D.2). The DOE-derived concentration guides are based on a 100-mrem (1-mSv) per year standard; dividing by 25 allows for more direct comparison to the 4-mrem (0.04-mSv) per year drinking water standard and Washington State ambient surface-water quality criteria (40 CFR 141 and WAC 173-201A; Appendix D, Tables D.4 and D.5). Significant results are discussed in the following paragraphs, and comparisons to previous years are provided.

Radionuclide concentrations monitored in Columbia River water were low throughout 2006. Tritium, strontium-90, uranium-234, uranium-238, plutonium-239/240, and naturally occurring beryllium-7 and potassium-40 were consistently measured in river water at levels greater than their reported minimum detectable concentrations. The concentrations of all other radionuclides were typically below the minimum detectable concentrations. Tritium, strontium-90, and plutonium-239/240 exist in worldwide fallout from historical nuclear weapons testing as well as in effluent from Hanford Site facilities. Tritium and uranium occur naturally in the environment, in addition to being present in Hanford Site effluent.

The 2006 average gross alpha and gross beta concentrations measured upstream and downstream of the Hanford Site were similar to those observed during recent years (Figures 10.4.3 and 10.4.4). Statistical comparisons for gross alpha and gross beta concentrations at Priest Rapids Dam and Richland were not performed because the majority

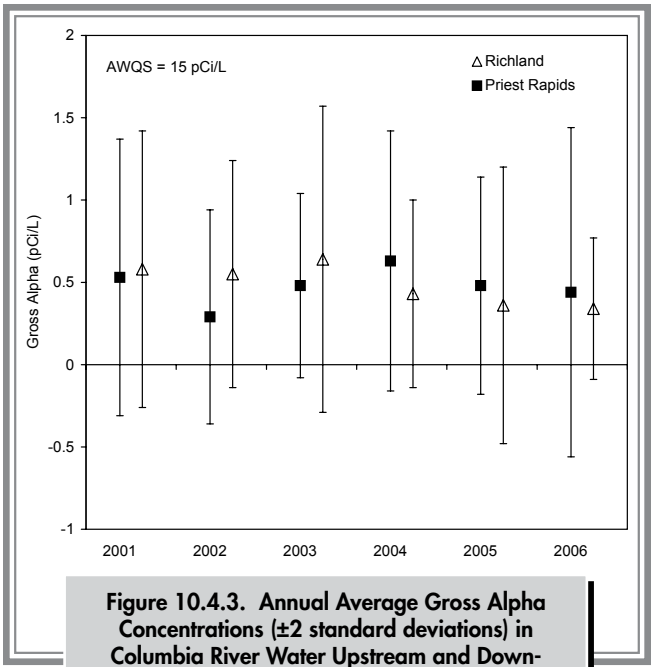


Figure 10.4.3. Annual Average Gross Alpha Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2001 Through 2006 (AWQS = ambient-water quality standard)

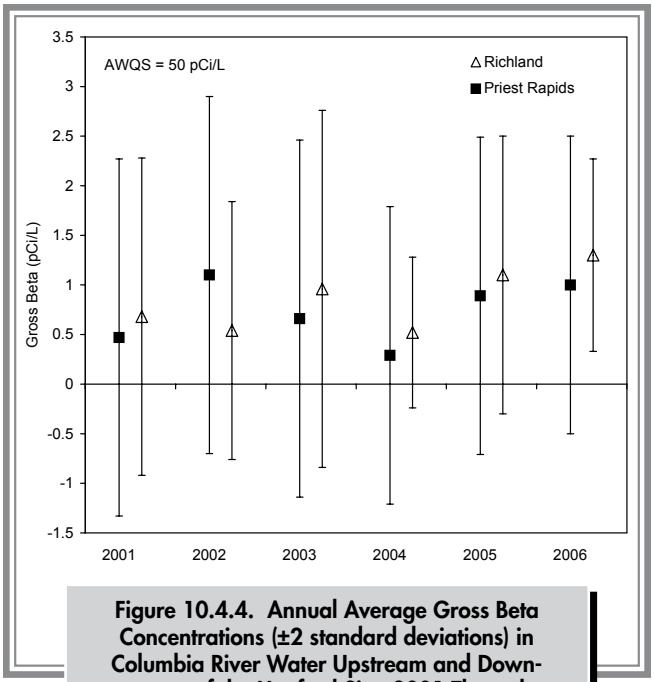


Figure 10.4.4. Annual Average Gross Beta Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2001 Through 2006 (AWQS = ambient-water quality standard)

of the concentrations were below the 1- and 3-pCi/L (0.037- and 0.11-Bq/L) minimum detectable concentrations, respectively. The average gross alpha and gross beta concentrations in Columbia River water at Richland during 2006 were less than the Washington State ambient surface-water quality criteria of 15 and 50 pCi/L (0.56 and 1.9 Bq/L).

The 2006 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in recent years. Statistical analyses indicated that monthly tritium concentrations in river-water samples at Richland were higher than concentrations in samples from Priest Rapids Dam (Figure 10.4.5). However, 2006 average tritium concentrations in Columbia River water collected at Richland were only 0.26% of the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L). Onsite sources of tritium entering the river included groundwater seepage and direct discharge from the 100-K Area permitted outfall (Section 10.3). Tritium concentrations measured at Richland, while representative of river water used by the city of Richland (first municipal water source downstream from the Hanford Site) for drinking water, tend to overestimate the average tritium concentrations across the river at this

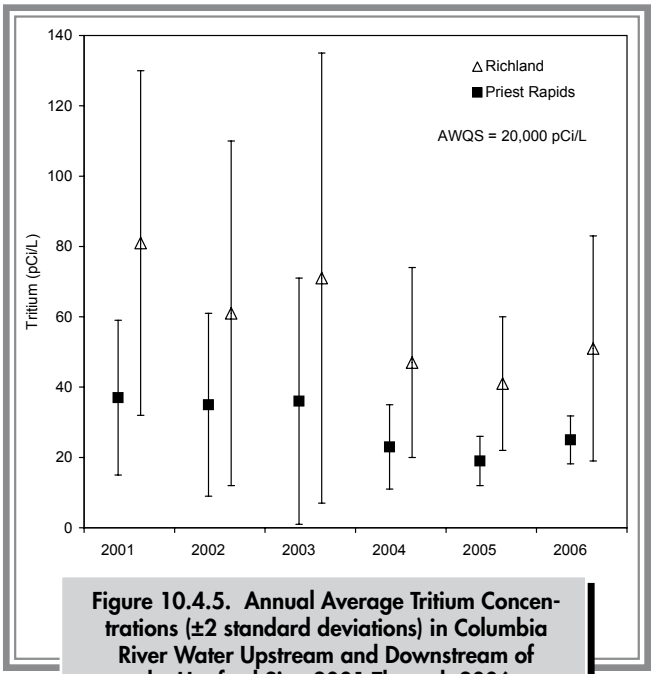


Figure 10.4.5. Annual Average Tritium Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2001 Through 2006 (AWQS = ambient-water quality standard)

location (PNL-8531). This bias is attributable to a groundwater plume originating from the 200-East Area entering the river along the portion of shoreline extending from the Hanford town site to below the 300 Area, which is relatively close to the Richland water intake. This plume is not completely mixed within the river at Richland. Sampling along cross-river transects at Richland during 2006 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 at Richland 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 average strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2006 were similar to those reported previously (Figure 10.4.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Areas. 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, there were no statistical differences between monthly strontium-90 concentrations at Priest Rapids Dam and Richland. Average strontium-90 concentrations in Columbia River water at Richland were less than 0.5% of the Washington State ambient surface-water quality criterion (8 pCi/L [0.30 Bq/L]).

Annual average total uranium concentrations (i.e., the sum of uranium-234, uranium-235, and uranium-238) observed in water samples collected upstream and downstream of the Hanford Site during 2006 were similar to those observed during recent years (Figure 10.4.7). Monthly total uranium concentrations measured at Richland during 2006 were not statistically higher than those measured at Priest Rapids Dam. Although there is no direct process discharge of uranium to the river, uranium is present in the groundwater beneath the 300 Area as a result of past Hanford Site operations. Uranium has been detected at elevated levels in shoreline springs at the 300 Area in the past (Section 10.5; PNNL-13692). Uranium from non-Hanford Site sources 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 is no Washington State ambient surface-water quality criterion directly applicable to

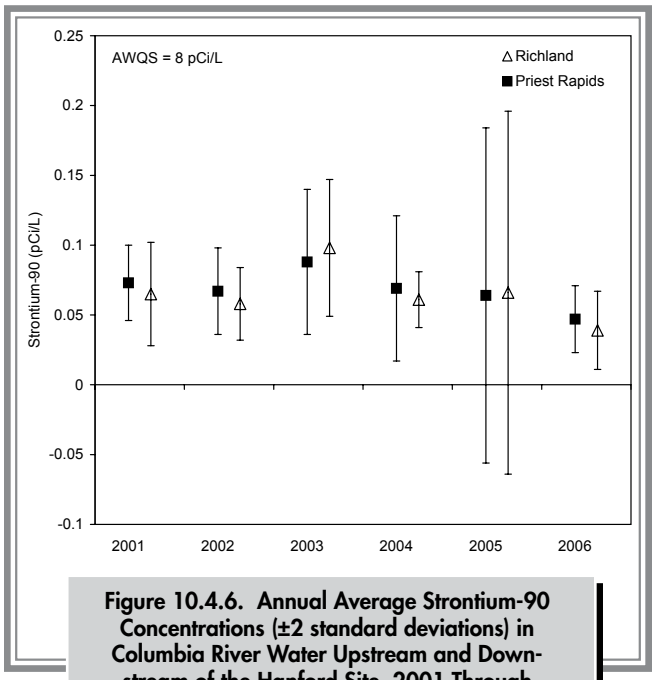


Figure 10.4.6. Annual Average Strontium-90 Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2001 Through 2006 (AWQS = ambient-water quality standard)

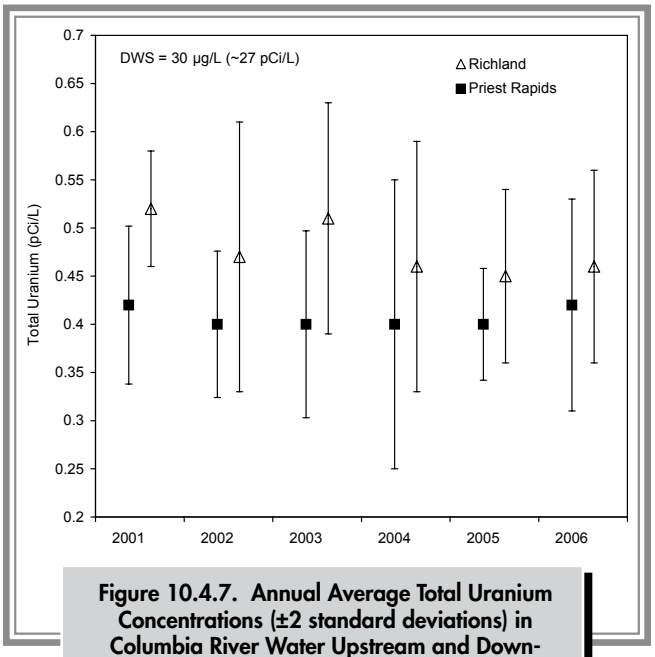


Figure 10.4.7. Annual Average Total Uranium Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2001 Through 2006 (DWS = drinking water standard)

uranium. However, total uranium levels in the river during 2006 were well below the EPA drinking water standard of 30 µg/L (approximately 27 pCi/L [1.0 Bq/L], Appendix D, Table D.4).

Water samples were collected but not analyzed for iodine-129 in 2006 because the unique instrument for this assay was broken, and an alternative for this ultra-trace measurement capability was not available in 2006. The onsite source of iodine-129 to the Columbia River is the discharge of contaminated groundwater along the portion of shoreline downstream of the Hanford town site. The iodine-129 plume originated in the 200 Areas from past waste-disposal practices. In previous years, quarterly iodine-129 concentrations in Columbia River water at Richland were statistically higher than those at Priest Rapids Dam, indicating a Hanford Site source of iodine-129. Past results have shown that iodine-129 values at Priest Rapids Dam are largely unaffected by river stage; however, the concentrations measured for river water at Richland are inversely proportional to the river stage (i.e., during lower flow, the concentrations of iodine-129 are higher and vice versa). The influence of river stage on concentrations of iodine-129 at Richland is reflected in the larger standard deviation, compared to the samples from Priest Rapids Dam, for the annual averages for 2001 to 2005 shown in Figure 10.4.8.

Plutonium-239/240 concentrations for filtered river-water samples at Richland were extremely low during 2006. All plutonium concentrations for dissolved fractions were reported as undetected by the analytical laboratory. Plutonium concentrations for material collected on the filters were above the detection limits in one of four samples at Richland (0.000039 ± 0.000022 pCi/L [0.0000014 ± 0.00000081 Bq/L]). Plutonium was not detected on any filter samples from Priest Rapids Dam. The average minimum detectable concentrations were 0.00004 pCi/L (0.0000015 Bq/L) for the filtered fraction and 0.0001 pCi/L (0.0000037 Bq/L) for the dissolved fraction. All concentrations and detection limits were well below the DOE-derived concentration guide of 30 pCi/L (1.1 Bq/L) (Appendix D, Table D.2). No Washington State ambient surface-water quality criterion exists for plutonium-239/240. Statistical comparisons for dissolved plutonium concentrations at Priest Rapids Dam and Richland were not performed because most of the concentrations were below the reported minimum detectable concentrations.

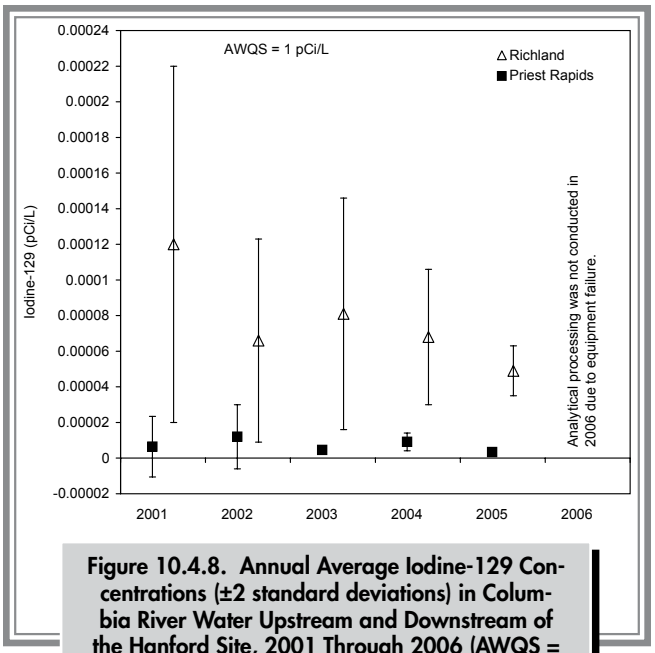


Figure 10.4.8. Annual Average Iodine-129 Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2001 Through 2006 (AWQS = ambient-water quality standard)

Columbia River Transect and Near-Shore Samples. Radiological results from samples collected along Columbia River transects and at near-shore locations near the Vernita Bridge, 100-N Area, Hanford town site, 300 Area, and Richland during 2006 are presented in Appendix C (Tables C.5 and C.6) and PNNL-16623, APP. 1. Sampling locations were documented using a global positioning system. Radionuclides consistently measured at concentrations greater than the minimum detectable activity included tritium, strontium-90, uranium-234, and uranium-238. All measured concentrations of these radionuclides were less than applicable Washington State ambient surface-water quality criteria.

Tritium concentrations measured along Columbia River transects at the Vernita Bridge, 100-N Area, Hanford town site, 300 Area, and Richland pump house during September 2006 are depicted in Figure 10.4.9. The transect at the Vernita Bridge is the most upstream location. Stations 1 and 10 are located along the Benton County and Grant/Franklin Counties shorelines, respectively. The 100-N Area, Hanford town site, 300 Area, and Richland transects have higher tritium concentrations near the Hanford Site (Benton

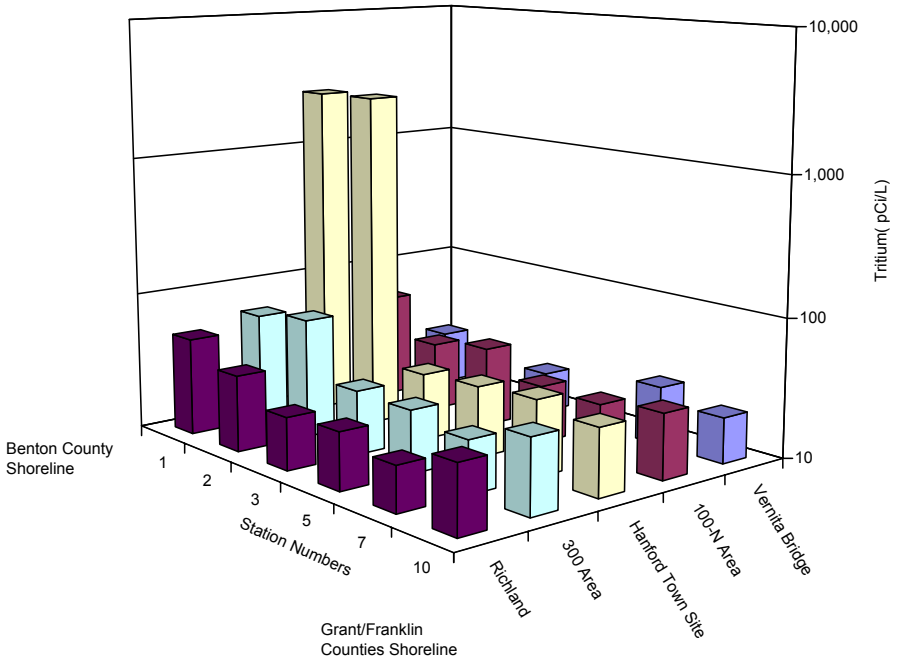


Figure 10.4.9. Tritium Concentrations in Cross-River Transect Water Samples from the Hanford Reach of the Columbia River, September 2006. The Washington State ambient-water quality standard for tritium is 20,000 pCi/L (740 Bq/L).

County) shore relative to the opposite shore. The presence of a tritium concentration gradient in the Columbia River at Richland supports previous studies showing that contaminants in the 200 Areas' groundwater plume entering the river at, and upstream of, the 300 Area are not completely mixed in the river at Richland (HW-73672; PNL-8531). The gradient is most pronounced during periods of relatively low river flow. Since transect sampling began during 1987 (PNL-8531), the average tritium concentration measured along the Richland transect has been less than that measured in monthly composited samples from the fixed-location monitoring station in Richland, illustrating the conservative bias (i.e., overestimate) of the fixed-location monitoring station. For samples collected in 2006, the highest tritium concentration measured in cross-river transect water was 2,600 ± 450 pCi/L (96 ± 0.17 Bq/L), and the highest concentration measured in near-shore water samples was 5,700 ± 980 pCi/L (210 ± 0.17 Bq/L) (Appendix C, Table C.5), with both samples collected at the Hanford town site.

During 2006, 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 where slightly elevated strontium-90 concentrations were measured in some samples obtained at near-shore locations and one value at Richland of 0.22 ± 0.054 pCi/L (0.0081 ± 0.0020 Bq/L). The maximum strontium-90 concentration for 2006 was 1.3 ± 0.21 pCi/L (0.048 ± 0.0078 Bq/L) for a near-shore water sample collected at the 100-N Area. The average strontium-90 concentration found during transect sampling at Richland was similar to those measured in monthly composite samples at Richland, indicating that strontium-90 concentrations in water collected at 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 during 2006 were elevated along both the Benton and Grant/Franklin Counties shorelines for the transect and near-shore samples. For September 2006, the highest total uranium concentration was measured for the sample

from the Franklin County shore of the 300 Area transect (0.88 ± 0.16 pCi/L [0.033 ± 0.0059 Bq/L]) (Appendix C, Table C.6; PNNL-16623, APP. 1). Elevated uranium concentrations on the Franklin County side of the river likely resulted from groundwater seepage and water from irrigation return canals that had elevated uranium levels from the use of phosphate fertilizers, which contain some uranium (PNL-7500).

10.4.1.3 Chemical and Physical Water Quality Results for Columbia River Water Samples

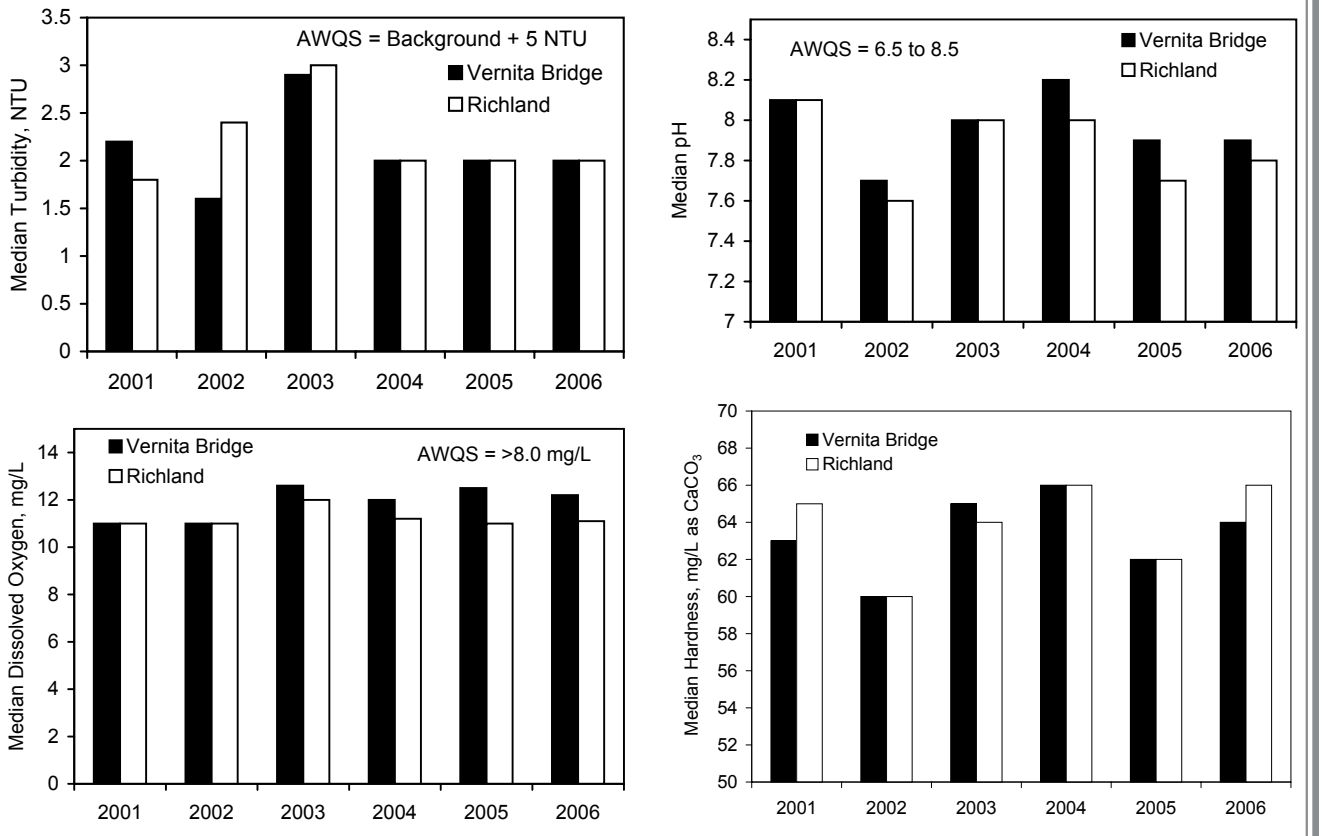
The Pacific Northwest National Laboratory and the U.S. Geological Survey (under contract to the Pacific Northwest National Laboratory) compiled chemical and physical water-quality data for the Columbia River during 2006. A number of the parameters measured have no regulatory limits; however, they are useful as indicators of water quality and contaminants of Hanford Site origin. Potential sources of pollutants not associated with the Hanford Site include irrigation return water, groundwater seepage associated with extensive irrigation north and east of the Columbia River (PNL-7500), and industrial, agricultural, and mining effluent introduced upstream from the Hanford Site.

Pacific Northwest National Laboratory Samples. Results of chemical analyses conducted by the Pacific Northwest National Laboratory on water collected at Columbia River transect and near-shore locations at the Vernita Bridge, 100-N Area, Hanford town site, 300 Area, and Richland are provided in PNNL-16623, APP. 1. The concentrations of metals and anions observed in river water during 2006 were similar to those observed in the past and remain below regulatory limits. Metals and anions were detected in Columbia River transect samples both upstream and downstream of the Hanford Site. Arsenic, antimony, cadmium, chromium, copper, lead, mercury, nickel, selenium, thallium, and zinc were detected in the majority of samples, with similar levels at most locations. Beryllium and silver were detected occasionally. Washington State ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; Appendix D, Table D.5). Increased water hardness (i.e., primarily higher concentrations of calcium and magnesium ions) can reduce the toxicity of some metals by limiting their absorption into aquatic organisms. Criteria for Columbia River water were calculated using a total hardness of 47 mg/L as calcium carbonate, the lowest value based on U.S. Geological Survey monitoring of Columbia River water near the Vernita Bridge and Richland in recent years. The total hardness reported by the U.S. Geological Survey at those locations from 1992 through 2006 ranged from 47 to 77 mg/L as calcium carbonate. All metal and anion concentrations in river water were less than the Washington State ambient surface-water quality criteria for the protection of aquatic life (Appendix C, Table C.7 and Appendix D, Table D.5). Arsenic concentrations exceeded the EPA standard for the protection of human health for the consumption of water and organisms; however, this EPA value is approximately 10,500 times lower than the Washington State chronic toxicity value, and similar concentrations were found at the Vernita Bridge and Richland (Appendix D, Table D.5).

For samples collected on the cross-river transects, concentrations of nitrate, chloride, and sulfate were elevated at the Hanford town site and nitrate was slightly elevated at the 100-N Area. Elevated nitrate concentrations at the Hanford town site shoreline are from the 200 Areas' contaminated groundwater plume. Chloride, nitrate, and sulfate concentrations were elevated, compared to mid-river samples, along the Franklin County shoreline at Richland and the 300 Area and likely resulted from groundwater seepage associated with extensive irrigation (the water for which is withdrawn from the Columbia River upstream of the Hanford Site) 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; U.S. Geological Survey Circular 1144). Average quarterly concentrations of chloride and nitrate were higher at the Richland transect than the Vernita Bridge transect. The concentrations of volatile organic compounds in Columbia River water samples (e.g., chlorinated solvents and benzene) were below the analytical laboratory's required detection limits for all samples, with no indication of a Hanford Site source.

Concentrations of chromium in the Hanford Reach are of interest because at several Hanford Site locations, groundwater contaminated with chromium above the ambient-water quality criterion intersects the river (Section 10.7). Filtered water samples collected at the 100-N Area were highly elevated for chromium, copper, nickel, and zinc compared to the unfiltered samples, and blank contamination of the filtered samples was suspected; thus, unfiltered water concentrations were reported for all metals at the 100-N Area. All Columbia River transect and near-shore filtered water samples for 2006 (and unfiltered samples at the 100-N Area) had concentrations below the ambient-water quality criterion (Appendix C, Table C.7). Some near-shore water samples collected at the 100-N Area, Hanford town site, and 300 Area had slightly elevated chromium levels compared to upstream samples at the Vernita Bridge.

U.S. Geological Survey Samples. Figure 10.4.10 illustrates U.S. Geological Survey Columbia River chemical and physical water-quality data for samples collected at the Vernita Bridge and Richland for 2001 through 2006. Results for 2006 are also tabulated in PNNL-16623, APP. 1 and summarized in Appendix C (Table C.2). These results have been published by the U.S. Geological Survey (WDR-US-2006). The 2006 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 2006, there was no indication of any deterioration of water quality resulting from site operations along the Hanford Reach of the Columbia River (Appendix D, Table D.3). For 2006, median concentrations of dissolved chromium were similar for water samples collected from near the Vernita Bridge and Richland and were well below the ambient-water quality criterion.



AWQS = Washington State Ambient-Water Quality Standard; NTU = Nephelometric turbidity unit.

Figure 10.4.10. U.S. Geological Survey Water Quality Measurements for the Columbia River Upstream and Downstream of the Hanford Site, 2001 Through 2006

10.4.2 Monitoring of Columbia River Sediment

As a result of past operations at the Hanford Site, large amounts of radioactive and non-radioactive materials were discharged to the Columbia River (PNWD-2223, HEDR). Upon release to the Columbia River, some of these materials were deposited on the riverbed as sediment, particularly in areas upstream of downstream dams. The concentrations of the radioactive materials decreased as they underwent radioactive decay. Fluctuations in the river flow, as a result of the operation of upriver hydroelectric dams, annual spring high river flows, and occasional floods, have resulted in the resuspension, relocation, and subsequent redeposition of the sediment (BNWL-2305). Upper-layer sediment in the Columbia River downstream of the Hanford Site contains low concentrations of radionuclides and metals of Hanford Site origin as well as radionuclides from nuclear weapons testing fallout, and metals and other non-radioactive contaminants from mining and agricultural activities (Beasley et al. 1981; BNWL-2305; PNL-8148; PNL-10535; Cox et al. 2004). Periodic sediment sampling confirms that concentrations are low and that no significant changes in concentrations have occurred. The accumulation of radioactive materials in sediment can lead to human exposure by ingestion of aquatic organisms associated with the sediment, sediment resuspension into drinking water supplies, or as an external radiation source irradiating people who are fishing, wading, swimming, 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 at the Hanford Site during 1971, the contaminant concentrations in Columbia River surface sediment near and downstream of the Hanford Site have been decreasing as a result of radioactive decay and the deposition of uncontaminated material on top of the older sediment, which occurs in the reservoirs of the dams located downstream of the Hanford Site (Cushing et al. 1981). However, discharges of some pollutants from the Hanford Site to the Columbia River still occur via permit-regulated liquid effluent discharges at the 100-K Area (Section 10.3) and via contaminated groundwater seepage (Section 10.5).

Several studies have been conducted to investigate the difference in sediment grain-size composition and total organic carbon content at routine Columbia River monitoring sites (Beasley et al. 1981; PNL-10535; PNNL-13417). 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 generally collected from reservoirs behind dams located upstream of the site and from White Bluffs Slough on the Hanford Reach.

10.4.2.1 Collection of Columbia River Sediment Samples and Analytes of Interest

During 2006, samples of the surface layer of Columbia River sediment were collected at depths of 0 to 10 centimeters (0 to 4 inches) from six river locations that were permanently submerged (some Hanford Reach sampling locations may not be submerged during extremely low river stage) (Figure 10.4.1 and Table 10.4.2). Sampling locations were documented using a global positioning system. Surface sediment collected by a dredge captures several years of integrated deposits. Gibbons (2000) estimated average sediment deposition rates of 0.723 centimeter (0.28 inch) per year for Priest Rapids Dam and 2.25 centimeters (0.88 inch) per year for McNary Dam. Assuming a maximum sediment sampling depth of 10 centimeters (3.9 inches) with the dredge, the samples would integrate up to 14 years at Priest Rapids Dam and 4.4 years at McNary Dam. Sediment deposition rates have not been estimated for Hanford Reach locations.

Samples were collected upstream of Hanford Site facilities from the Priest Rapids Dam reservoir (the nearest upstream impoundment) to provide 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. Any increases in contaminant concentrations found in sediment above McNary Dam compared 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, as

well as atmospheric fallout from weapons testing, also may contribute to the contaminant load found in McNary Dam sediment. Thus, sediment samples are periodically taken in the reservoir above Ice Harbor Dam (the first dam on the Snake River upstream of the river mouth) to assess Snake River input. Sediment samples also were collected along the Hanford Reach of the Columbia River, 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 that lies within the influence of the McNary Dam impoundment.

Monitoring sites in the reservoirs behind McNary and Priest Rapids Dams consisted of two stations spaced approximately equidistant on a transect line crossing the Columbia River; the samples were collected near the boat-exclusion buoys immediately upstream of each dam. All other monitoring sites consisted of a single sampling location. Samples were collected using a clam-shell style sediment dredge, and the sampling method is discussed in PNL-MA-580. All sediment samples were analyzed for gamma-emitting radionuclides (Appendix F), strontium-90, uranium-234, uranium-235, uranium-238, and metals (DOE/RL-91-50, Rev. 3). Selected samples were also analyzed for plutonium-238 and plutonium-239/240. The specific analytes selected for sediment samples were based on findings of previous Columbia River sediment investigations, reviews of past and present effluent contaminants discharged from site facilities, and reviews of contaminant concentrations observed in Hanford Site groundwater monitoring wells located near the river.

10.4.2.2 Radiological Results for Columbia River Sediment Sample Analyses

Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2006 included potassium-40, cesium-137, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240. The concentrations of all other radionuclides were below the reported minimum detectable concentrations for most samples (PNNL-16623, APP. 1). Cesium-137 and plutonium isotopes exist in worldwide fallout as well as in effluent from Hanford Site facilities. Potassium-40 and uranium isotopes occur naturally in the environment, and uranium isotopes are also present in Hanford Site effluent. 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 during 2006 were similar to those reported for previous years (Appendix C, Table C.8), and there were no obvious differences between locations. The only unusual values for sediment samples for 2004 through 2006 have been for cesium-137 at the White Bluffs Slough, which were roughly two times higher than 2006 values from Priest Rapids Dam. In addition, europium-152 was detected at White Bluffs Slough for 2004 through 2006, with sediment samples from all other locations below the detection limits. Previous studies of soils from the White Bluffs Slough detected elevated concentrations of cesium-137 and europium-152 (PNL-3127; PNL-8789). Average, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (2001 through 2006) are presented in Figure 10.4.11.

10.4.2.3 Chemical Results for Columbia River Sediment Sample Analyses

Detectable amounts of most metals were found in all river sediment samples (Figure 10.4.12; Appendix C, Table C.9; PNNL-16623, APP. 1). Maximum and average concentrations of most metals were higher for sediment collected in the reservoir upstream of Priest Rapids Dam than either Hanford Reach or McNary Dam sediment. The concentrations of cadmium, mercury, and zinc had the largest differences between locations and may be associated with upstream mining activity. Currently, there are no Washington State freshwater sediment quality criteria to compare with the measured values.

10.4.3 Monitoring of Onsite Pond Water and Sediment

Two onsite ponds, West Lake and the Fast Flux Test Facility pond (Figure 10.4.1), located near facilities in various stages of remediation, were sampled periodically during 2006. The ponds are accessible to migratory waterfowl, deer, and other wildlife, creating a potential biological pathway for the dispersion of contaminants (PNL-10174). The Fast

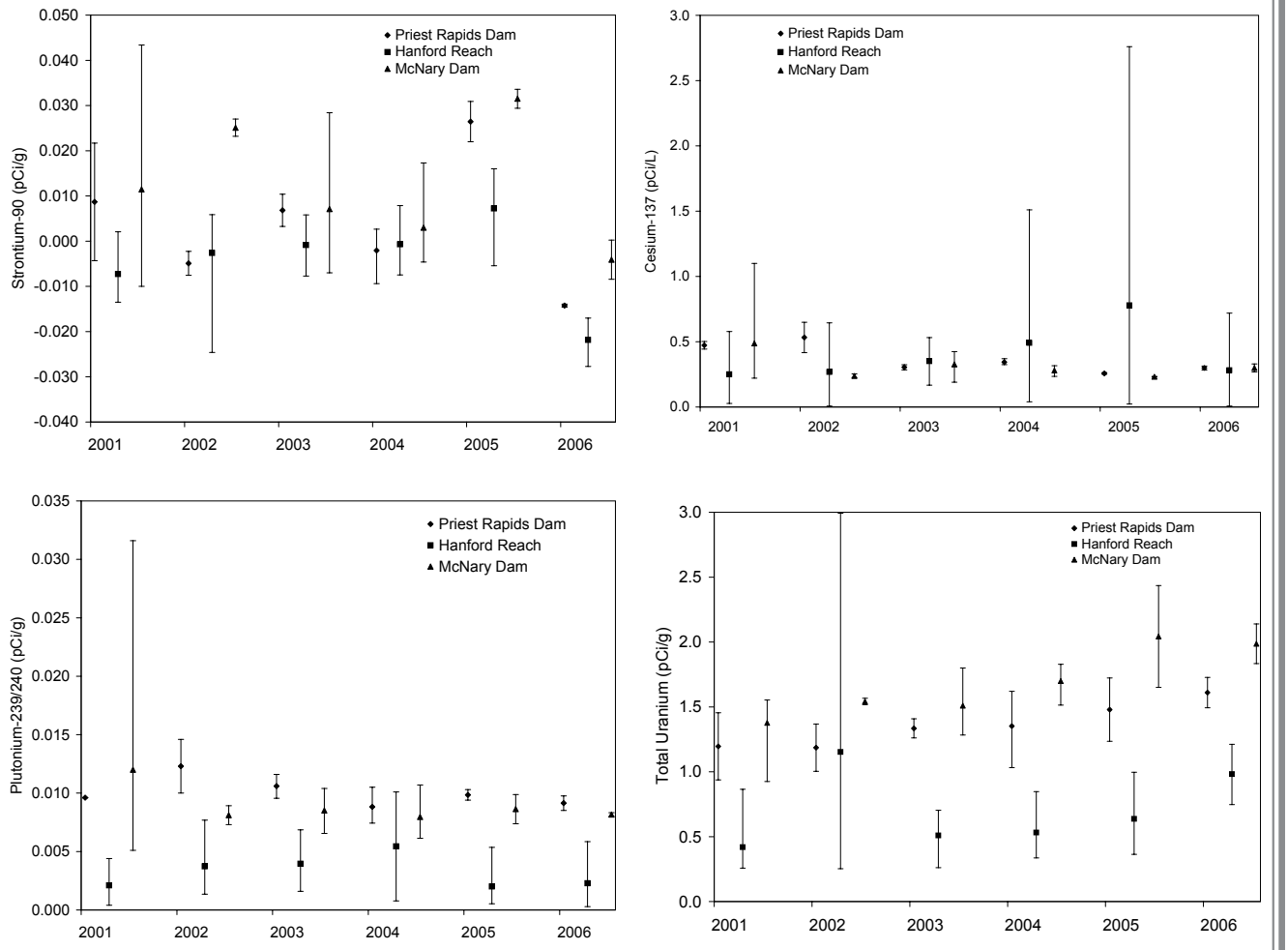


Figure 10.4.11. Average, Maximum, and Minimum Concentrations of Selected Radionuclides Measured in Columbia River Sediment, 2001 Through 2006. All 2002 through 2004 results for strontium-90 were below detection limits.

Flux Test Facility pond is a disposal site for process water, primarily cooling water drawn from 400 Area 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 it is influenced by precipitation and changing water-table elevations that are related to the discharge of water to the ground in the 200 Areas. The water level in West Lake fluctuates and changes from standing water in winter and spring to dry or nearly dry in summer and fall.

10.4.3.1 Collection of Pond Water and Sediment Samples and Analytes of Interest

During 2006, grab samples were collected quarterly from the Fast Flux Test Facility pond (water) and from West Lake (water and sediment). All water samples were analyzed for tritium. Water samples from the Fast Flux Test Facility pond were also analyzed for gross alpha and gross beta concentrations as well as gamma-emitting radionuclides. The groundwater table in the 200-East Area has dropped in recent years (Section 10.7), and this has decreased the size

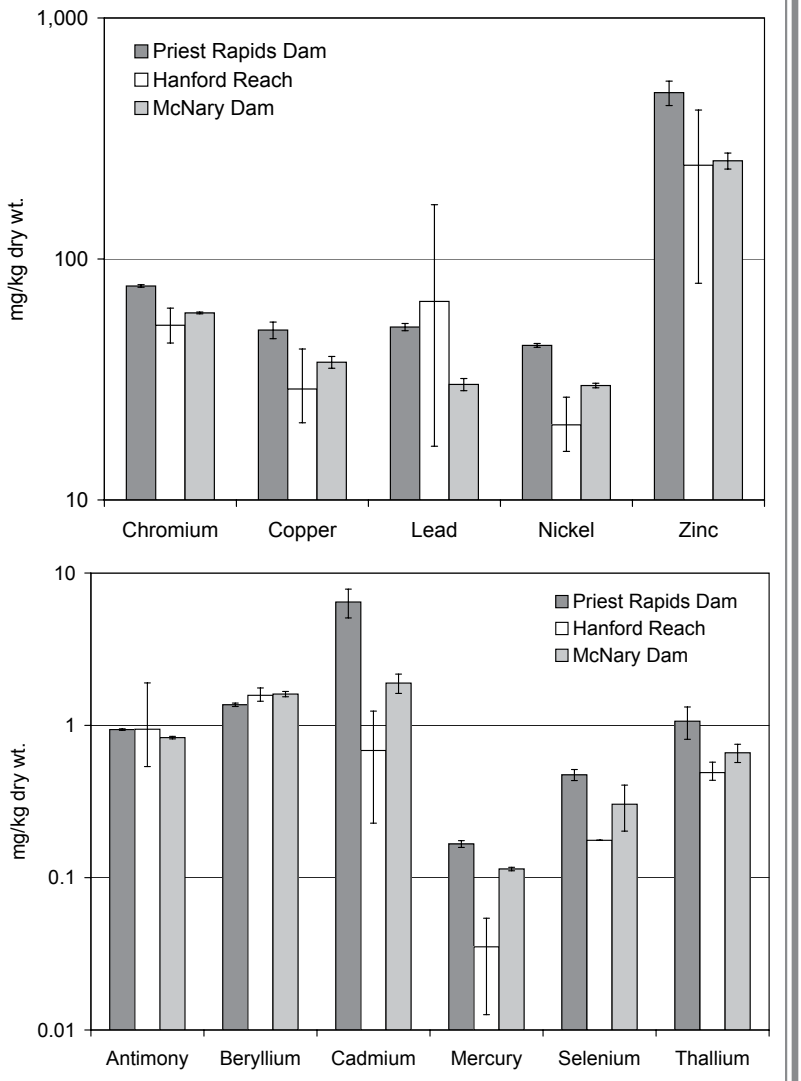


Figure 10.4.12. Average, Maximum, and Minimum Concentrations of Selected Metals Measured in Columbia River Sediment (Washington and Oregon), 2006. The upper and lower bars represent maximum and minimum values. For some metals, the maximum results are similar to the average and are not visible on the figure.

of West Lake and caused the suspended sediment loading to increase. Since 2002, it has not been practical for the analytical laboratory to process West Lake water samples for gross alpha, gross beta, strontium-90, technetium-99, uranium-234, uranium-235, and uranium-238 because of the high sediment load; thus, sediment samples were submitted for these analytes. Radionuclides were chosen for analysis based on their presence in local groundwater and their potential to contribute to the overall radiation dose to biota that frequent the ponds.

10.4.3.2 Radiological Results for Pond Water and Sediment Sample Analyses

All radionuclide concentrations in onsite pond water samples were less than applicable DOE-derived concentration guides (DOE Order 5400.5; Appendix D, Table D.2) and Washington State ambient surface-water quality criteria (WAC 173-201A; 40 CFR 141; PNNL-16623, APP. 1; Appendix D, Tables D.3 and D.4).

Figure 10.4.13 shows the annual average gross beta and tritium concentrations in Fast Flux Test Facility pond water from 2001 through 2006. Average levels of both constituents have remained stable in recent years. The average tritium concentration in Fast Flux Test Facility pond water during 2006 was 13% of the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L). The sources of contaminants in the pond water are groundwater contaminant plumes from the 200 Areas that have migrated to wells within the 400 Area that supply water to facility operations.

Tritium concentrations in West Lake water during 2006 were higher to those observed in the past (Figure 10.4.14) with the highest values reported for July and October when the lake was nearly dry. The average concentration of tritium in West Lake water in 2006 was 1.5% of the Washington State ambient surface-water quality criterion level (20,000 pCi/L [740 Bq/L]) and reflected groundwater concentrations in the area.

Samples of West Lake sediment in 2006 had the following ranges of values:

- Gross alpha – 5.1 to 9.5 pCi/g (0.19 to 0.35 Bq/g)
- Gross beta – 10 to 27 pCi/g (0.37 to 1.0 Bq/g)

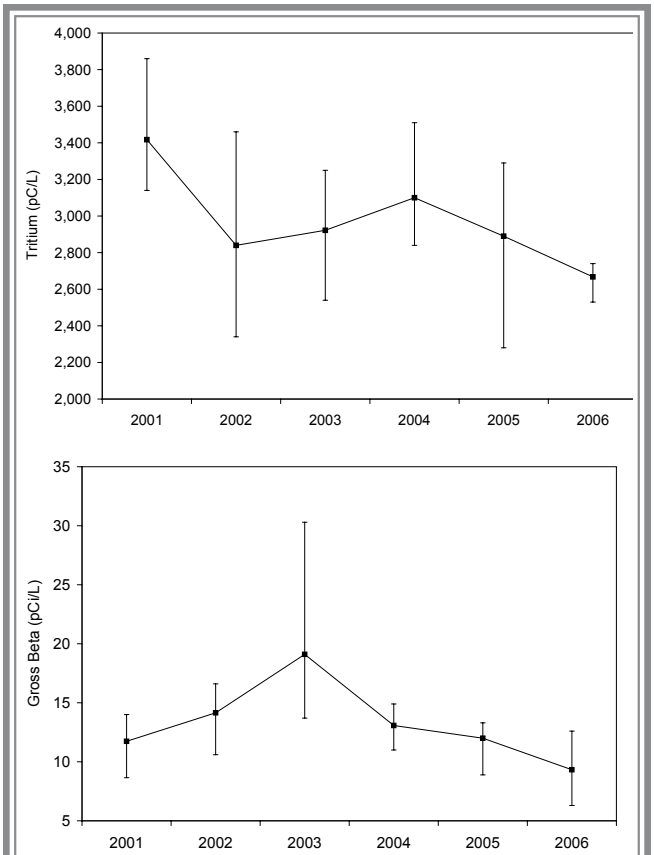


Figure 10.4.13. Average, Maximum, and Minimum Gross Beta and Tritium Concentrations in Water Samples from the Fast Flux Test Facility Pond on the Hanford Site, 2001 Through 2006

- Potassium-40 – 11 to 18 pCi/g (0.41 to 0.67 Bq/g)
- Strontium-90 – 0.052 to 0.65 pCi/g (0.0019 to 0.024 Bq/g)
- Cesium-137 – 0.26 to 1.9 pCi/g (0.0096 to 0.070 Bq/g)
- Uranium-234 – 0.28 to 4.9 pCi/g (0.010 to 0.18 Bq/g)
- Uranium-235 – 0.0084 (undetected) to 0.18 pCi/g (0.00031 to 0.0067 Bq/g)
- Uranium-238 – 0.28 to 4.5 pCi/g (0.010 to 0.17 Bq/g).

These levels of radionuclides are similar to previous measurements (PNL-7662). Uranium concentrations are believed to result from naturally occurring uranium in the surrounding soil (BNWL-1979).

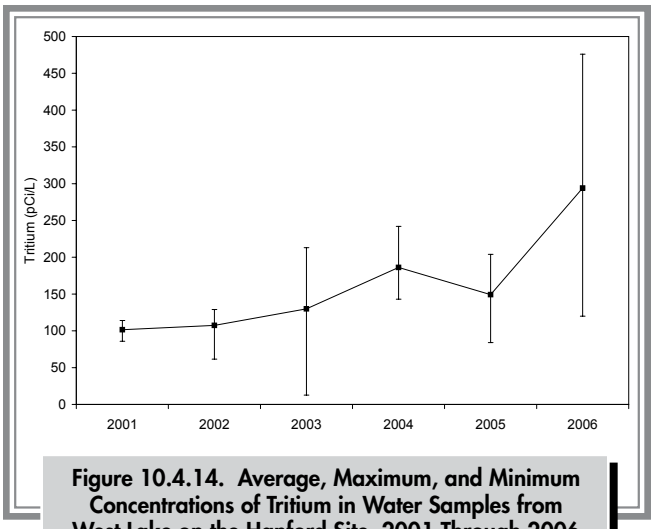


Figure 10.4.14. Average, Maximum, and Minimum Concentrations of Tritium in Water Samples from West Lake on the Hanford Site, 2001 Through 2006

10.4.4 Monitoring of Offsite Irrigation Water

During 2006, water samples were collected from an irrigation canal located across the Columbia River and downstream from the Hanford Site at Riverview, and from an irrigation water supply on the Benton County shoreline near the southern boundary of the Hanford Site (Horn Rapids irrigation pumping station) (Figure 10.4.1). As a result of public concerns about the potential for Hanford Site-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 (Section 10.14).

Collection, Analysis, and Analytical Results for Offsite Irrigation Water Samples

Water from the Riverview irrigation canal and the Horn Rapids irrigation pumping station was sampled three times during the 2006 irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters,

tritium, strontium-90, uranium-234, uranium-235, and uranium-238. During 2006, radionuclide concentrations measured in irrigation water were at the same levels detected in Columbia River water samples collected upstream of the Hanford Site (PNNL-16623, APP. 1). All radionuclide concentrations were below their respective DOE-derived concentration guides and Washington State ambient surface-water quality criteria (DOE Order 5400.5; WAC 173-201A; 40 CFR 141).

10.5 Columbia River Shoreline Springs Monitoring

G. W. Patton

Samples of Columbia River shoreline spring water and associated sediment were collected along the Hanford Reach and analyzed to determine the potential impact of radiological and chemical contaminants from the Hanford Site on the public and the aquatic environment. Sections 10.5.1 and 10.5.2 discuss the results for Columbia River shoreline spring water and sediment samples.

10.5.1 Water Monitoring at Columbia River Shoreline Springs

The Columbia River is the discharge area for the unconfined aquifer underlying the Hanford Site. Groundwater provides a means for transporting Hanford Site-associated contaminants, which have leached into groundwater from past waste-disposal practices, to the Columbia River (DOE/RL-92-12, Rev. 1; 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 shoreline springs. Routine monitoring of shoreline 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. In addition, contaminants in groundwater near the Columbia River are monitored using shoreline groundwater-sampling tubes (aquifer tubes) (Section 10.7; PNNL-14444).

Shoreline springs were documented along the Hanford Reach long before Hanford Site operations began during World War II (Jenkins 1922). During the early 1980s, researchers walked a 66-kilometer (41-mile) stretch of the 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, Hanford town site, and 300 Area. Today, the 100-N Area no longer stands out. Declining water-table elevations, a consequence of the end of operations at N Reactor, have reduced discharge from the springs. In recent years, it has become increasingly difficult to locate shoreline springs in the 100-N Area.

The presence of shoreline springs also varies with river stage (river-level elevation). The water table near the Hanford Reach is strongly influenced by river stage fluctuations. River stage in the Hanford Reach is controlled by upriver conditions and operations at upriver dams. As water levels fluctuate, groundwater levels and, thus, the presence of shoreline springs in the Hanford Reach vary. At the 300 Area, the river stage is also influenced by the elevation of the McNary Dam pool. River water moves into the Hanford Site aquifer as the river stage rises (bank storage) and then discharges from the aquifer in the form of shoreline springs 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 when the level of the aquifer 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 discharged immediately following a river stage decline generally consists of river water or a mixture of river water and groundwater. The percentage of groundwater in the spring water discharge increases over time following a drop in river stage. Measuring the specific conductance of the spring water discharge provides an indicator of the extent of bank storage because Hanford Site groundwater has a higher specific conductance than Columbia River water.

Because of the effect of bank storage on groundwater discharges and contaminant concentrations, as well as variations in aquifer thickness, porosity, and plume concentrations, it is difficult to accurately estimate the volume of contaminated groundwater discharging via springs to the Columbia River within the Hanford Reach. Studies of shoreline springs conducted during 1983 (PNL-5289) and 1988 (PNL-7500) and results of near-shore studies (PNNL-11933; PNNL-13692) noted that discharges from the springs had only localized effects on river contaminant concentrations.

10.5.1.1 Collection of Water Samples from Columbia River Shoreline Springs and Constituents of Interest

Routine monitoring of selected shoreline springs was initiated during 1988. Currently, shoreline spring water samples are collected for contaminant monitoring and to support groundwater operable unit investigations (DOE/RL-91-50, Rev. 3). Tables 10.5.1 and 10.5.2 and Figure 10.4.1 summarize the sampling locations and frequencies, and sample types and analyses included in shoreline springs monitoring during 2006. This section describes the monitoring efforts and summarizes the results for these aquatic environments. Detailed analytical results are reported in PNNL-16623, APP. 1. Analytes of interest for samples from shoreline 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 early fall.

The majority of samples collected during 2006 were analyzed for gamma-emitting radionuclides, gross alpha, gross beta, and tritium. Samples from selected springs were analyzed for strontium-90, technetium-99, uranium-234, uranium-235, and uranium-238. Riverbank spring water samples collected in 2005 and 2006 were not analyzed for iodine-129 because the unique instrument used for this assay was broken and an alternative for this ultra-trace measurement capability was not available in 2006. Most samples were analyzed for metals and anions. Samples from selected locations were analyzed for volatile organic compounds. All analyses were conducted on unfiltered samples, except for metals analyses, which were conducted on both filtered and unfiltered samples (Appendix C, Table C.10; PNNL-16623, APP. 1).

Table 10.5.1. Hanford Reach Shoreline Springs Water Monitoring, 2006

Springs Locations	Sample Type	Sampling Frequency	Analyses
100-B Area	Grab	Annually	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, gamma energy analysis, metals (filtered and unfiltered), anions, VOA
100-K Area	Grab	Annually	Alpha, beta, ^{3}H, ^{90}Sr, gamma energy analysis, metals (filtered and unfiltered), anions, VOA
100-N Area	Grab	Annually	Alpha, beta, ^{3}H, ^{90}Sr, gamma energy analysis, metals (filtered and unfiltered), anions
100-D Area	Grab	Annually	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma energy analysis, metals (filtered and unfiltered), anions
100-H Area	Grab	Annually	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U,[(a)] gamma energy analysis, metals (filtered and unfiltered), anions
100-F Area	Grab	Annually	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma energy analysis, metals (filtered and unfiltered), anions, VOA
Hanford town site	Grab	Annually	Alpha, beta, ^{3}H, ^{129}I, ^{99}Tc, U, gamma energy analysis, metals (filtered and unfiltered), anions
300 Area	Grab	Annually	Alpha, beta, ^{3}H, ^{129}I, ^{90}Sr, U, gamma energy analysis, metals (filtered and unfiltered), anions, alkalinity, VOA

(a) U = Isotopic uranium-234, uranium-235, and uranium-238.
VOA = Volatile organic compounds.

10.5.1.2 Radiological Results for Water Samples from Columbia River Shoreline Springs

Table 10.5.2. Hanford Reach Shoreline Springs Sediment Monitoring, 2006

Springs Locations[a]	Sampling Frequency	Analyses
100-B Area	Annually	Gamma energy analysis, ^{90}Sr, U,[b] metals
100-H Area	Annually	Gamma energy analysis, ^{90}Sr, U,[b] metals
100-F Area	Annually	Gamma energy analysis, ^{90}Sr, U,[b] metals
Hanford town site	Annually	Gamma energy analysis, ^{90}Sr, U,[b] metals
300 Area	Annually	Gamma energy analysis, ^{90}Sr, U,[b] metals

(a) See Figure 10.4.1.
(b) U = Isotopic uranium-234, uranium-235, and uranium-238 analyzed by alpha spectrometry (alpha energy analysis).

Contaminants of Hanford Site origin continued to be detected in water from shoreline springs entering the Columbia River along the Hanford Site during 2006. Tritium, strontium-90, technetium-99, uranium-234, uranium-235, and uranium-238 were detected in spring water (Appendix C, Table C.10). All radiological contaminant concentrations measured in shoreline springs during 2006 were less than applicable DOE-derived concentration guides (DOE Order 5400.5; Appendix D, Table D.2).

Figure 10.5.1 depicts concentrations of selected radionuclides in 300 Area shoreline spring water (spring 42-2 and spring DR 42-2) from 2001 through 2006. Concentrations of radionuclides in 300 Area shoreline springs in 2006 were similar to concentrations measured in previous years. Concentrations of radionuclides in shoreline spring water vary over the years with changes in the degree of river water and groundwater mixing (i.e., bank storage effect). The elevated tritium levels measured in 300 Area shoreline springs are indicators of the contaminated groundwater plume from the 200 Areas (Section 5.9 in PNL-10698).

Concentrations of selected radionuclides in shoreline spring water near the Hanford town site (spring 28-2) from 2001 through 2006 are provided in Figure 10.5.2. Annual fluctuations in these values reflect the influence of bank storage during the sampling period. The elevated radionuclide levels measured in the Hanford town site shoreline springs are indicators of the contaminated groundwater plume from the 200 Areas (Section 5.9 in PNL-10698).

Gross beta concentrations in shoreline spring water at the 100 Areas locations, Hanford town site, and 300 Area were elevated compared to gross beta concentrations in Columbia River water at Priest Rapids Dam, but were below the state's 50-pCi/L (2-Bq/L) ambient-water quality criterion. Gross beta concentrations were highest for riverbank spring water at the Hanford town site, 300 Area, and 100-F Area.

Tritium concentrations varied widely with location. The highest tritium concentration measured in shoreline springs was at the Hanford town site (19,000 ± 1,300 pCi/L [700 ± 48 Bq/L]), which was just below the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L) (WAC 173-201A; 40 CFR 141), followed by 8,900 ± 660 pCi/L (330 ± 24 Bq/L) in the 300 Area, and 8,900 ± 390 pCi/L (330 ±14 Bq/L) in the 100-N Area. Tritium concentrations in most shoreline spring water samples were elevated compared to the 2006 Columbia River water concentrations at Priest Rapids Dam.

Water samples from shoreline springs were analyzed for strontium-90 in the 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F Areas. The highest strontium-90 concentration detected in shoreline spring water was at the 100-H Area (3.6 ± 0.52 pCi/L [0.13 ± 0.019 Bq/L]). This value was 45% of the state's ambient surface-water quality criterion of 8 pCi/L (0.30 Bq/L). Groundwater at the 100-N Area has historically had the highest strontium-90 concentrations; however, since 1997, no visible shoreline springs have been observed along the shoreline where strontium-90 concentrations in groundwater are elevated.

Water samples from shoreline springs in the 100-B Area, 100-H Area, and at the Hanford town site were analyzed for technetium-99. All results for technetium-99 were below the EPA drinking water standard of 900 pCi/L (33 Bq/L) (Appendix D, Table D.4). The highest technetium-99

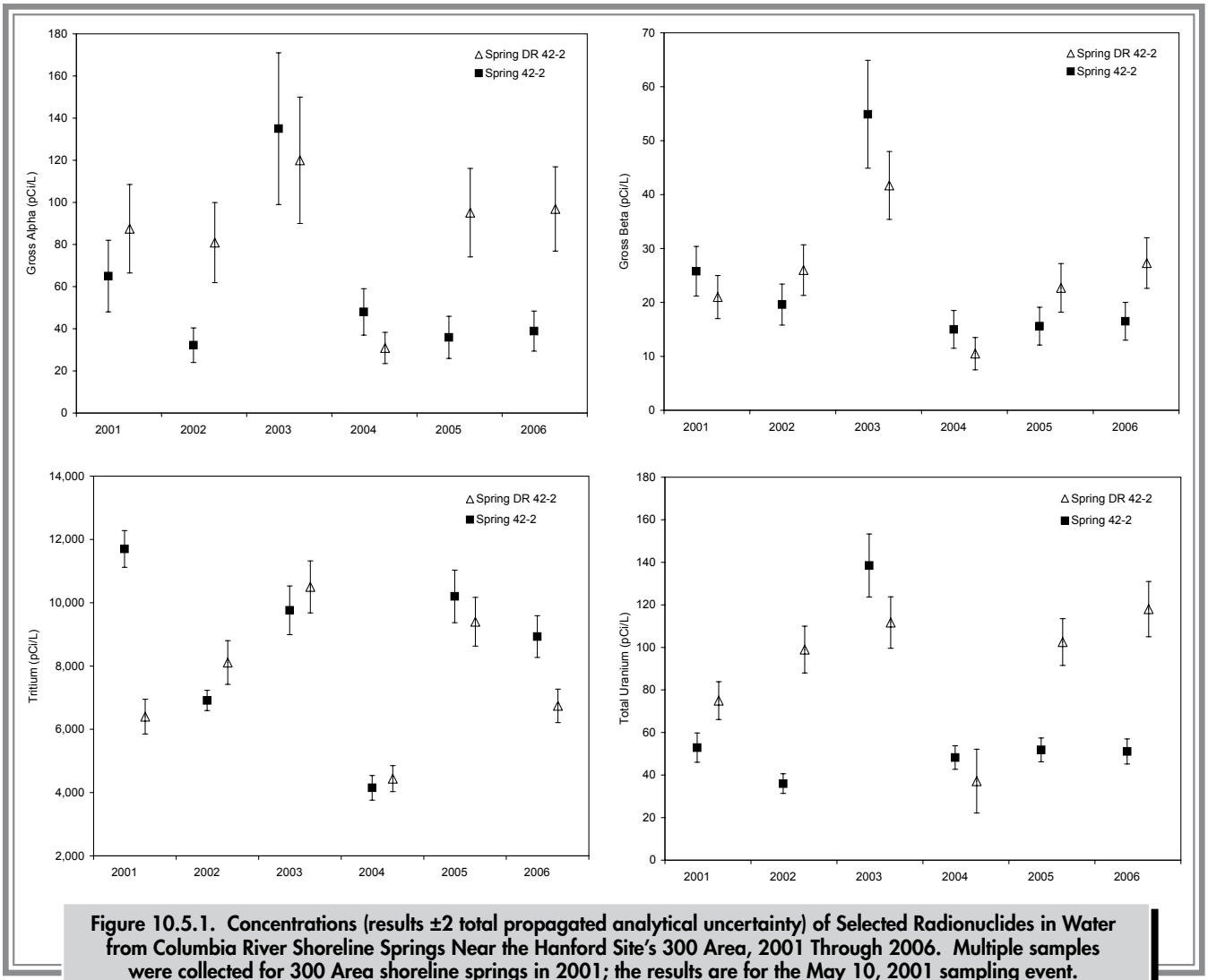


Figure 10.5.1. Concentrations (results ±2 total propagated analytical uncertainty) of Selected Radionuclides in Water from Columbia River Shoreline Springs Near the Hanford Site's 300 Area, 2001 Through 2006. Multiple samples were collected for 300 Area shoreline springs in 2001; the results are for the May 10, 2001 sampling event. Note: DR refers to downriver; thus, DR 42-2 is a spring located downriver from Hanford Site spring 42-2.

concentration was found in shoreline spring water from the Hanford town site (25 ± 1.7 pCi/L [0.92 ± 0.063 Bq/L]).

Water samples from shoreline springs at the Hanford town site and 300 Area were collected in 2005 and 2006 and submitted to a laboratory for iodine-129 analyses. However, these samples could not be analyzed for iodine-129 because the unique instrument used for this assay was broken, and an alternative for this ultra-trace measurement capability was not available in 2006. From 2000 through 2004, the highest concentrations were measured in water samples from the Hanford town site springs, with all values below the state's surface-water quality criterion of 1 pCi/L (0.037 Bq/L) (Appendix D, Table D.4).

Uranium was monitored in shoreline spring-water samples from the 100-D Area, 100-H Area, 100-F Area, Hanford town site, and 300 Area in 2006 (Figure 10.4.1). The highest total uranium level was found in 300 Area spring water (120 ± 13 pCi/L [4.4 ± 0.48 Bq/L] or approximately 130 ± 14 µg/L), which was collected downgradient from the retired 300 Area process trenches. The total uranium concentration in this spring exceeded the EPA drinking water standard of 30 µg/L (approximately 27 pCi/L [1.0 Bq/L]). The 300 Area spring had an elevated gross alpha concentration (97 ± 20 pCi/L [3.6 ± 0.74 Bq/L]), which exceeded the Washington State ambient surface-water quality criterion of 15 pCi/L (0.56 Bq/L) (Appendix D, Table D.4). Elevated

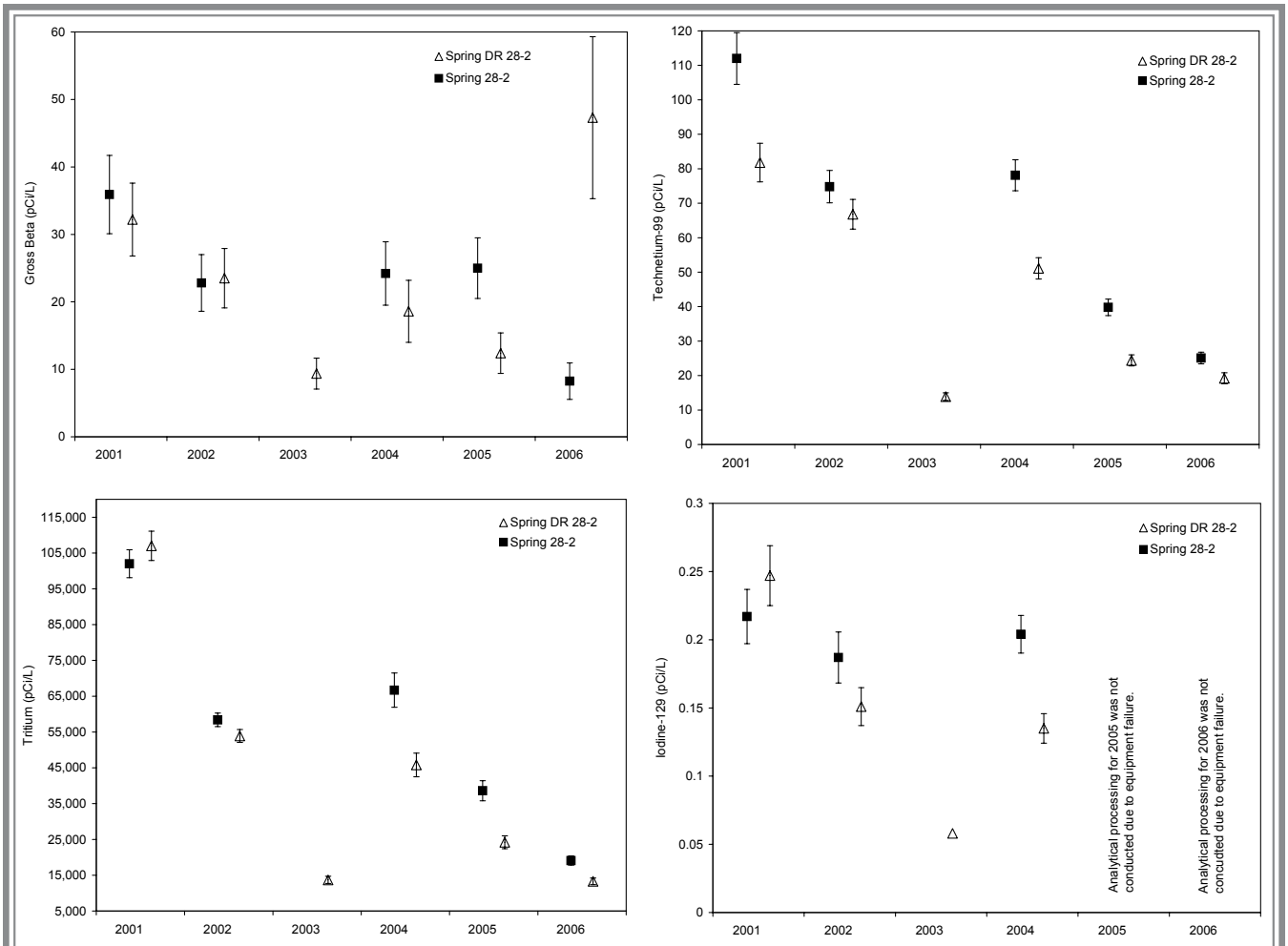


Figure 10.5.2. Concentrations (results ±2 total propagated analytical uncertainty) of Selected Radionuclides in Columbia River Shoreline Springs Water at the Hanford Town Site (Spring 28-2 and Spring 28-2 DR), 2001 Through 2006. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol. Note: DR refers to downriver; thus, DR 28-2 is a spring located downriver from Hanford town site spring 28-2.

uranium concentrations exist in the unconfined aquifer beneath the 300 Area in the vicinity of former uranium fuel fabrication facilities and inactive waste sites. The increase in uranium concentrations in 2003 samples from shoreline spring 42-2 (Figure 10.5.1) was not unexpected. A pulse of increased uranium concentrations in groundwater was created by waste-site excavation activities during fall 2002 at a location just inland of this shoreline spring (PNNL-14548). The pulse has passed well 399-1-10A, located adjacent to the spring, and may have discharged to the river. Gross alpha and gross beta concentrations in 300 Area shoreline spring water from 2001 through 2006 parallel uranium and are likely associated with its presence. Concentrations of radionuclides in 300 Area shoreline springs in 2006 were similar to concentrations measured in previous years and varied with changes in bank storage.

10.5.1.3 Chemical Results for Water Samples from Columbia River Shoreline Springs

Hanford Site-origin chemical contaminants continued to be detected in water from shoreline springs entering the Columbia River along the Hanford Site during 2006. Metals and anions of interest (chloride, fluoride, nitrate, and sulfate) were detected in spring water. Concentrations of volatile organic compounds were near or below their detection limits

in all samples. Trace amounts (<1 µg/L) of chlorinated organic compounds were observed for the following locations: trichloroethene and carbon tetrachloride for the 300 Area, trichloroethene and chloroform at the 100-B Area, and chloroform at the 100-K and 100-F Areas. Trichloroethene has been consistently detected at low concentrations in 300 Area shoreline spring water.

Concentration ranges of selected chemicals measured in shoreline spring water during 2001 through 2006 are presented in Table 10.5.3. For most locations, the 2006 chemical sample results were similar to those reported previously (PNNL-14687). Nitrate concentrations were highest in spring-water samples from the 100-F Area. Dissolved chromium concentrations were highest in the 100-D, 100-H, and 100-K Areas' shoreline springs. Hanford Site groundwater monitoring results for 2006 indicated similar contaminant concentrations at shoreline areas near the springs' discharge locations (Section 10.7, Figure 10.7.6).

The state's ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; Appendix D, Table D.5). For comparison purposes, spring-water criteria were calculated using the same 47-milligram per liter calcium carbonate hardness given in Appendix D, Table D.5. The concentrations of most metals measured in water collected from springs along the Hanford Site shoreline during 2001 through 2006 were below Washington State ambient surface-water chronic toxicity levels (WAC 173-201A). However, for 2001 through 2006, the maximum concentrations of dissolved chromium in shoreline spring water from the 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F Areas were above the Washington State ambient surface-water chronic and acute toxicity levels (Appendix D, Table D.5). For 2006 riverbank spring-water samples, dissolved chromium was above the Washington State ambient surface-water level for acute toxicity level at the 100-H Area and above the chronic toxicity level at the 100-B, 100-N, 100-D, 100-H, and 100-F Areas. Arsenic concentrations in shoreline spring water were well below the Washington State ambient surface-water chronic toxicity level, but concentrations in all samples (including upriver Columbia River water samples) exceeded the EPA limit for the protection of human health for the consumption of water and organisms; however, this EPA value is more than 10,500 times lower than the Washington State chronic toxicity standard (40 CFR 141; Appendix D, Table D.5). Nitrate concentrations at all spring-water locations were below the drinking water standard (Appendix D, Table D.4).

10.5.2 Monitoring Columbia River Shoreline Springs Sediment

Beginning in the 1990s, periodic studies were conducted to collect and analyze sediment from riverbank springs in the 100 Areas and 300 Area (DOE/RL-92-12, Rev. 1; WHC-EP-0609; WHC-SD-EN-TI-125; WHC-SD-EN-TI-198). Routine sampling of sediment from shoreline springs began during 1993 at the Hanford town site and 300 Area. Sampling of shoreline springs sediment in the 100-B, 100-K, and 100-F Areas began during 1995 and in the 100-H Area in 2003. Substrates at the shoreline springs in the 100-N and 100-D Areas consist predominantly of large cobble and are unsuitable for sampling.

Radiological Results for Sediment Samples from Columbia River Shoreline Springs

During 2006, sediment samples were collected at shoreline springs in the 100-B, 100-F, 100-H, and 300 Areas and the Hanford town site. No sediment was available for sampling at the 100-K Area location because the springs that were scheduled for sampling were not flowing during the scheduled sampling time. Results for 2006 samples were similar to those observed for previous years (PNNL-16623, APP. 1; Appendix C, Table C.11). Beryllium-7 (in one of eight samples), potassium-40, strontium-90, cesium-137, and uranium isotopes were the only radionuclides reported above the minimum detectable concentrations. During 2006, radionuclide concentrations in shoreline spring sediment were similar to those observed in Columbia River sediment, with the exception of the 300 Area where uranium concentrations were above the background concentrations measured for sediment from Priest Rapids Dam. Elevated uranium concentrations for 300 Area spring sediment

Table 10.5.3. Concentration Ranges for Selected Chemicals in Water Monitoring Samples from Columbia River Shoreline Springs at the Hanford Site, 2001 Through 2006

	Ambient-Water Quality Criterion Level[a]	100-B Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	Hanford Town Site	300 Area
No. of Samples		10	7	8	8	9	5	11	10
Dissolved Metals (µg/L)									
Antimony	NA	0.11 - 0.31	0.13 - 0.29	0.16 - 0.46	0.17 - 0.30	0.13 - 0.27	0.14 - 0.22	0.15 - 0.26	0.18 - 0.26
Arsenic	190	0.60 - 1.6	0.35 - 1.4	1.5 - 2.7	0.54 - 2.5	0.33 - 2.9	1.4 - 2.6	0.99 - 3.7	0.96 - 5.6
Cadmium	0.59	0.0056 - 0.024	0.0080 - 0.023	0.015 - 0.030	0.0074 - 0.062	0.0097 - 0.040	0.018 - 0.12	0.010 - 0.028	0.016 - 0.031
Chromium	10[b]	5.1 - 18	0.59 - 42	6.0 - 17	0.49 - 57	0.76 - 33	3.3 - 18	0.52 - 2.7	1.5 - 5.0
Copper	6	0.20 - 0.51	0.37 - 0.51	0.22 - 0.43	0.32 - 0.82	0.40 - 0.67	0.31 - 1.1	0.29 - 0.88	0.30 - 0.47
Lead	1.1	0.0040 - 0.60	0.0040 - 0.25	0.0052 - 0.24	0.016 - 0.91	0.011 - 0.40	0.0082 - 0.36	0.0040 - 0.29	0.0040 - 0.41
Nickel	83	0.091 - 1.6	0.11 - 1.3	0.13 - 1.7	0.22 - 6.4	0.13 - 1.5	0.20 - 1.7	0.046 - 1.4	0.31 - 2.1
Silver	0.94[c]	0.0012 - 0.0097[d]	0.0012 - 0.0085	0.0017 - 0.0085	0.0017 - 0.0085	0.0012 - 0.010	0.0012 - 0.0040	0.0017 - 0.0040	0.0017 - 0.0085
Thallium	NA	0.0046 - 0.020	0.0079 - 0.021	0.0057 - 0.0086	0.0066 - 0.024	0.0054 - 0.022	0.0072 - 0.013	0.0073 - 0.019	0.0040 - 0.018
Zinc	55	0.14 - 4.6	0.43 - 3.1	1.2 - 1.7	1.2 - 3.0	1.1 - 2.5	0.66 - 4.2	0.54 - 2.6	0.78 - 2.8
No. of Samples		7	7	9	8	9	5	11	10
Total Recoverable Metals (µg/L)									
Chromium	96[e]	8.1 - 20	0.83 - 41	4.6 - 17	5.9 - 69	0.89 - 63	10 - 37	0.88 - 24	1.8 - 30
Mercury	0.012	0.00038 - 0.0026[f]	0.00075 - 0.018[g]	0.00040 - 0.00094	0.00047 - 0.028	0.00056 - 0.041	0.0076 - 0.029[h]	0.00073 - 0.018	0.00080 - 0.047
Selenium	5	0.50 - 1.5	0.10 - 0.50	0.50 - 1.0	0.10 - 2.4	0.10 - 0.87	0.68 - 2.1	0.45 - 1.7	1.2 - 3.8
No. of Samples		10	7	5	8	7	4	13	15
Anions (mg/L)									
Nitrate	45[i]	0.10 - 2.4	0.028 - 3.1	2.0 - 4.7	0.10 - 2.6	0.56 - 6.9	2.6 - 9.8	0.47 - 5.1	1.7 - 6.1

(a) Ambient-water quality criteria values (WAC 173-201A-240) for chronic toxicity unless otherwise noted.
(b) Value for hexavalent chromium.
(c) Value for acute toxicity; chronic value not available.
(d) Number of samples = 9.
(e) Value for trivalent chromium.
(f) Number of samples = 6.
(g) Number of samples = 5.
(h) Number of samples = 4.
(i) Drinking water standard (WAC 246-290).
NA = Not available.

compared to Priest Rapids Dam sediment have been previously reported (PNNL-14687).

Concentrations of metals in shoreline spring sediment samples during 2006 were similar to concentrations in Hanford Reach Columbia River sediment samples (PNNL-16623, APP. 1; Appendix C, Table C.9). Currently, there are no Washington State freshwater sediment quality criteria for comparison to the measured values.

10.6 Radiological Monitoring of Hanford Site Drinking Water

R. W. Hanf and L. M. Kelly

During 2006, Pacific Northwest National Laboratory personnel conducted radiological monitoring of drinking water supplied to Hanford Site facilities by DOE-owned pumps and water-treatment facilities. Fluor Hanford, Inc., the site water-compliance organization, conducted routine chemical, physical, and microbiological monitoring of onsite drinking water. Individual water systems operated by Fluor Hanford, Inc. and Washington Closure Hanford LLC performed process monitoring (includes chemical and physical sampling) at the water-treatment plants and distribution systems to determine compliance with applicable regulations.

WAC 246-290 requires that all drinking water analytical results be reported routinely to the Washington State Department of Health. Radiological results for Hanford Site drinking water samples are reported to the state through this annual environmental report and through an annual supplemental data compilation (e.g., PNNL-16623, APP. 1). Process monitoring reports are provided directly to the state each month by the contractor responsible for operating the water system. Chemical, physical, and microbiological data are reported to the state directly by the state-accredited laboratory performing the analyses and to Fluor Hanford, Inc., but are not published.

All DOE-owned drinking water systems on the Hanford Site were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels during 2006. Contaminant concentrations measured during the year were similar to those observed in recent years (see Section 8.6 in PNNL-15222 and Section 10.6 in PNNL-15892).

10.6.1 Hanford Site Drinking Water Systems

During 2006, drinking water was supplied to DOE facilities on the site by nine DOE-owned, contractor-operated, public water systems (Table 10.6.1). Two systems, one at the Wye Barricade and one at the Yakima Barricade, were designated as Group B water systems by the Washington State Department of Health in 2005 (a Group B system serves an average non-residential population of less than 25 for 60 or more days within a calendar year). These systems consist of holding tanks that are supplied with water trucked from the 200-West Area water-treatment plant. Eight of the nine systems used water from the Columbia River. One system in the 400 Area used groundwater from the unconfined aquifer beneath the site. Fluor Hanford, Inc. operated seven of the systems. Two systems were operated

Table 10.6.1. Hanford Site Drinking Water Systems and Systems Operators

System[a]	Operator
200-West Area	Fluor Hanford, Inc.
100-K Area	Fluor Hanford, Inc.
100-N Area	Washington Closure Hanford LLC
300 Area	Washington Closure Hanford LLC
400 Area	Fluor Hanford, Inc.
200-East Area	Fluor Hanford, Inc.
609 Fire Station	Fluor Hanford, Inc.
Wye Barricade	Fluor Hanford, Inc.
Yakima Barricade	Fluor Hanford, Inc.

(a) 400 Area system water from 400 Area groundwater wells. Water for all other systems is from the Columbia River. Systems in the 100-B Area and at 251-West no longer supply potable water to consumers.

by Washington Closure Hanford LLC. The system in the 300 Area distributed water supplied by the city of Richland. In addition to the 300 Area, the city of Richland provided drinking water to the Richland North Area, and the Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center in 2006.

10.6.2 Hanford Site Drinking Water Treatment Facilities

Raw water was treated at four DOE-owned water treatment facilities in the 100-K, 100-N, 200-West, and 400 Areas (Figure 10.6.1). Water for the 100-K, 100-N, and 200-West

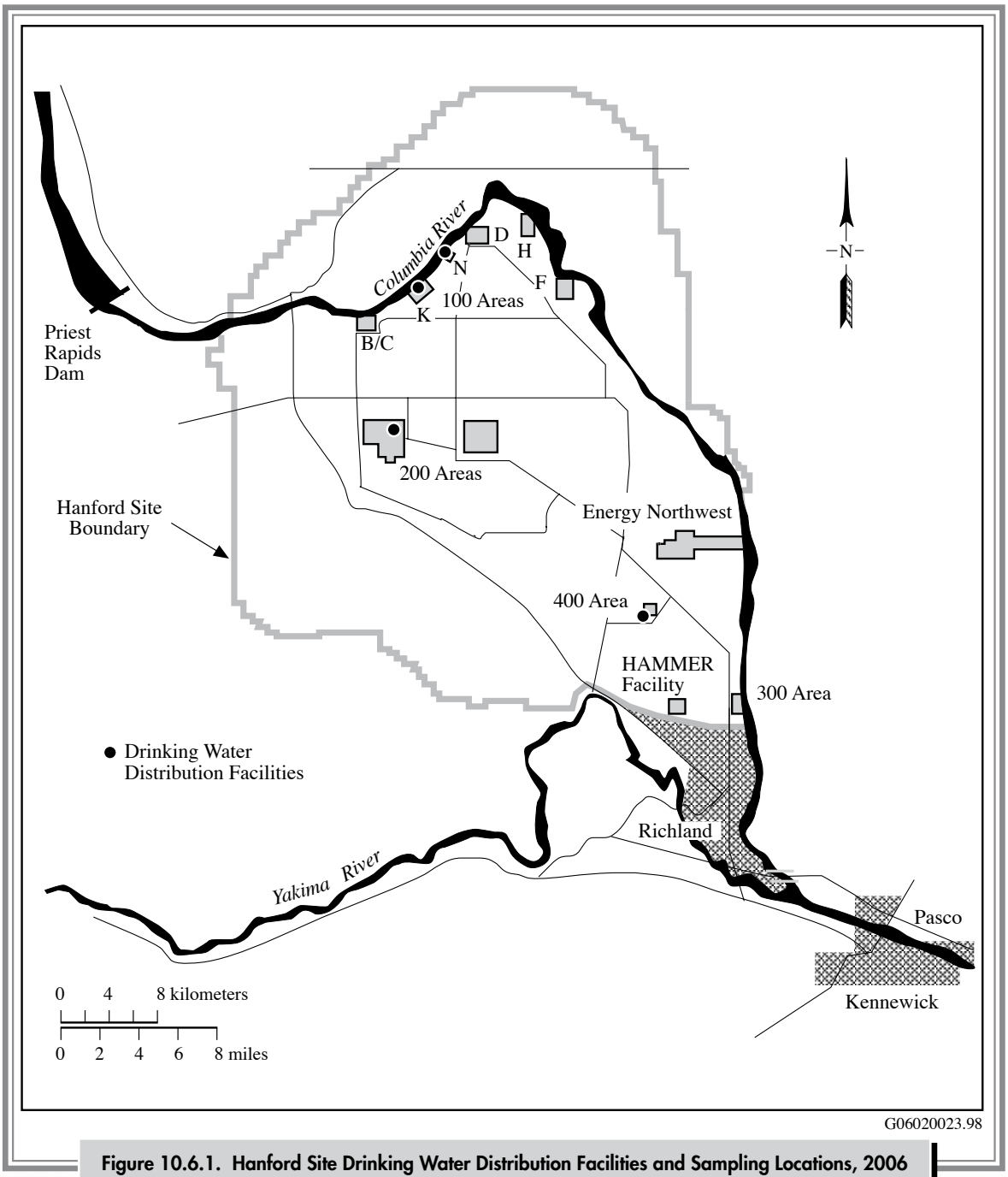


Figure 10.6.1. Hanford Site Drinking Water Distribution Facilities and Sampling Locations, 2006

Areas facilities was obtained from the Columbia River. Water treated in the 400 Area was pumped from wells. The 400 Area continued to use well 499-S1-8J (P-16) as the primary drinking water supply well, and wells 499-S0-8 (P-14) and 499-S0-7 (P-15) were used as backup sources. The three wells furnished water to a common header that supplies three aboveground storage tanks. The backup well with the lowest tritium level, as demonstrated by sampling and analysis, was used as the primary backup water supply. Well P-15 did not supply water to the 400 Area in 2006. Well P-14 was used in June and supplied 2,039,358 liters (538,800 gallons).

10.6.3 Collection of Drinking Water Samples and Analytes of Interest

Samples at all four drinking water treatment facilities were collected monthly and analyzed either quarterly or annually for radiological contaminants. All were samples of treated water collected before the water was distributed for general use. Drinking water in the 300 and Richland North Areas and at the HAMMER training and education center was not routinely monitored for radiological contaminants by DOE contractor personnel. However, personnel from Pacific Northwest National Laboratory's Surface Environmental Surveillance Project routinely collected water samples from the Columbia River at Richland's river-water intake. The Columbia River is a major source of the city of Richland's drinking water. The radiological analytical results for these river-water samples are summarized in Section 10.4 and tabulated in Appendix C (Table C.4). The city of Richland also monitors its water for radiological and chemical contaminants as well as for general water quality. As a community water system, the city is required to annually report monitoring results and characterize the risks (if any) from exposure to contaminants in the water in what is known as a Consumer Confidence Report. The reports are mailed to all consumers as an insert with a monthly utility bill. Results are also made available on the city of Richland's website (http://www.ci.richland.wa.us/RICHLAND/Utilities/index.cfm?PageNum=15).

10.6.4 Radiological Results for Hanford Site Drinking Water Samples

Drinking water samples collected for radiological analysis in 2006 were analyzed for gross alpha, gross beta, tritium, strontium-90, iodine-131, radium-226, and radium-228. Results for radiological monitoring of Hanford Site drinking water during 2006 are summarized in Table 10.6.2. Individual analytical results are reported in PNNL-16623, APP. 1. The maximum amount of beta-gamma radiation from manmade radionuclides allowed in drinking water by Washington State and the EPA is an annual average concentration that will not produce an annual dose equivalent to the whole body or any internal organ greater than 4 mrem (0.04 mSv). Maximum contaminant levels for gross alpha (excluding uranium and radon) and radium-226 and radium-228 (a combined total) are 15 pCi/L (0.56 Bq/L) and 5 pCi/L (0.18 Bq/L), respectively. The maximum allowable annual average limit for tritium is 20,000 pCi/L (740 Bq/L) (40 CFR 141; WAC 246-290). These concentrations are assumed to produce a total body or organ dose of 4 mrem (0.04 mSv) per year. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any internal organ must not exceed 4 mrem (0.04 mSv).

During 2006, annual average concentrations of all monitored radionuclides in Hanford Site drinking water were below state and federal maximum allowable contaminant levels. All gross alpha, gross beta, and tritium results for river-water samples were below their minimum detectable concentrations (i.e., concentrations were too low to measure), as were radium-228 results for 5 of 12 river-water samples. Federal law states that all community systems designated by Washington State as using waters contaminated by effluents from nuclear facilities must sample for iodine-131. All river and well water iodine-131 results were below their respective minimum detectable concentrations. There is currently no DOE source for this contaminant at the Hanford Site, but the Energy Northwest power-generating reactor is a potential source. Radium-226 was not detected in any of the river-water samples analyzed. Strontium-90 was detected in all three of the river-water

Table 10.6.2. Annual Average Concentrations (pCi/L)[a] of Selected Radiological Constituents in Hanford Site Drinking Water, 2006

Constituent	No. of Samples Analyzed From Each Location	Systems				Standards
		100-K Area	100-N Area	200-West Area	400 Area	
Gross alpha[b]	4[c]	0.30 ± 0.59[d]	0.06 ± 0.90[d]	0.18 ± 0.55[d]	0.36 ± 0.82[d]	15[e,f]
Gross beta[b]	4[g]	1.35 ± 1.07[d]	0.94 ± 1.61[d]	1.63 ± 2.55[d]	6.14 ± 0.57	50[f]
Tritium	1[h]	10.2 ± 86[d,i]	-14.2 ± 85[d,i]	50.2 ± 87[d,i]	2,737 ± 66[c]	20,000[f]
Strontium-90	1[h]	0.05 ± 0.03[i]	0.05 ± 0.03[i]	0.06 ± 0.04[i]	-0.01 ± 0.03[d,i]	8[e,f]
Iodine-131[b]	4[c]	0.009 ± 0.30[d]	-0.01 ± 0.31[d]	0.29 ± 0.25[d]	-0.18 ± 0.56[d]	3[j]
Radium-226[b]	4[c]	0.01 ± 0.13[d]	-0.03 ± 0.20[d]	0.05 ± 0.07[d]	0.04 ± 0.11[d]	combined
Radium-228[b]	4[c]	0.49 ± 0.11	0.60 ± 0.29	0.60 ± 0.17	0.63 ± 0.57	5[f]

(a) Multiply pCi/L by 0.037 to convert to Bq/L.
(b) Annual average ±2 times the standard deviation.
(c) Samples were collected and analyzed quarterly.
(d) Analytical results for all samples were below the detection limit.
(e) WAC 246-290.
(f) 40 CFR 141.
(g) Samples were collected monthly, composited, and analyzed quarterly.
(h) Samples were collected quarterly, composited, and analyzed annually.
(i) Single result ± the total propagated analytical error.
(j) EPA-570/9-76/003.

samples analyzed for strontium. Gross beta was found in all four 400 Area well-water samples, and radium-228 was measured in two of four well-water samples. Gross alpha, strontium-90, and radium-226 were not detected in 400 Area well-water samples (Table 10.6.2).

The Soil and Groundwater Remediation Project collected and analyzed raw (untreated) water samples from all three 400 Area drinking water wells. A tritium plume that originates in the 200-East Area extends under the 400 Area and has historically affected tritium concentrations in all 400 Area drinking water wells. During 2006, annual average tritium concentrations in all three wells were below the 20,000 pCi/L (740 Bq/L) state and federal annual average drinking water standard (Table 10.6.3; Figure 10.6.2).

Table 10.6.3. Tritium Concentrations (pCi/L)[a] in Hanford Site 400 Area Drinking Water Wells, 2006[b]

Sampling Date	Primary Drinking Water Well 499-S1-8J (P-16)	Backup Drinking Water Well 499-S0-8 (P-14)	Backup Drinking Water Well 499-S0-7 (P-15)
January 24, 2006	2,990 ± 280	2,810 ± 270	12,700 ± 680
April 20, 2006	3,080 ± 280	2,980 ± 270	11,500 ± 630
July 25, 2006	2,840 ± 260	2,790 ± 250	12,300 ± 650
November 1, 2006	NS	2,590 ± 260	11,000 ± 590

(a) Multiply pCi/L by 0.037 to convert to Bq/L.
(b) Reported concentration ±2 total propagated analytical error.
NS = No sample.

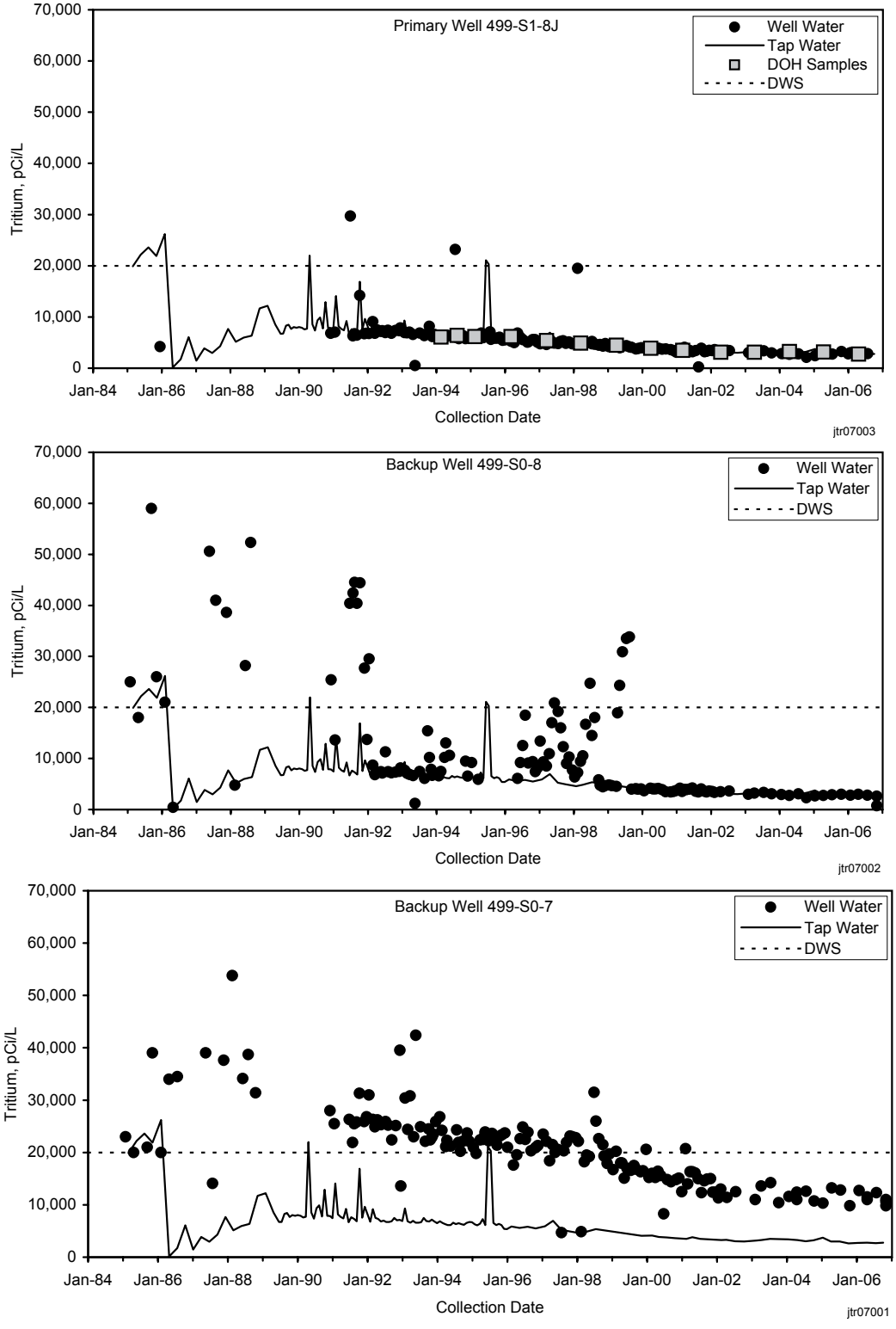


Figure 10.6.2. Tritium Concentrations in Drinking Water from Three Wells in the Hanford Site's 400 Area, 1984 Through 2006. (DOH = Washington State Department of Health; DWS = drinking water standard). Multiply pCi/L by 0.037 to convert to Bq/L.

10.7 Groundwater Monitoring

M. J. Hartman

Groundwater is a supply of water found in layers beneath the earth's surface. At the Hanford Site, groundwater has been affected by past industrial activities. Fifty years of nuclear weapons production resulted in approximately 1.7 trillion liters (450 billion gallons) of liquid waste released to the ground. Some of the associated contaminants have reached the groundwater. Hazardous chemicals in the groundwater include carbon tetrachloride, chromium, and nitrate. Radioactive contaminants include iodine-129, strontium-90, technetium-99, tritium, and uranium. Currently, groundwater contaminant levels are greater than drinking water standards beneath 12% of the area of the Hanford Site. This is down from 17.5% just a few years ago.

Hanford Site groundwater is not a source of public drinking water and does not significantly affect offsite drinking water sources, such as the Columbia River and city wells. There are, however, possible near-shore effects where Hanford Site groundwater flows into the Columbia River.

The DOE, the EPA, and the Washington State Department of Ecology have developed a remediation plan for protecting the Columbia River. The Soil and Groundwater Remediation Project is largely responsible for implementing the plan. The Soil and Groundwater Remediation Project publishes an annual groundwater monitoring report (e.g., PNNL-16346), summarized here.

10.7.1 Highlights and Items of Interest

KW Reactor Chromium Plume. In 1998, chromium concentrations in groundwater near the KW Reactor began to rise. In 2006, the DOE installed new wells for a pump-and-treat system to clean up this plume. One new well had chromium concentrations over 2,000 µg/L. The pump-and-treat system began to operate in January 2007.

100-N Area Pump-and-Treat Alternatives. The DOE placed the 100-N Area pump-and-treat system on standby (shut off pumps) in March 2006 and is testing another cleanup method. Workers injected apatite-forming chemicals into two wells along the 100-N Area shoreline (one in June and the other in September 2006). Scientists are monitoring the concentrations of strontium-90 and other parameters around the injection sites. The DOE plans to install an apatite barrier 90 meters (~300 feet) long in 2007.

100-H Area Pump-and-Treat. Concentrations of chromium in 100-H Area groundwater have declined since 1997 when a pump-and-treat system began to operate. Concentrations in compliance wells were below the remedial action goal of 22 µg/L in most samples between April and December 2006.

Depth of Carbon Tetrachloride in the 200-West Area. In recent years, groundwater samples have been collected from different depths in the aquifer beneath the 200-West Area. These samples give new information on how carbon tetrachloride concentrations vary with depth in the groundwater. It appears that a greater mass of carbon tetrachloride is present in the aquifer than previously thought.

Technetium-99 at T Tank Farm. Technetium-99 levels continued to increase in wells east of the T Tank Farm in the 200-West Area. The highest concentrations at the top of the aquifer (~24,000 pCi/L [888 Bq/L]) are in a well downgradient of the northeast corner of the tank farm. Concentrations are higher (56,000 pCi/L [2,072 Bq/L]) in an adjacent well that is screened 10 meters (33 feet) below the water table.

Trichloroethene in the 300-FF-5 Operable Unit. Scientists found organic compounds in water samples collected during the drilling of four characterization wells in the 300-FF-5 Operable Unit. Samples collected from a silty layer contained some high concentrations of trichloroethene. The samples were from a depth other than what is sampled in typical wells. The DOE is continuing to investigate this site.

CERCLA Five-Year Review. The DOE conducted the second review of records of decision for CERCLA cleanup in 2006. These reviews are required every 5 years to determine whether cleanup activities protect human health and the environment. The EPA is responsible for certifying the review. Table 10.7.1 summarizes the review's conclusions about groundwater. More information on the 5-year review is available at the website www.hanford.gov, "CERCLA Five-Year Review."

EM-22 Technology Proposals. In 2006, the U.S. Congress authorized $10 million for "...analyzing contaminant migration to the Columbia River, and for the introduction of new technology approaches to solving contamination migration issues." The DOE's Office of Environmental Management (EM-22) will administer these funds. The DOE funded nine proposals after addressing comments from a peer review panel. The funded proposals include the following:

- Five related to chromium in groundwater in the 100-K and 100-D Areas.
- Two related to strontium-90 in groundwater in the 100-N Area.
- One related to carbon tetrachloride in groundwater in the 200-West Area.
- One related to uranium in groundwater in the 300 Area.

The DOE is considering funding nine additional proposals. More information on the EM-22 proposals is available at the website www.hanford.gov/cp/gpp/science/em21.cfm.

Groundwater Data. Workers sampled 974 monitoring wells and shoreline aquifer tubes in 2006, many of them more than once. Laboratories analyzed over 30,000 samples of Hanford Site groundwater, generating over 88,000 data points for the year. Tables 10.7.2 and 10.7.3 list the number of wells and analyses by groundwater interest area and monitoring purpose.

Table 10.7.1. Summary of Groundwater Issues from 2006 CERCLA Five-Year Review

Area	Conclusions
100 Areas	Most of the groundwater interim actions are meeting remedial-action objectives.
	The interim action for the 100-N Area strontium-90 plume is not meeting objectives and an alternative technology is being tested.
200 Areas	The 200-ZP-1 interim action is being expanded to address additional portions of the carbon tetrachloride plume. The 200-ZP-1 Operable Unit is in the north portion of the 200-West Area.
	The vapor-extraction system for removing carbon tetrachloride from the vadose zone has proven to be effective and will continue operating.
	The 200-UP-1 interim action has met remedial-action objectives. This operable unit underlies the south part of the 200-West Area.
300 Area	Monitored natural attenuation of uranium has not achieved remedial-action objectives and additional treatability studies are underway.
Former 1100 Area	The final remedy selected for this area met the remedial-action objectives, and the remedy remains protective.

Determinations of long-term protectiveness for the 100, 200, and 300 Areas are deferred until more complete remedies are selected.

Table 10.7.2. A Summary of the Hanford Site Soil and Groundwater Remediation Project by Groundwater Interest Area, 2006

	Hanford Site	100-BC-5	100-FR-3	100-HR-3-D	100-HR-3-H	100-KR-4	100-NR-2
Number of wells and aquifer tubes	974	43	37	191	38	67	88
Number of sampling events	3,499	44	40	1,000	347	320	285
Number of analyses	30,246	357	342	4,772	1,093	1,939	2,740
Number of results	88,110	715	1,169	7,123	2,101	4,421	6,216
Percent of results non-detected	48	23	43	19	25	34	41
	1100-EM-1	**200-BP-5**	**200-PO-1**	**200-UP-1**	**200-ZP-1**	**300-FF-5**	
Number of wells	43	115	99	72	100	81	
Number of sampling events	65	269	245	234	407	243	
Number of analyses	514	5,549	3,823	2,474	4,458	2,185	
Number of results	1,662	13,398	12,501	10,926	17,172	10,706	
Percent of results non-detected	59	44	49	59	55	65	

Table 10.7.3. A Summary of the Hanford Site Soil and Groundwater Remediation Project by Monitoring Purpose,[a] 2006

	Restoration[b]	Waste Management[c]	Environmental Surveillance[d]
Number of wells	474	286	497
Number of sampling events	2,261	1,052	1,762
Number of analyses	13,685	14,797	16,451
Number of results	37,194	45,204	48,596
Percent of results non-detected	46	48	51

(a) Because of the co-sampling among groundwater monitoring programs, the wells monitored, sampling events, analyses, results, and non-detectable results overlap among monitoring purposes.
(b) Wells associated with remediation activities.
(c) Wells sampled to determine impact, if any, of a waste management unit (e.g., RCRA) on groundwater.
(d) Wells sampled to detect impact, if any, of site operations on groundwater over the entire Hanford Site and adjacent offsite areas.

10.7.2 Groundwater Flow

Groundwater in the unconfined aquifer generally flows from west to east across the Hanford Site into the Columbia River. Scientists infer the direction of groundwater flow from water-table elevations, barriers to flow (e.g., basalt or mud units at the water table), and the distribution of contaminants.

The water-table map for April 2006 (Figure 10.7.1) shows general directions of groundwater flow. Groundwater enters the unconfined aquifer from the west and eventually flows into the Columbia River. Additional water infiltrates through the soil beneath the Hanford Site. The flow of groundwater from the aquifer to the river is about 1.1 to 2.5 cubic meters (39 to 99 cubic feet) per second (PNNL-14753, Rev. 1). This flow is very small compared to the average flow of the river, which is approximately 3,400 cubic meters (120,000 cubic feet) per second.

The water table beneath the 200-East Area is relatively flat because the aquifer is very permeable. Groundwater enters the region from the west and divides, with some flowing to the north through Gable Gap (the gap between Gable Butte and Gable Mountain) and some moving southeast. In the south part of the Hanford Site, groundwater flows toward the 300 Area from the northwest, west, and southwest.

The natural pattern of groundwater flow was altered during the Hanford Site's operating years by water-table mounds. The mounds formed when large volumes of wastewater were discharged to the ground in each reactor area and the

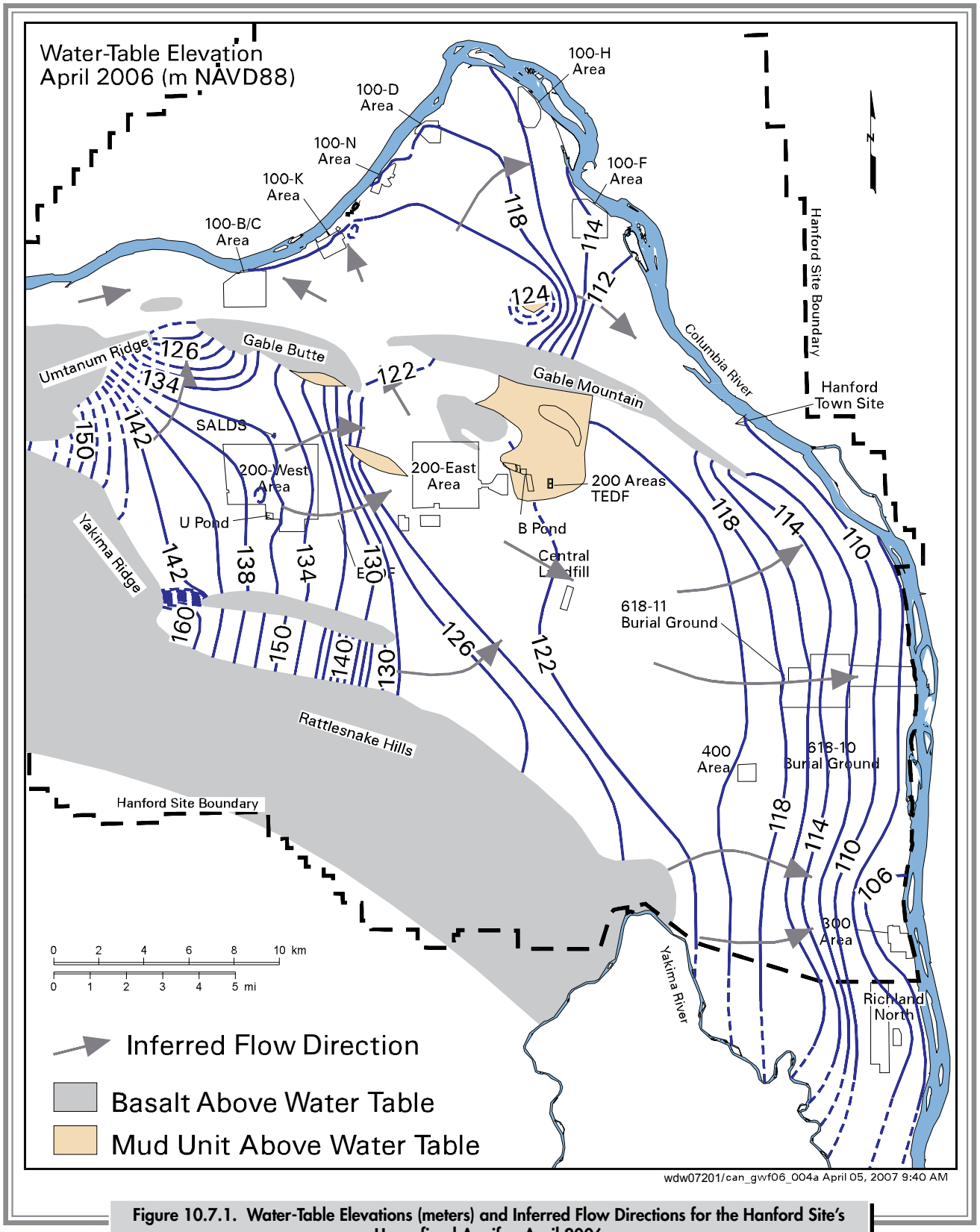


Figure 10.7.1. Water-Table Elevations (meters) and Inferred Flow Directions for the Hanford Site's Unconfined Aquifer, April 2006

200 Areas. Since waste disposal to the ground decreased in the 1990s, these mounds have declined or disappeared.

Pump-and-treat systems also alter groundwater flow. Extraction wells in the 100-K, 100-D, 100-H, and 200-West Areas capture water from the surrounding areas. Water flows away from injection wells (where treated water is injected back into the aquifer), which are located upgradient of the plumes.

10.7.3 Groundwater Monitoring and Remediation

The Hanford Site's waste sites are grouped into "source operable units" to help manage cleanup work. The groundwater beneath the waste sites is divided into "groundwater operable units." These regulatory-defined groundwater operable units do not cover the entire Hanford Site. Therefore, to provide scheduling, data review, and interpretation for the entire Hanford Site, groundwater staff have defined informal "groundwater interest areas" that include the groundwater operable units and intervening regions. Figure 10.7.2 illustrates these interest areas and the operable unit boundaries. During 2006, groundwater monitoring continued at CERCLA groundwater operable units and at 24 RCRA sites (Table 10.7.4 and Figure 10.7.3).

10.7.3.1 Overview

The DOE plans to clean up the Hanford Site's groundwater and return it to its beneficial use where practical, or at least prevent further degradation (DOE/RL-2002-68, Rev. 0). The DOE will 1) clean up high-risk waste sites, 2) shrink the contaminated area, 3) reduce natural and artificial recharge at selected locations, 4) clean up groundwater, and 5) monitor groundwater. Figures 10.7.4 and 10.7.5 show the principal groundwater contaminant plumes.

The total area of contaminant plumes with concentrations above drinking water standards was about 186 square kilometers (71.8 square miles) in 2006 (Table 10.7.5). This area is about 12% of the total area of the Hanford Site. The tritium and iodine-129 plumes have the largest areas. The dominant plumes had sources in the 200-East Area and extend toward the east and southeast. Tritium and iodine-129 plumes are also present in the 200-West Area. Technetium-99 plumes are present in the 200-East and 200-West Areas. One technetium-99 plume has moved northward from the 200-East Area. Uranium plumes are found in the 100-H, 200-East, 200-West, and 300 Areas. Strontium-90 concentrations exceed the drinking water standard in the 100 Areas (except the 100-D Area), the 200-East Area, and beneath the former Gable Mountain Pond. Other radionuclides, including cesium-137, cobalt-60, and plutonium, exceed drinking water standards in a few wells.

Nitrate is a widespread chemical contaminant in Hanford Site groundwater. Plumes originated from the 100 and 200 Areas and from offsite industry and agriculture. Carbon tetrachloride forms a large plume beneath the 200-West Area. Trichloroethene plumes are found in the 100-F and 200-West Areas. New wells in the 300 Area detected trichloroethene at levels above the drinking water standard at depth in the aquifer. Chromium exceeds the 100-µg/L drinking water standard in parts of the 100-K and 100-D Areas. Chromium exceeds the state's aquatic standard (10 µg/L) in these areas and parts of the 100-B/C, 100-H, and 100-F Areas. Local plumes of chromium also are present in the 200 Areas, particularly the north part of the 200-West Area.

Tables 10.7.6 and 10.7.7 list the highest levels of contaminants by groundwater interest area and monitoring purpose. The monitoring purpose is divided into restoration, waste management, and environmental surveillance. Restoration refers to wells related to groundwater cleanup. Waste management refers to wells sampled to determine impacts, if any, of a waste-management unit (e.g., RCRA site). Environmental surveillance refers to wells sampled to detect impacts, if any, of site operations on groundwater over the entire Hanford Site and adjacent offsite areas. Table D.4 in Appendix D lists drinking water standards.

The following text discusses groundwater contamination, monitoring, and remediation for each of the groundwater operable units and the confined aquifers.

10.7.3.2 Groundwater Monitoring Results for the 100-BC-5 Operable Unit

This operable unit includes the groundwater beneath the 100-B/C Area, located in the northwest Hanford Site (Figure 10.7.2). Most of the contamination is in the north part

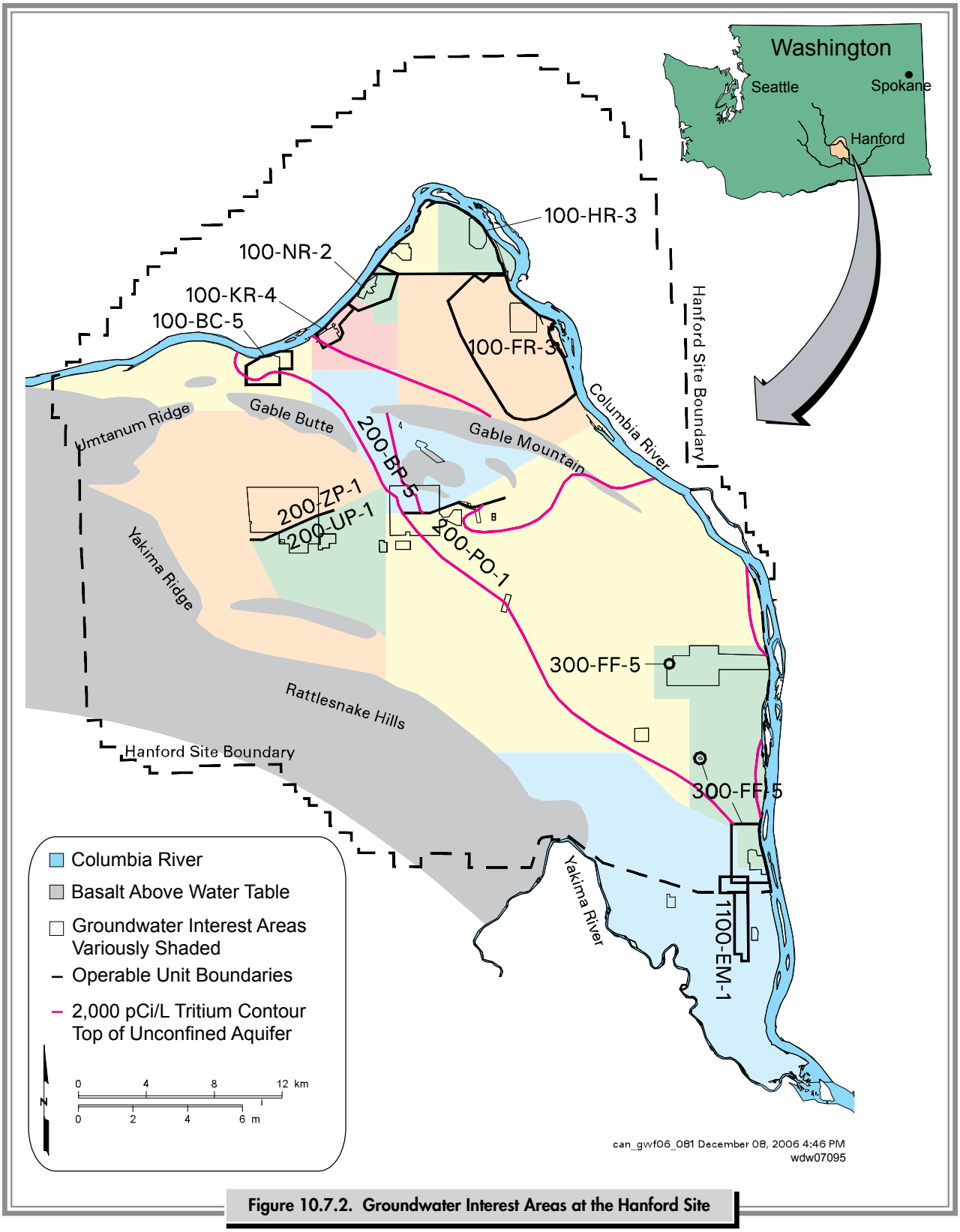


Figure 10.7.2. Groundwater Interest Areas at the Hanford Site

Table 10.7.4 Regulated Units Requiring Groundwater Monitoring on the Hanford Site, 2006

Site or Waste Management Area	Type of Monitoring Program	Regulated Under	2006 Highlights
	RCRA Regulated Units		
116-N-1 (1301-N) facility	Final status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
116-N-3 (1325-N) facility	Final status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
120-N-1, 120-N-2 (1324-N/NA) facilities	Final status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
116-H-6 (183-H) evaporation basins	Final status corrective action	WAC 173-303-645(11)(g)	Monitoring during CERCLA interim action: chromium, nitrate, technetium-99, uranium
216-A-29 ditch	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
216-B-3 pond	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
216-S-10 pond and ditch	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection;[a] only two shallow and one deep downgradient wells remain
216-U-12 crib	Interim status assessment	WAC 173-303-400; 40 CFR 265.93(d)	Continued assessment; nitrate
316-5 process trenches	Final status corrective action	WAC 173-303-645(11)(g)	Monitoring during CERCLA natural attenuation interim action: uranium and organics
Integrated Disposal Facility	Establishing background	WAC 173-303-645	Planned facility; seven of eight wells in place
Liquid Effluent Retention Facility	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Insufficient wells; no statistical comparisons
Low-Level Waste Management Area 1	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
Low-Level Waste Management Area 2	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection;[a] north wells dry; no unconfined aquifer
Low-Level Waste Management Area 3	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	No statistical comparisons until background re-established
Low-Level Waste Management Area 4	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
Nonradioactive Dangerous Waste Landfill	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
PUREX cribs	Interim status assessment	WAC 173-303-400; 40 CFR 265.93(d)	Continued assessment: iodine-129, nitrate, tritium
SST Waste Management Area A-AX	Interim status detection	WAC 173-303-400; 40 CFR 265.93(d)	Continued assessment: nitrate, technetium-99
SST Waste Management Area B-BX-BY	Interim status assessment	WAC 173-303-400; 40 CFR 265.93(d)	Continued assessment: nitrate, nitrite, technetium-99, uranium
SST Waste Management Area C	Interim status detection	WAC 173-303-400; 40 CFR 265.93(b)	Continued detection[a]
SST Waste Management Area S-SX	Interim status assessment	WAC 173-303-400; 40 CFR 265.93(d)	Continued assessment: chromium, technetium-99

Table 10.7.4 (contd)

Site or Waste Management Area	Type of Monitoring Program	Regulated Under	2006 Highlights
SST Waste Management Area T	Interim status assessment	WAC 173-303-400; 40 CFR 265.93(d)	Continued assessment: technetium-99, nitrate, chromium
SST Waste Management Area TX-TY	Interim status assessment	WAC 173-303-400; 40 CFR 265.93(d)	Continued assessment: chromium, nitrate, technetium-99
SST Waste Management Area U	Interim status assessment	WAC 173-303-400; 40 CFR 265.93(d)	Continued assessment: nitrate, technetium-99
Other Regulated Units			
200 Area Treated Effluent Disposal Facility	Compliance with permit	WAC 173-216	No influence on upper aquifer
Environmental Restoration Disposal Facility	Similar to RCRA detection	EPA/ROD/R10-95/100	No impact on groundwater
State Approved Land Disposal Site	Compliance with permit	WAC 173-216	No permit limits exceeded
Solid Waste Landfill	Compliance with permit	WAC 173-304	Six constituents exceeded background or standards; low levels of organics

(a) Analysis of RCRA CIP provided no evidence of groundwater contamination with hazardous constituents from the unit.
CIP = Contamination indicator parameters.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act*.
CFR = *Code of Federal Regulations*.
EPA = U.S. Environmental Protection Agency.
PUREX = Plutonium-Uranium Extraction Plant.
RCRA = *Resource Conservation and Recovery Act*.
ROD = Record of decision.
SST = Single-shell tank.
WAC = *Washington Administrative Code*.

of the area, beneath former waste-disposal trenches and basins. Tritium and strontium-90 exceeded drinking water standards in several wells. Tritium levels in two wells in the northeast 100-B/C Area spiked in recent years, but the reasons for the spikes are not known. Tritium also exceeded the drinking water standard near a burial ground where tritium was recently found in the soil. Nitrate and chromium continued to be below drinking water standards, but chromium exceeded the state's 10-µg/L standard for protection of aquatic life (WAC 173-201A-240).

No active groundwater remediation is underway in the 100-BC-5 Operable Unit. Monitoring has continued while waste sites are cleaned up. The DOE published Draft B of a pilot project risk assessment in 2006 (DOE/RL-2005-40, Draft B), which will serve as an example for risk assessments in the other reactor areas. The pilot risk assessment characterized the potential risks to human health and the environment under the cleanup standards used in remedial actions performed to date.

10.7.3.3 Groundwater Monitoring Results for the 100-KR-4 Operable Unit

The principal groundwater issues in this operable unit include 1) remediation of chromium contaminated groundwater, 2) tracking contaminant plumes from past-practices sites, and 3) monitoring groundwater near the KE and KW Basins.

Interim Remedial Action. A pump-and-treat system is being used to remove hexavalent chromium from the aquifer beneath an infiltration trench (Figure 10.7.6). The system removed approximately 21 kilograms (46 pounds) of chromium in 2006 and has removed 291 kilograms (642 pounds) since startup in 1997. Although the mapped

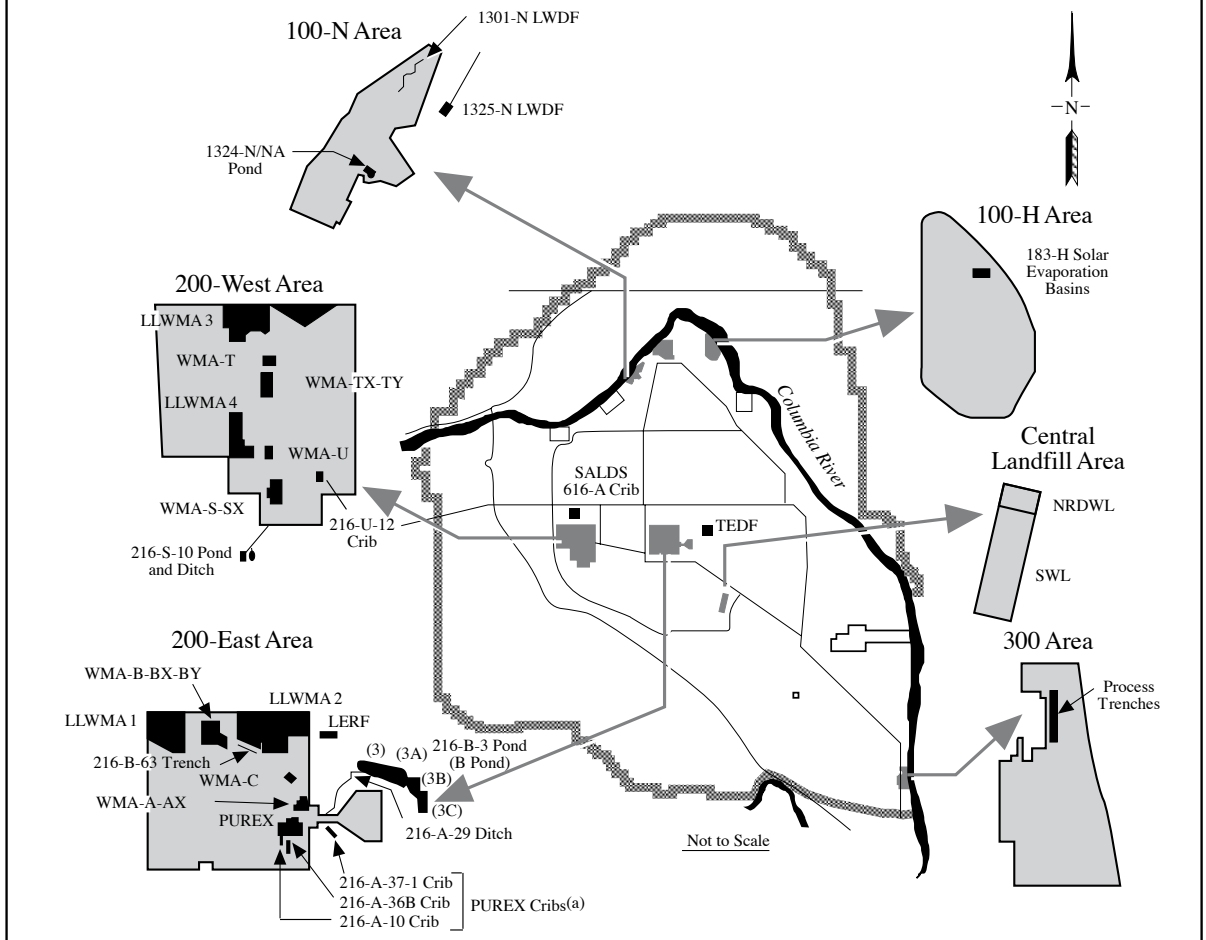


Figure 10.7.3. Locations of the Regulated Waste Management Units on the Hanford Site

extent of contamination has been fairly constant during the past 10 years, the area of highest concentrations (>100 µg/L) has decreased markedly. The concentration goal for the interim remedial action is 22 µg/L in groundwater near the Columbia River.

In 1998, chromium concentrations in groundwater near the KW Reactor began to rise. Although an exact source for this chromium has not been identified, it is most likely related to the KW water-treatment plant or underground pipes. In 2006, chromium concentrations continued to increase in a well between the reactor building and the river. The DOE installed four chromium extraction wells for use in a new pump-and-treat system at this plume. The system began to operate in January 2007.

In 2006, personnel sampled four wells northeast of the 100-K Area for a treatability test conducted in 2005. This test used

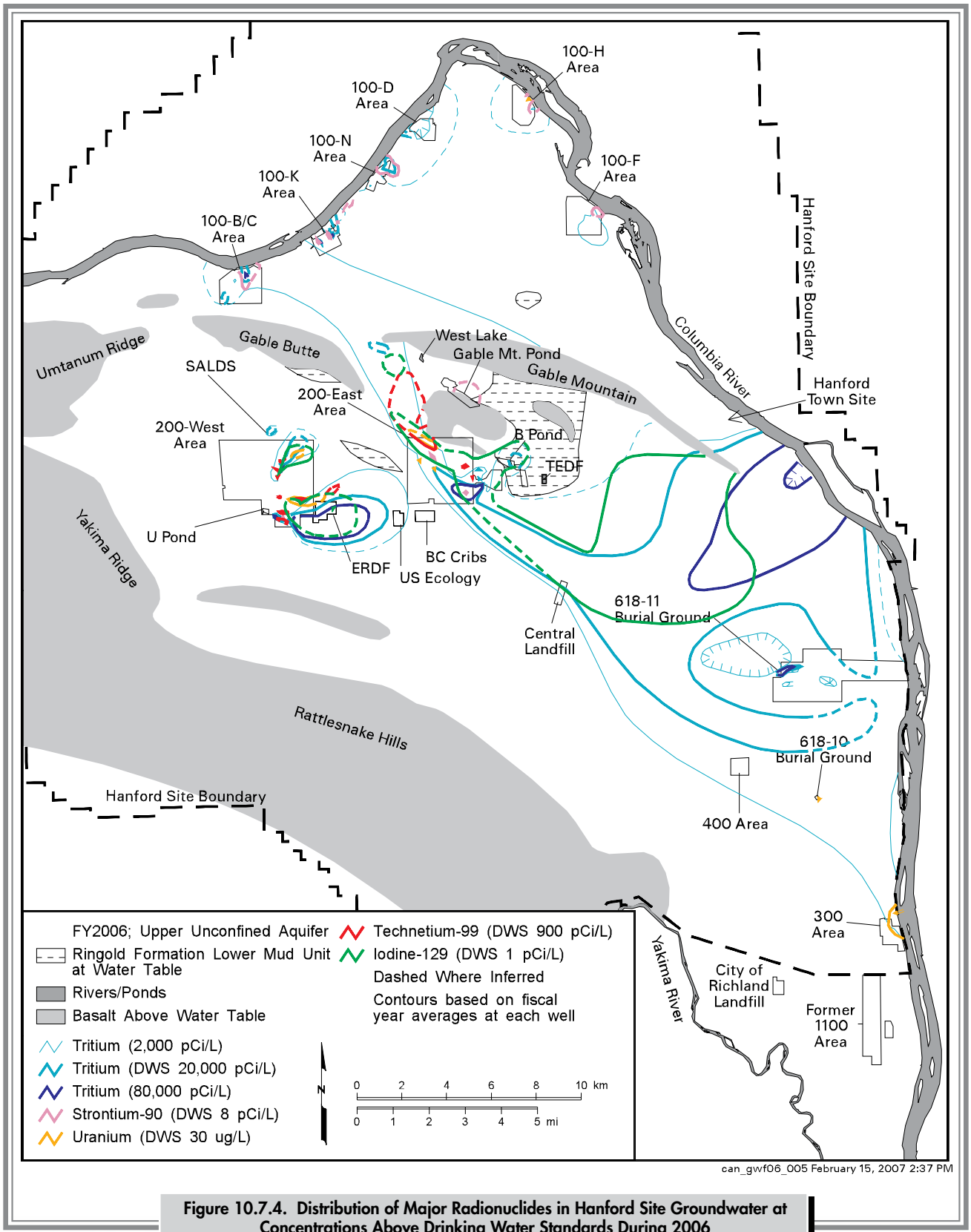


Figure 10.7.4. Distribution of Major Radionuclides in Hanford Site Groundwater at Concentrations Above Drinking Water Standards During 2006

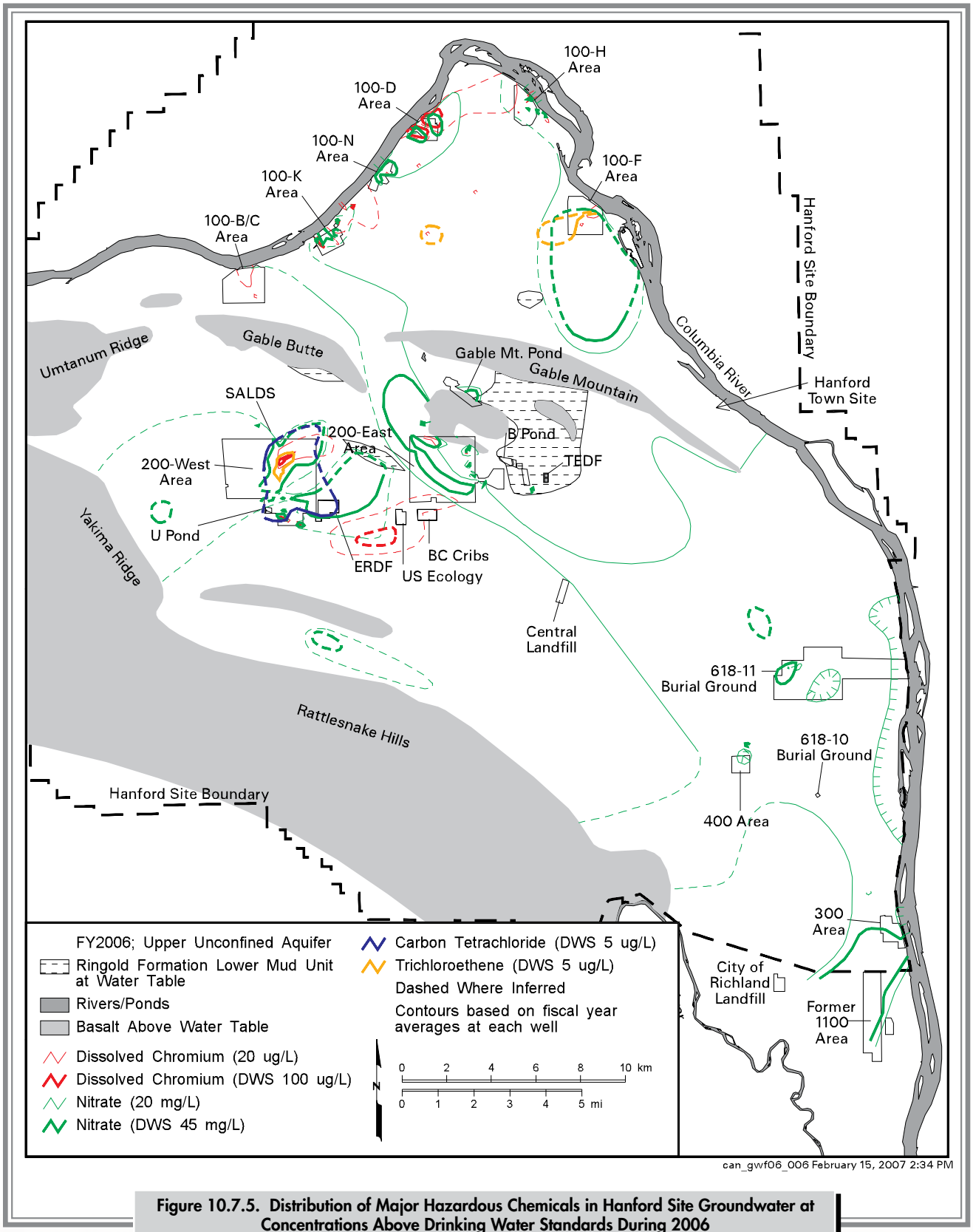


Figure 10.7.5. Distribution of Major Hazardous Chemicals in Hanford Site Groundwater at Concentrations Above Drinking Water Standards During 2006

Table 10.7.5. Areas of Contaminant Plumes on the Hanford Site at Levels Above Drinking Water Standards, 2006

Constituent	Drinking Water Standard	Area, km² (mi²)	Constituent	Drinking Water Standard	Area, km² (mi²)
Tritium	20,000 pCi/L	121.2 (46.8)	Dissolved chromium	100 µg/L	2.0 (0.8)
Iodine-129	1 pCi/L	67.0 (25.9)	Strontium-90	8 pCi/L	2.4 (0.9)
Nitrate	45 mg/L	40.0[a] (15.4)	Technetium-99	900 pCi/L	3.9 (1.5)
Carbon tetrachloride	5 µg/L	9.8 (3.8)	Total uranium	30 µg/L	1.6 (0.6)
Trichloroethene	5 µg/L	3.8 (1.5)	Combined plumes		186[a,b] (71.8)

(a) Excludes nitrate from offsite sources.
(b) Total reflects some overlap of contaminant plumes.
1 pCi/L = 0.037 Bq/L.
1 µg/L = 0.001 ppm.
1 mg/L = 1 ppm.

Table 10.7.6. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater by Groundwater Interest Area, 2006

	Hanford Site	100-BC-5	100-FR-3	100-HR-3-D	100-HR-3-H	100-KR-4	100-NR-2
Tritium (pCi/L)	1,760,000	125,000	13,600	28,500	6,030	669,000	26,300
Iodine-129 (pCi/L)	42.7	NA	NA	NA	NA	NA	NA
Nitrate (mg/L)	3,810	28.8	100	89	253	160	410
Carbon tetrachloride (µg/L)	3,760	NA	ND	NA	NA	ND	NA
Trichloroethene (µg/L)	96	NA	3.3	NA	NA	5.1	NA
Dissolved chromium (µg/L)	2,170	48	60.3	2,160	113	2,170	163
Strontium-90 (pCi/L)	16,300	41.9	3.5	7.84	30.7	908	16,300
Technetium-99 (pCi/L)	76,600	116	ND	ND	870	130	NA
Total uranium (µg/L)	844	NA	13.3	4.48	85.5	6.78	NA

	1100-EM-1	200-BP-5	200-PO-1	200-UP-1	200-ZP-1	300-FF-5
Tritium (pCi/L)	258	95,500	571,000	361,000	1,760,000	1,470,000
Iodine-129 (pCi/L)	ND	5.01	9.11	30.6	42.7	NA
Nitrate (mg/L)	536	3,150	127	1,740	3,810	974
Carbon tetrachloride (µg/L)	0.27	ND	0.75	690	3,760	0.65
Trichloroethene (µg/L)	2	ND	0.72	10	24	96
Dissolved chromium (µg/L)	1.34	58.3	41.1	965	782	23
Strontium-90 (pCi/L)	NA	3,390	20.6	1.5	2.8	3.32
Technetium-99 (pCi/L)	36.3	42,900	7,930	47,100	76,600	241
Total uranium (µg/L)	71.4	844	27.2	461	129	191

NA = Not analyzed.
ND = Not detected.

the chemical calcium polysulfide, which is a strong reducing agent that alters aquifer materials to form a permeable barrier. The barrier will continue to remove hexavalent chromium as groundwater flows through the treatment zone. In 2006, hexavalent chromium concentrations dropped to levels near to or below detection limits.

Table 10.7.7. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater by Monitoring Purpose, 2006

	Restoration	Waste Management	Environmental Surveillance
Tritium (pCi/L)	1,760,000	1,760,000	1,470,000
Iodine-129 (pCi/L)	42.7	42.7	30.6
Nitrate (mg/L)	3,810	3,810	1,740
Carbon tetrachloride (µg/L)	3,760	3,694	1,200
Trichloroethene (µg/L)	96	96	10
Dissolved chromium (µg/L)	2,170	965	2,028
Strontium-90 (pCi/L)	16,300	2,970	16,300
Technetium-99 (pCi/L)	76,600	76,600	26,800
Total uranium (µg/L)	442	844	844

Monitoring Past-Practice Waste Sites. Other contaminants of potential concern in the operable unit are carbon-14, nitrate, strontium-90, trichloroethene, and tritium. These contaminants are associated with waste disposal and facility operations that occurred during the reactor operating years (1955 to 1971).

K Basins. The KE and KW Basins are integral parts of each reactor building. Since the late 1970s, they have stored irradiated fuel from the last run of the N Reactor as well as miscellaneous fuel fragments recovered from cleanup at other reactor areas. The DOE has removed the fuel and is nearly finished removing radioactive sludge from the KE Basin. Following sludge removal, workers will decontaminate the basin interior, remove shielding water, and

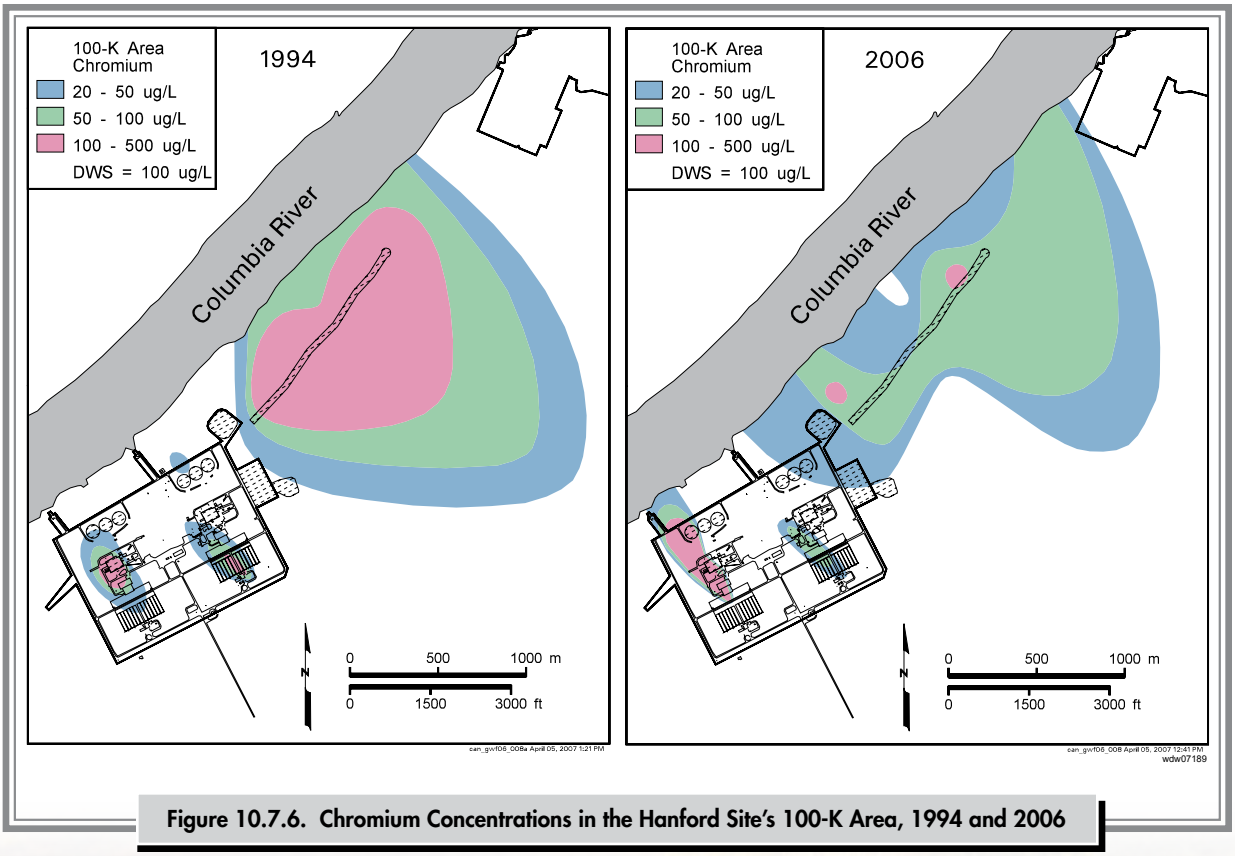


Figure 10.7.6. Chromium Concentrations in the Hanford Site's 100-K Area, 1994 and 2006

demolish the basin. Groundwater monitoring downgradient of the basins showed no evidence of new leaks in 2006.

10.7.3.4 Groundwater Monitoring Results for the 100-NR-2 Operable Unit

The primary groundwater contaminant plume in the 100-N Area is strontium-90 (Figure 10.7.7), which originated at two liquid-waste disposal cribs. A tritium plume also originated at the 100-N Area cribs, which have been excavated and filled with clean soil in recent years. Tritium concentrations in groundwater are declining, and the plume is shrinking. Nitrate, sulfate, and petroleum hydrocarbons also are present in 100-N Area groundwater.

Interim Remedial Action. The DOE put a strontium-90 pump-and-treat system on standby in March 2006. The system had operated since 1997 as an interim remedial action. Strontium-90 concentrations may be rebounding following cessation of groundwater extraction in the former extraction wells (Figure 10.7.8). Concentrations spiked in well 199-N-103A in June and rose sharply in September in wells 199-N-75 and 199-N-105A. Continued monitoring will help determine if these changes were caused by rebound or simply reflect the effects of a high water table in spring 2006.

In 2006, the DOE continued to evaluate an alternative treatment method, apatite sequestration of strontium-90. Workers recently installed 29 wells along the 100-N Area river shoreline to support this technology. Apatite-forming chemicals were injected into two test wells during the year, and the concentrations of strontium-90 and other parameters were monitored in surrounding wells and aquifer tubes. The goal is to create a permeable, reactive barrier near the shoreline that will capture strontium-90 as groundwater flows toward the river. The DOE is also researching phytoremediation (removal of contaminants by plants) using a native shrub, Coyote Willow, to remove shallow groundwater and soil contamination adjacent to the Columbia River.

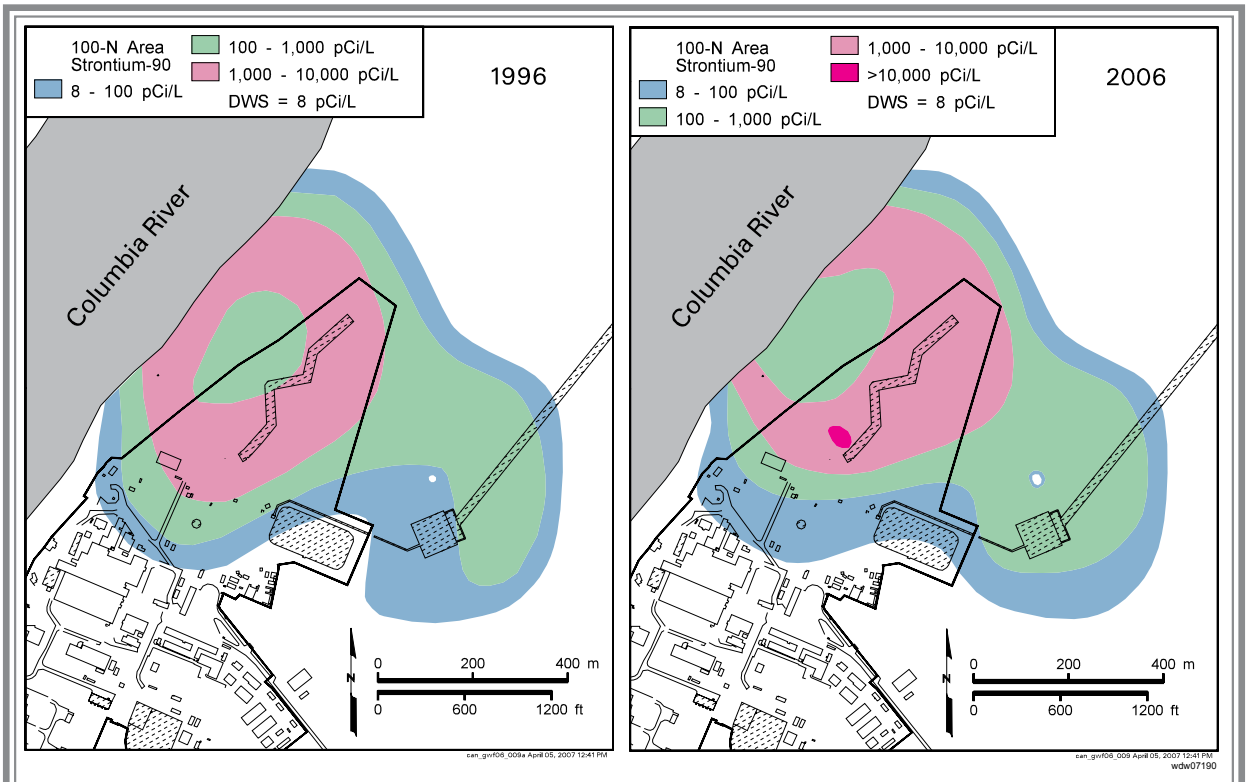


Figure 10.7.7. Strontium-90 Concentrations in the Hanford Site's 100-N Area Groundwater, 1996 and 2006

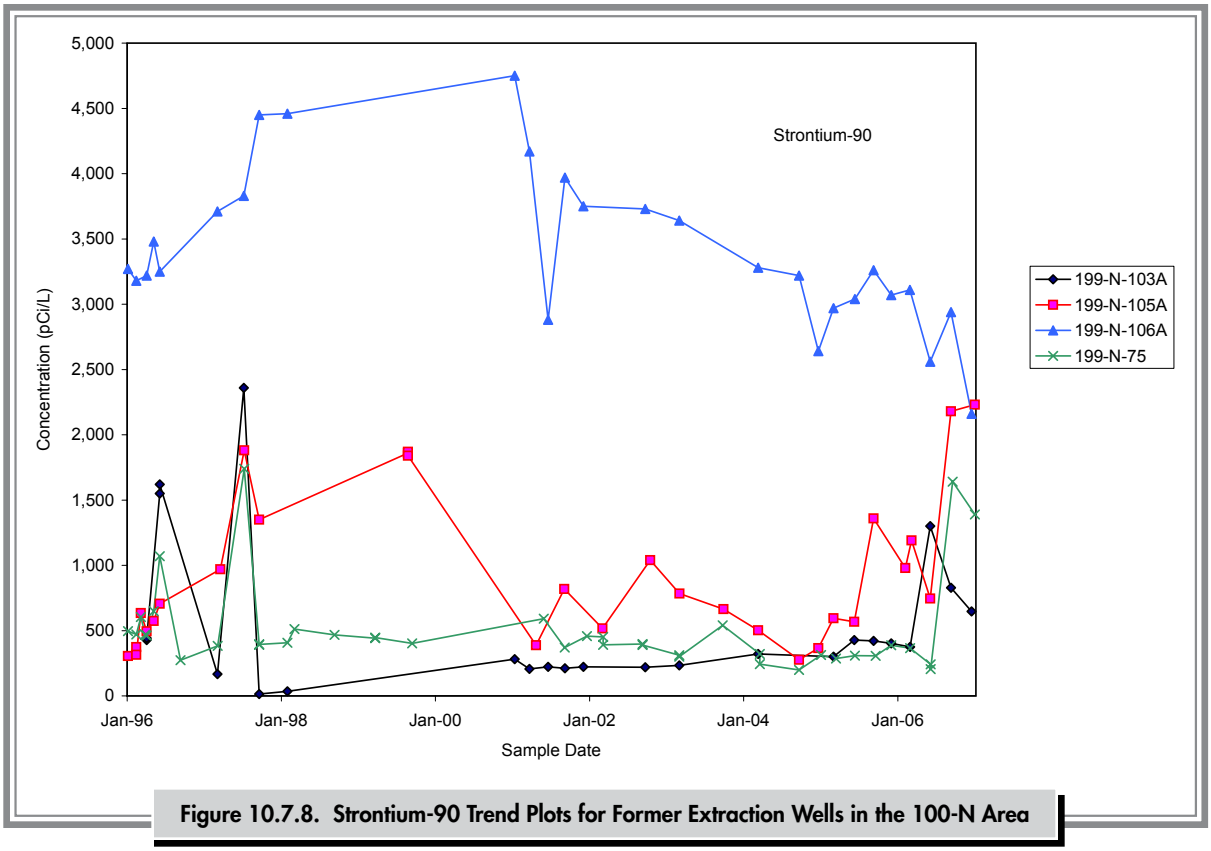


Figure 10.7.8. Strontium-90 Trend Plots for Former Extraction Wells in the 100-N Area

10.7.3.5 Groundwater Monitoring Results for the 100-HR-3-D Operable Unit

The 100-HR-3 Operable Unit underlies the 100-D and 100-H Areas and the region between. Hexavalent chromium is the primary contaminant of concern in groundwater beneath the 100-D Area (Figure 10.7.9), which comprises the west part of the operable unit (100-HR-3-D). Routine disposal of reactor coolant, which contained sodium dichromate as a corrosion inhibitor, was a principal source of this contamination. Other possible sources were spills and leaks of sodium dichromate stock solution to the ground. Chromium is distributed in the north and southwest plumes, and other contaminant plumes include tritium, nitrate, and sulfate.

Interim Remedial Action. The north chromium plume is the target of a pump-and-treat system, which is designed to reduce the amount of chromium entering the Columbia River. A second pump-and-treat system for chromium intercepts groundwater in the central 100-D Area near the shoreline. In 2006, chromium concentrations remained above the remediation goal (22 µg/L) in compliance wells. The two extraction systems removed 85 kilograms (187 pounds) of chromium from the aquifer in 2006 and have removed 348 kilograms (767 pounds) since 1997. The southwest chromium plume is being remediated with a permeable barrier. Workers created the barrier by injecting a chemical solution containing sodium dithionite into a line of wells between 1997 and 2002. The chemical solution modified aquifer materials so they immobilize chromium in the ground. Data from recent years indicate that chromium is breaking through the barrier. At the end of September 2006, concentrations in barrier wells ranged from below detection limits to 380 µg/L, with concentrations in approximately 66% of the wells below the remedial action goal of 20 µg/L. Most of the elevated concentrations are in the northeast half of the barrier. Downgradient of the barrier, concentrations met the 20-µg/L goal at two of the seven compliance wells.

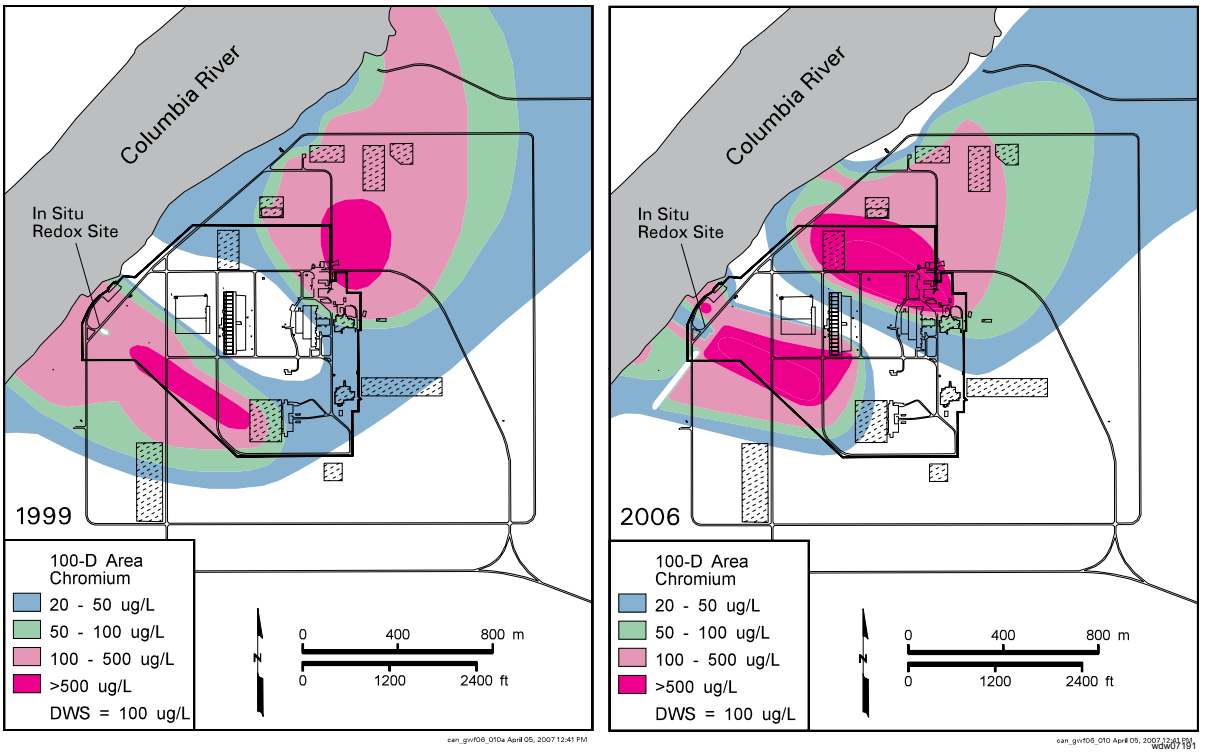


Figure 10.7.9. Chromium Concentrations in the Hanford Site's 100-D Area Groundwater, 1999 and 2006

10.7.3.6 Groundwater Monitoring Results for the 100-HR-3-H Operable Unit

The east part of the 100-HR-3 Operable Unit (100-HR-3-H) underlies the 100-H Area. Hexavalent chromium is the primary contaminant of concern in this area, but concentrations are much lower than in the 100-D Area (Figure 10.7.10). Nitrate is also elevated, but concentrations have declined from their peak historical levels. Strontium-90 exceeds the drinking water standard (8 pCi/L [0.3 Bq/L]) beneath a waste site in the southeast 100-H Area. Uranium is elevated in a small area downgradient of another waste site.

Interim Remedial Action. The chromium plume in the 100-H Area is the target of a pump-and-treat system. The remediation of the plume removed 8.2 kilograms (18.1 pounds) of chromium from the aquifer in 2006 and has removed 47 kilograms (104 pounds) since 1997. Hexavalent chromium levels continued to decline in 2006 in the one remaining compliance well and in former compliance wells that have been converted to extraction wells. From April through December 2006, concentrations were below the 22-µg/L remedial action goal in all but a few samples from those wells (Figure 10.7.11).

10.7.3.7 Groundwater Monitoring Results for the 100-FR-3 Operable Unit

Nitrate concentrations in groundwater continued to exceed the drinking water standard beneath much of the 100-F Area and the downgradient region. Other groundwater contaminants include strontium-90 and trichloroethene. Chromium exceeds the 10-µg/L state aquatic standard in some wells near the Columbia River.

No active groundwater remediation is underway in the 100-FR-3 Operable Unit. Monitoring has continued while waste sites are cleaned up.

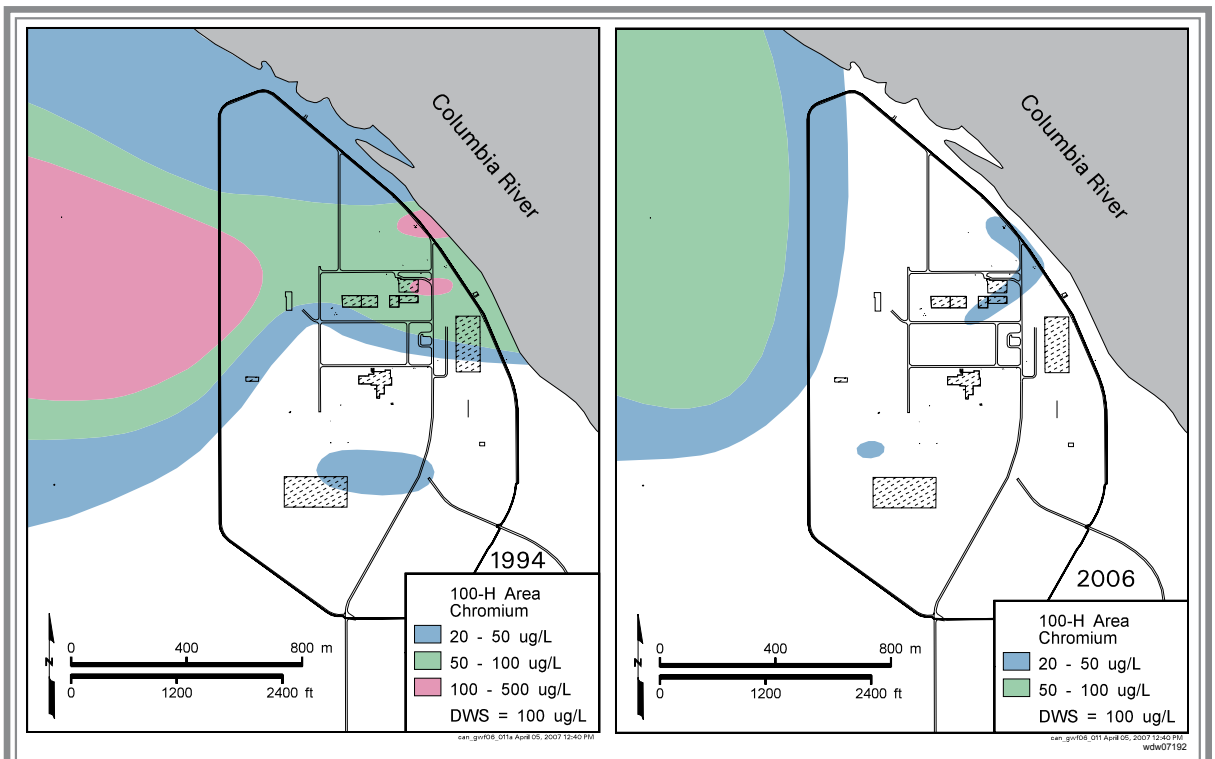


Figure 10.7.10. Chromium Concentrations in the Hanford Site's 100-H Area Groundwater, 1994 and 2006

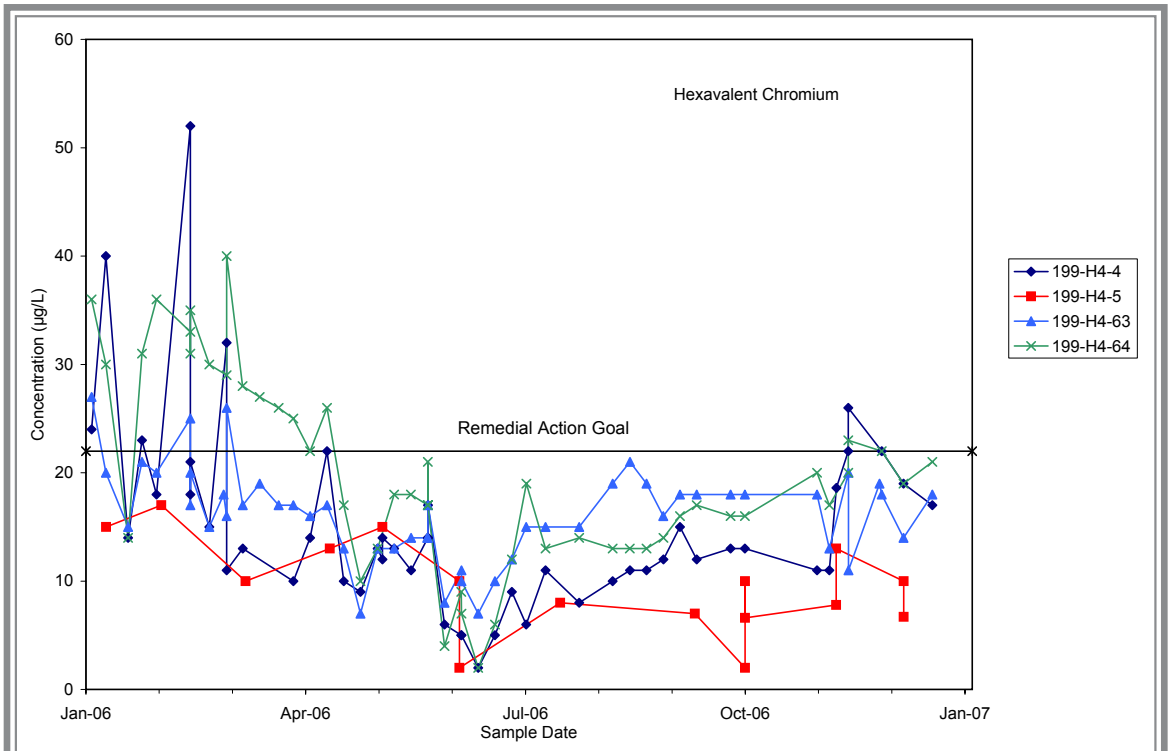


Figure 10.7.11. Chromium Trend Plots for Compliance Well 199-H4-5 and Former Compliance Wells (now extraction wells)

10.7.3.8 Groundwater Monitoring Results for the 200-ZP-1 Operable Unit

The 200-ZP-1 Operable Unit encompasses the north portion of the 200-West Area (Figure 10.7.2). The primary contaminant of concern is carbon tetrachloride (Figure 10.7.12), which is the target of an interim remedial action. The plume's sources were associated with waste disposal from the Plutonium Finishing Plant. Trichloroethene and chloroform also are associated with this plume. Other contaminants in the operable unit include tritium, nitrate, chromium, fluoride, iodine-129, technetium-99, and uranium.

Work on the feasibility study for the 200-ZP-1 groundwater Operable Unit is ongoing. In 2006, the DOE screened potential cleanup methods. The screening considered eight major contaminants and used a generalized conceptual model of the extent and depth of contamination.

The distribution of carbon tetrachloride is complex because it can migrate in three forms: 1) a dense liquid that does not easily dissolve, 2) a gas, and 3) dissolves in water. Scientists evaluated data collected at various depths from 19 wells. The 200-ZP-1 remedial investigation report (DOE/RL-2006-24, Rev. 0) combined these results with geologic data to form a conceptual model of the plume. The plume extends to the top of the Ringold lower mud unit where mud is present and to the top of the basalt where mud is absent. The contamination occurs at increasing depth to the east of the known source areas. Concentrations are relatively low at the water table in the east-central part of the 200-West Area. It appears that more carbon tetrachloride is present in the unconfined aquifer than previously estimated.

Interim Remedial Action. Since 1994, the DOE has operated an interim action pump-and-treat system to prevent carbon tetrachloride in the upper part of the aquifer from spreading. The system has helped limit the high-concentration portion of the plume (>2,000 µg/L), as shown in Figure 10.7.12. The DOE extended the remediation system to the north in 2005 to capture carbon tetrachloride contamination at levels above 2,000 µg/L. The DOE

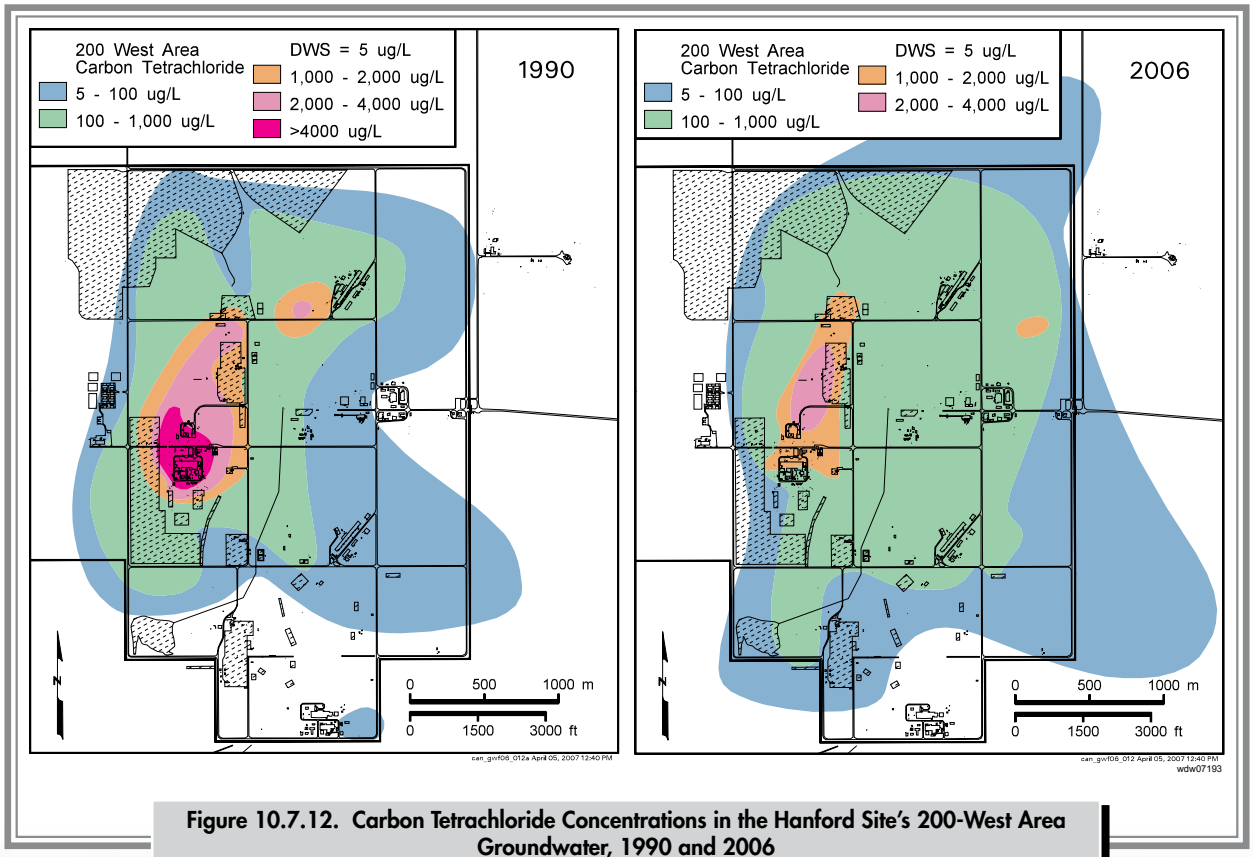


Figure 10.7.12. Carbon Tetrachloride Concentrations in the Hanford Site's 200-West Area Groundwater, 1990 and 2006

converted an additional monitoring well to an extraction well in September 2006. The system removed 890 kilograms (1,962 pounds) of carbon tetrachloride from the aquifer in 2006 and 10,197 kilograms (22,480 pounds) has been removed since 1994.

Soil-Vapor Extraction. A cleanup system in this operable unit extracts soil vapor from the vadose zone and treats it to remove carbon tetrachloride. As of the end of September 2006, the system had removed approximately 78,900 kilograms (174,000 pounds) of carbon tetrachloride from the vadose zone since extraction operations started in 1991. It removed 173 kilograms (381 pounds) in 2006.

10.7.3.9 Groundwater Monitoring Results for the 200-UP-1 Operable Unit

The 200-UP-1 Operable Unit underlies the south portion of the 200-West Area (Figure 10.7.2). The primary contaminants of concern are technetium-99 and uranium. Tritium, chromium, iodine-129, and nitrate plumes also have sources in this operable unit. Carbon tetrachloride in the 200-UP-1 Operable Unit originated from sources in the 200-ZP-1 Operable Unit.

A study of vertical contaminant distribution in a portion of the 200-UP-1 Operable Unit showed that in most areas, the highest technetium-99 concentrations are near the water table. In three wells, concentrations were higher 19 to 33 meters (62 to 108 feet) below the water table. Uranium was limited to the portion of the aquifer near the water table.

Interim Remedial Action. A groundwater pump-and-treat system formerly operated near the U Plant to contain the technetium-99 and uranium plumes located in this area. In January 2005, groundwater extraction ceased, and the DOE began conducting a rebound study to determine if contaminant concentrations would remain below the cleanup goal. The rebound study concluded in January 2006, after which semiannual groundwater monitoring continued. The Washington State Department of Ecology is preparing an Explanation of Significant Difference, which may revise the remedial action objective for uranium. After the Explanation of Significant Difference is issued, a decision will be made on whether to restart the pump-and-treat system. The results of the rebound study and subsequent semiannual groundwater sampling indicate that enough technetium-99 and uranium were removed from the aquifer that concentrations of both constituents remain below their current cleanup goals (Figures 10.7.13 and 10.7.14).

10.7.3.10 Groundwater Monitoring Results for the 200-BP-5 Operable Unit

This operable unit includes groundwater beneath the north 200-East Area (Figure 10.7.2). Iodine-129, technetium-99, and tritium plumes extend northward between Gable Mountain and Gable Butte. Uranium forms a narrow plume that extends northwest of the 200-East Area. Nitrate forms a plume that extends to the north and probably originated from multiple sources within the 200-East Area. Other contaminants include cesium-137, cobalt-60, cyanide, nitrite, plutonium, strontium-90, sulfate, and uranium.

A plume of technetium-99 extends from waste-disposal sites and single-shell waste storage tanks in the northwest 200-East Area to the northwest (Figure 10.7.4). A significant portion of the plume is north of the 200-East Area boundary and may represent early releases of technetium-99 from waste-disposal cribs, but near-field technetium-99 concentration levels are the result of more recent contributions from single-shell waste tanks and local cribs. Detection of technetium-99 north of the gap between Gable Mountain and Gable Butte indicates that technetium-99 has historically moved north into and through the gap. Data from a new well in this region improved the understanding of the distribution of this contaminant in 2006.

The highest uranium concentrations in the 200-BP-5 Operable Unit during the last several years occurred within and to the east of a single-shell tank farm (B-BX-BY) (Figure 10.7.15). The contamination is present in a narrow northwest-southeast band. Uranium concentrations have been increasing in wells northwest of the tank farm in the last several years. This may suggest that the plume is migrating to the northwest toward the Gable Mountain/Gable Butte gap area.

No active groundwater remediation is currently underway in this operable unit, and final remediation decisions are yet to be made.

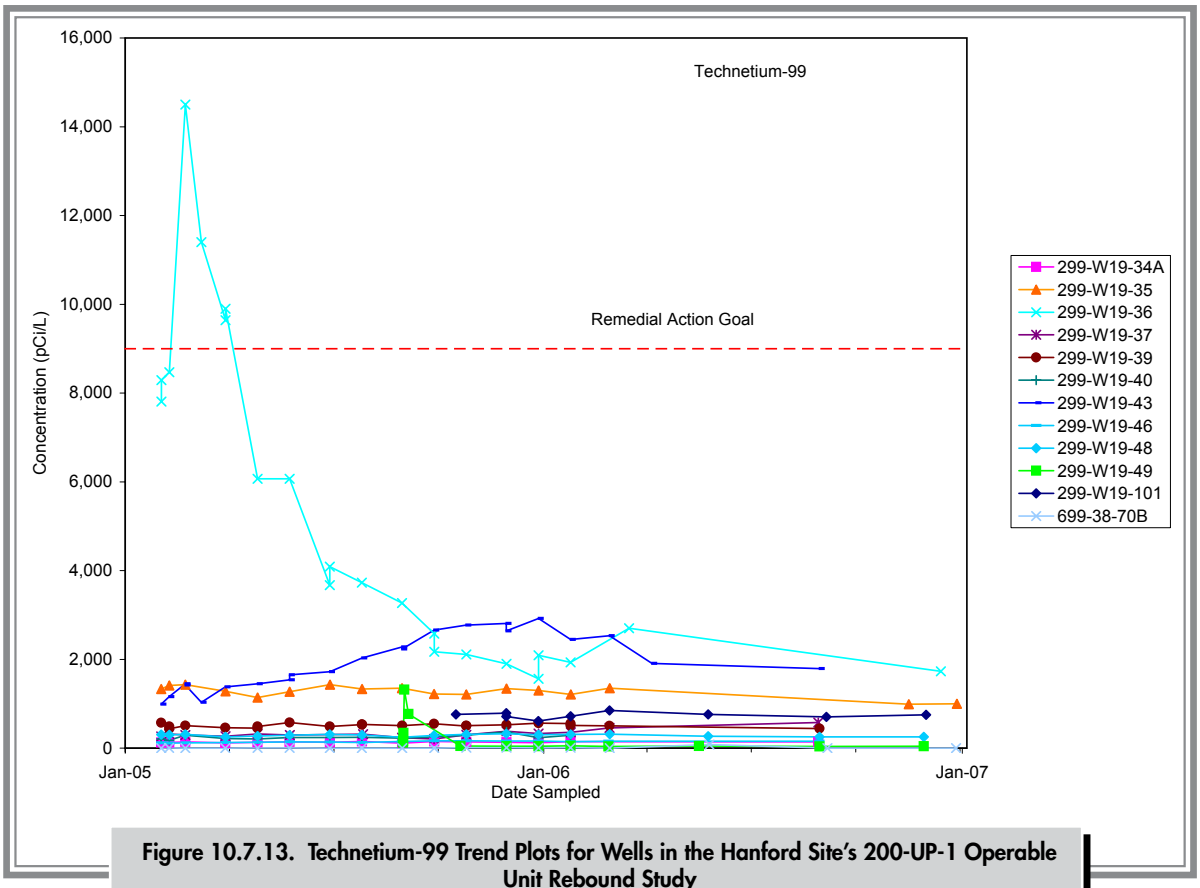


Figure 10.7.13. Technetium-99 Trend Plots for Wells in the Hanford Site's 200-UP-1 Operable Unit Rebound Study

10.7.3.11 Groundwater Monitoring Results for the 200-PO-1 Operable Unit

The 200-PO-1 Operable Unit encompasses the south portion of the 200-East Area and a large portion of the Hanford Site extending to the east and southeast (Figure 10.7.2). Plumes of iodine-129, tritium, and nitrate that exceed drinking water standards originated at disposal facilities in this operable unit. Other contaminants include strontium-90 and technetium-99, but these are limited to very small areas near cribs or tank farms.

The tritium and iodine-129 plumes in this operable unit are the largest contaminant plumes on the Hanford Site. The iodine-129 plume has not reached the Columbia River at concentrations above the drinking water standard. Tritium concentrations in near-river wells and in a rivershore spring exceed the drinking water standard. However, concentrations of tritium have declined significantly in recent years because of radioactive decay and dispersion (Figure 10.7.16).

Currently, no active groundwater remediation is occurring in this operable unit, and final remediation decisions are yet to be made.

10.7.3.12 Groundwater Monitoring Results for the 300-FF-5 Operable Unit

This operable unit includes three geographic regions: the 300 Area, the 618-11 burial ground region, and the 316-4 cribs/618-10 burial ground region. In 2006, the DOE installed 13 new wells for a uranium treatability test or aquifer characterization.

Contaminants of concern in 300 Area groundwater are uranium, trichloroethene, and cis-1,2-dichloroethene. Monitoring and plume characterization activities indicate relatively constant or gradually decreasing levels for these contaminants. Uranium is the primary contaminant of concern and remains above the drinking water standard (30 µg/L) beneath part of the 300 Area (Figure 10.7.17).

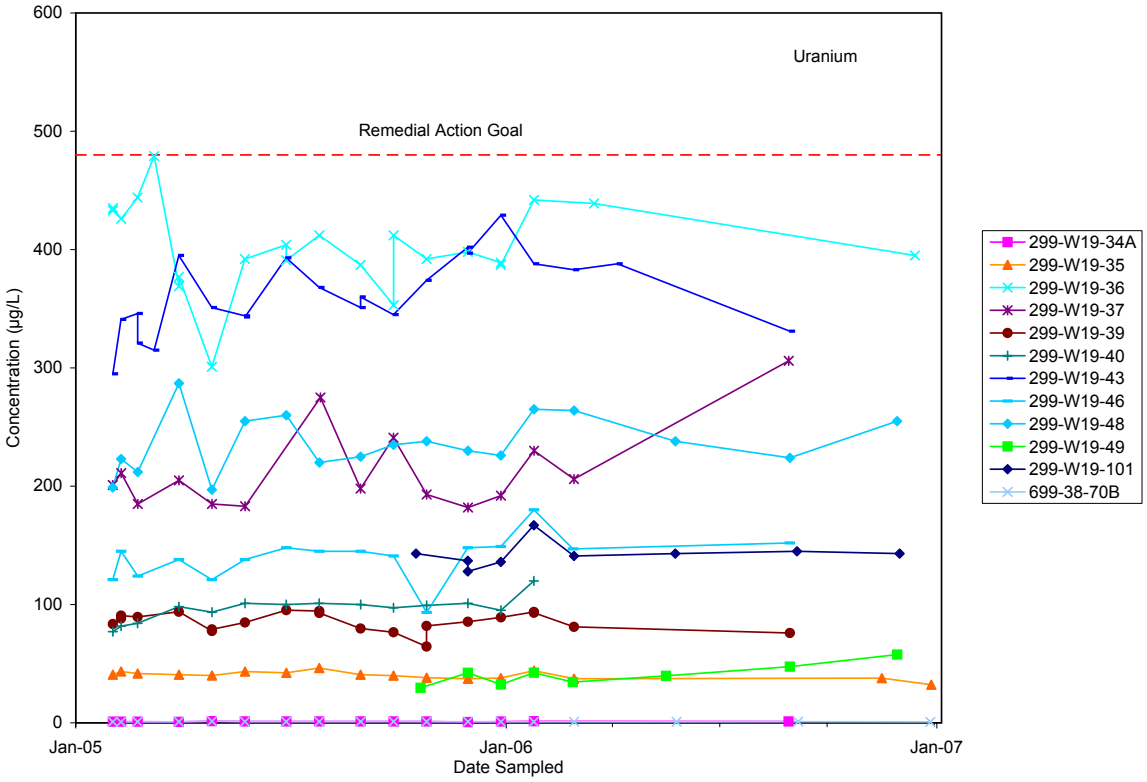


Figure 10.7.14. Uranium Trend Plots for Wells in the Hanford Site's 200-UP-1 Operable Unit Rebound Study

Trichloroethene continued to be below the 5-µg/L drinking water standard in routine groundwater samples. However, during drilling of four characterization boreholes for the limited field investigation in the 300 Area, scientists found trichloroethene at unexpectedly high concentrations in water samples from a different depth than is routinely monitored by existing wells. The highest concentration was 630 µg/L in a well adjacent to the south side of the 316-3 process trench. All of the samples with high concentrations came from a relatively fine-grained unit within the upper portion of the Ringold Formation.

Groundwater downgradient of the 618-11 burial ground remains contaminated by a high-concentration tritium plume, whose origin is believed to be irradiated material in the burial ground. Concentrations at a well adjacent to the burial ground have decreased from greater than 8 million pCi/L (296,000 Bq/L) in 2000 to 996,000 pCi/L (36,852 Bq/L) in June 2006.

During excavation of the 618-2 burial ground in 2006, plutonium and other radiological contaminants were detected unexpectedly in soil samples. Plutonium was not detected in groundwater samples from nearby monitoring wells.

300-FF-5 Operable Unit Phase III Feasibility Study. Because the uranium plume beneath the 300 Area has not decreased in concentration as rapidly as predicted, the DOE continued to investigate the natural processes that cause the plume to persist and the residual sources that may supply uranium to the plume. In 2006, the DOE assembled an inventory of technologies for reducing the level of uranium contamination in groundwater. Promising technologies include methods to permanently sequester or reduce the mobility of uranium in place. Preliminary screening of these technologies was completed for two of three criteria—applicability and effectiveness. Screening for the third criterion, relative cost, will continue during 2007.

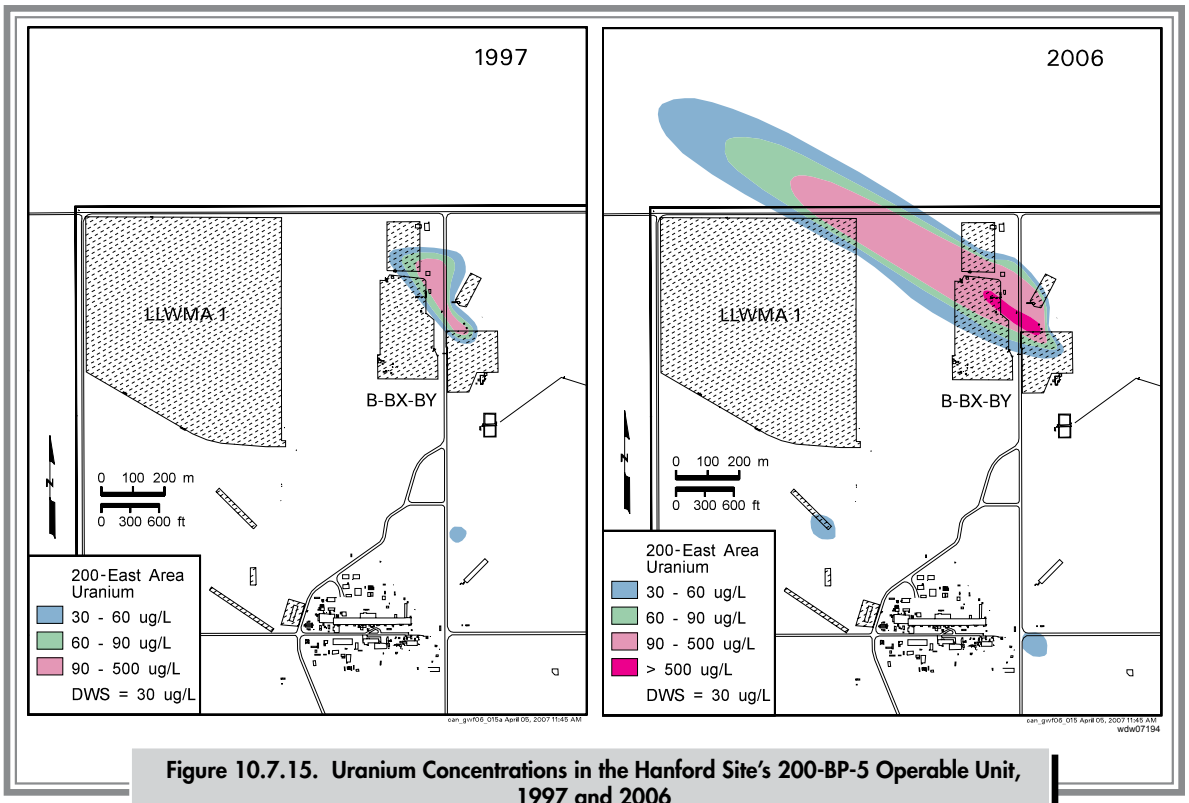


Figure 10.7.15. Uranium Concentrations in the Hanford Site's 200-BP-5 Operable Unit, 1997 and 2006

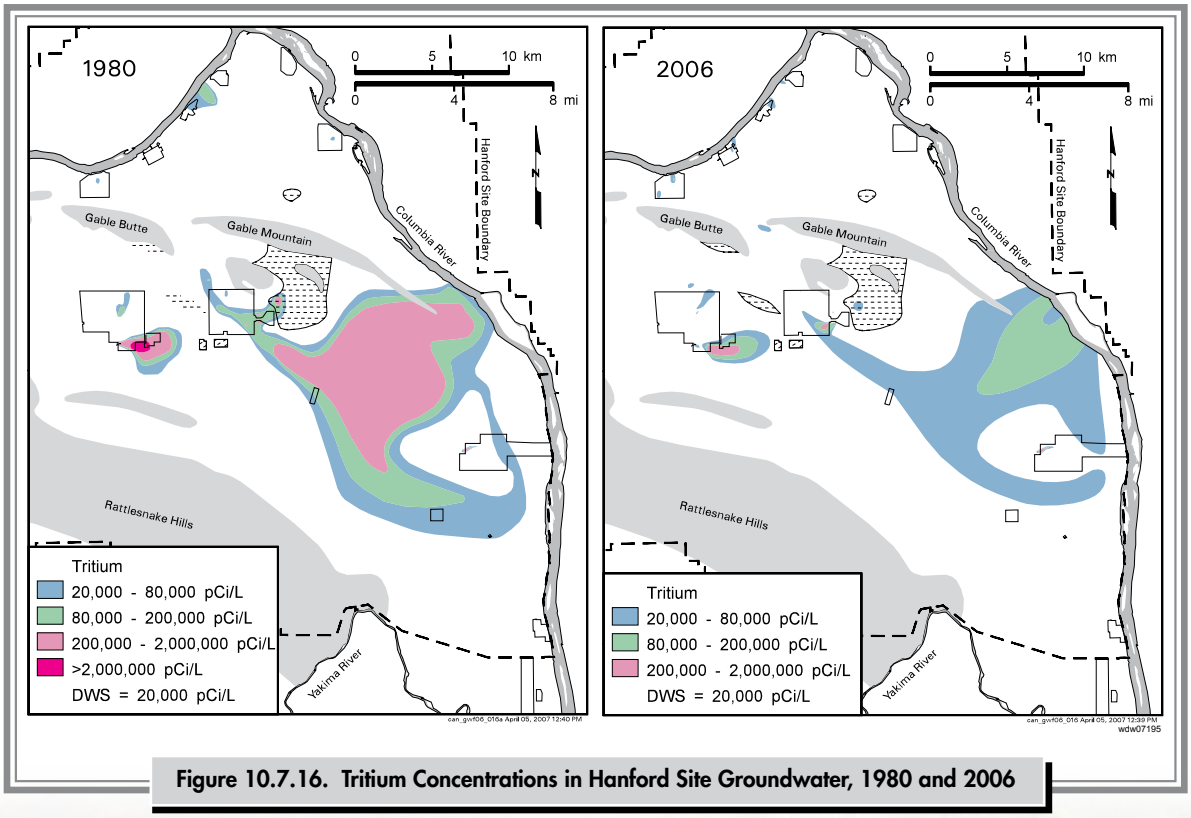


Figure 10.7.16. Tritium Concentrations in Hanford Site Groundwater, 1980 and 2006

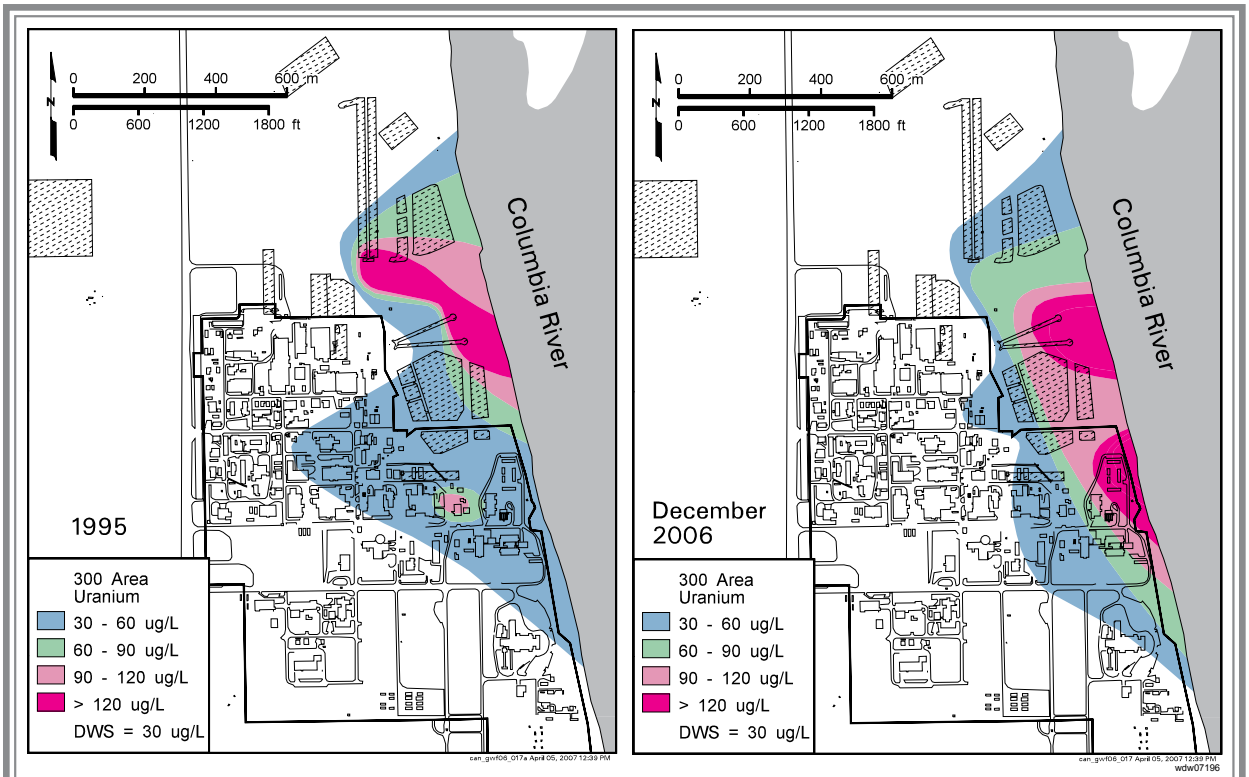


Figure 10.7.17. Uranium Concentrations in the Hanford Site's 300 Area Groundwater, 1995 and 2006

A treatability test to immobilize uranium in the aquifer by injecting polyphosphate began in 2006. This technology immobilizes uranium by turning it into an insoluble mineral.

10.7.3.13 Groundwater Monitoring Results for the 1100-EM-1 Operable Unit

The 1100-EM-1 Operable Unit is located in the south part of the Hanford Site and the adjacent part of Richland (Figure 10.7.2). Trichloroethene was the primary contaminant of concern. Contaminants also flow into the area from offsite sources (e.g., nitrate from agriculture and industry).

The final remedy selected for volatile organic compounds in 1100-EM-1 Operable Unit groundwater is monitored natural attenuation. Concentrations of trichloroethene have remained below the drinking water standard since 2001.

The DOE frequently monitors wells in the city of Richland well field to detect any changes in Hanford Site contaminants. The tritium plume originating from sources in the 200-East Area has not been detected in these wells. Only low levels of tritium are detected.

Uranium concentrations in wells downgradient of the DOE's inactive Horn Rapids Landfill have been increasing since 1996, but remained below the 30-µg/L drinking water standard in 2006. The source is believed to be a facility located upgradient of the landfill off the Hanford Site.

10.7.3.14 Groundwater Monitoring Results for the Basalt-Confined Aquifer

Although most of the Hanford Site's groundwater contamination is in the unconfined aquifer, the DOE monitors deep wells in case contamination moves downward and offsite through the basalt-confined aquifer. No evidence of offsite migration via the confined aquifer has been detected.

Within the upper basalt-confined aquifer system, groundwater occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds. Groundwater in this aquifer generally flows from west to east across the Hanford Site, up through fractures or other pathways in the confining layers, into the unconfined aquifer, and into the Columbia River. Vertical gradients between the basalt-confined aquifer and the unconfined aquifer are upward on most of the Hanford Site. Downward gradients occur in the west portion of the Hanford Site, near the former location of B Pond, and north and east of the Columbia River.

Tritium continued to be detected at low levels in some basalt-confined wells. One elevated tritium concentration near the 200-East Area is in an area where the confined aquifer and the overlying unconfined aquifer are connected. Iodine-129, strontium-90, gamma-emitting isotopes, and uranium isotopes were not detected in the confined aquifer. Cyanide, nitrate, and technetium-99 were elevated in one confined-aquifer well in the northwest part of the 200-East Area. Migration of waste from the vadose zone or unconfined aquifer during well construction is responsible for this contamination.

10.7.4 Shoreline Groundwater Monitoring

The DOE monitors groundwater near the Columbia River via aquifer tubes, which are small diameter, flexible tubes installed in the shallow aquifer, and natural shoreline seepage points or springs. Results are summarized in the following paragraphs. Section 10.5 of this report discusses results of shoreline springs monitoring.

Concentrations of strontium-90 continued to exceed the 8-pCi/L (0.296-Bq/L) drinking water standard in aquifer tubes in the 100-BC-5 and 100-NR-2 interest areas. Some of the 100-N Area tubes had concentrations over 3,000 pCi/L (111 Bq/L).

Tritium concentrations exceeded the 20,000-pCi/L (740-Bq/L) drinking water standard in shoreline springs at the Hanford town site, but were below the standard in aquifer tube samples.

Uranium concentrations exceeded the 30-µg/L drinking water standard in aquifer tubes and shoreline springs in the 300 Area.

Hexavalent chromium concentrations exceeded the 100-µg/L drinking water standard in 100-D Area aquifer tubes. Concentrations in aquifer tubes or shoreline springs exceeded the 10-µg/L state aquatic standard in the 100-B/C, 100-K, 100-D, 100-H, and 100-F Areas.

Nitrate concentrations exceeded the 45-mg/L drinking water standard in aquifer tubes in the 100-K, 100-D, 100-H, and 300 Areas. Levels have exceeded the standard in a tube downgradient of the 100-F Area in the past, but the tube was not sampled in 2006. Levels in all Hanford Site shoreline springs were below the standard.

Trichloroethene was detected in several aquifer tubes in the 300 Area. Most results were below the 5-µg/L drinking water standard, but the concentration in one sample from September 2006 was 96 µg/L.

10.7.5 Well Installation, Maintenance, and Decommissioning

The DOE installs new wells when needed for monitoring or characterization, services wells that require maintenance, and decommissions wells that are no longer needed. The Washington State Department of Ecology, the EPA, and the DOE worked together to develop a prioritized list of new wells needed to meet the requirements of various groundwater monitoring regulations. The DOE installed 44 new wells during 2006. These included monitoring wells and wells to support tests of new technologies for groundwater remediation.

Approximately 7,544 unique well-identification numbers have been identified within the Hanford Site. These include all wells, characterization boreholes, aquifer tubes, soil-gas probes, piezometers, or other subsurface installations. A total of 3,094 (41%) have been either administratively removed from the well inventory (e.g., if personnel determined the wells no longer existed) or physically decommissioned

(sealed with grout) because they were no longer needed. The DOE maintains a list of wells that are candidates for decommissioning. All candidate wells must be reviewed and approved by potential well users before decommissioning. During 2006, a total 2,934 wells were in use, and 82 vadose zone wells were physically decommissioned.

10.7.6 Groundwater Science and Technology

M. D. Freshley

The Soil and Groundwater Remediation Project includes a science and technology effort to provide data, tools, and scientific understanding to support remediation and site-closure decisions. The DOE accomplishes these activities under the Remediation and Closure Science Project. During 2006, the Remediation and Closure Science Project focused on updating conceptual models for key waste sites and performing biological uptake studies for key contaminants.

Conceptual Model Updates. Scientists at the Hanford Site use conceptual models to describe subsurface contamination and key processes affecting contaminant migration. In 2006, conceptual models for waste sites and vadose zone and groundwater contamination continued to focus on the 300 Area, 100-N Area, and carbon tetrachloride transport in Hanford Site sediments.

The movement of contaminants in groundwater is sometimes affected by chemical reactions between the contaminants and sediment grains. Reactive-transport models are used to help understand the fate and transport of contaminants in the subsurface. Scientists are applying this type of model to the 300 Area uranium plume. In 2006, scientists completed experiments with different sediments from the 300 Area. They conducted these experiments to provide information on the transport of uranium through sediments with many different grain sizes in the 300 Area and to determine how reactive transport parameters measured on very fine soil grains (less than 2 millimeters [0.08 inch]) can be extrapolated to actual sediments with many different grain sizes. Investigators published a journal article updating the conceptual model (Catalano et al. 2006) and submitted a second manuscript (Arai et al. 2006, submitted). A model completed in 2006 predicts hydraulic properties of 300 Area sediments based on grain-size distributions. These data provide input along with the geochemical measurements to a reactive transport model for uranium in the 300 Area. The modeling shows the importance of differences in water chemistry of groundwater and Columbia River water and the impact of river-stage variation. Scientists performed subsurface geophysical surveys in the 300 Area to characterize the contact between the Ringold and Hanford Site formations, which is used in numerical modeling. Additional measurements help calculate uranium flux from the groundwater to the Columbia River.

The Remediation and Closure Science Project generated a general conceptual model for strontium-90 fate and transport in the 100-N Area during 2006. These results support the apatite sequestration treatability study that is underway in 2007 (see Section 10.7.3.4). The project also evaluated the hydraulic impact of shutting down the groundwater pump-and-treat system in the 100-N Area.

Scientists performed laboratory experiments to determine hydraulic and fluid parameters used in modeling the soil-vapor extraction system in the 200-West Area (PNNL-15914). They incorporated results into the "Subsurface Transport Over Multiple Phases" (STOMP) computer code to evaluate the capability of soil to retain carbon tetrachloride. In addition, results from intermediate-scale experiments with residual carbon tetrachloride to measure dissolution rates in the vadose zone were also incorporated into STOMP. Two journal articles focusing on the carbon tetrachloride problem at the Hanford Site were published (Dobson et al. 2006; Oostrom et al. 2006).

Biological Uptake of Uranium. During 2006, scientists completed the final studies of uranium uptake by periphyton (microscopic plants and animals attached to submerged surfaces). Results showed that maximum uptake occurred between 3 and 6 days, followed by a downward trend of the higher concentrations.

10.8 Food and Farm Products Monitoring

R. W. Hanf

During 2006, food and farm products, including asparagus, apples, leafy vegetables, milk, potatoes, tomatoes, and wines, were collected at places around the Hanford Site (Figure 10.8.1), and samples were analyzed to monitor concentrations of radiological contaminants. Samples were obtained from the following:

- Locations generally downwind (east and southeast) of the site where airborne emissions or contaminated dust from the Hanford Site would potentially be deposited.
- Other locations generally upwind of and distant from the Hanford Site to provide information on reference (background) contaminant levels.
- Farms irrigated with water taken from the Columbia River downstream of the Hanford Site.

Results of sample analyses are used to assess the amounts of Hanford Site contaminants in food and farm products by 1) comparing analytical results obtained from like samples collected from the same regions over long periods of time, 2) comparing analytical results from samples collected at downwind locations to results from samples obtained from generally upwind or distant locations, and 3) comparing analytical results from samples collected in areas irrigated with water withdrawn from the Columbia River downstream from the Hanford Site to analytical results from samples obtained from locations irrigated with water from other regional sources.

The concentrations of most radionuclides in food and farm product samples in 2006 were below levels that could be detected by the analytical laboratories. However, some contaminants potentially from the Hanford Site (uranium-234 and tritium) were found at low levels in some samples. These findings are discussed in the following sections. Data for naturally occurring potassium-40 are included to show the amounts of this natural radioactive element in food products relative to concentrations of contaminants potentially from the Hanford Site. Radiological doses associated with possible Hanford Site-produced contaminants that were detected are discussed in Section 10.14.

10.8.1 Collection of Food and Farm Product Samples

Some food and farm product samples are collected each year on quarterly or annual schedules. Others may only be sampled every 2 or 3 years. The rationale for sampling and analyzing some media more frequently than others is discussed in the *Hanford Site Environmental Monitoring Plan* (DOE/RL-91-50, Rev. 3). The types and number of samples scheduled for collection in any given year are documented in the annual Hanford Site environmental surveillance master sampling schedule (PNNL-15618). Typically, enough crop material for two samples is collected at each location. A portion of this material is submitted to a laboratory for analysis and the remainder is archived at the Pacific Northwest National Laboratory in the event the analytical laboratory needs additional material for confirmatory or follow-up analyses. Table 10.8.1 shows the products, sampling locations and frequencies, types of analyses, and numbers of samples collected and analyzed for radioactive contaminants during 2006. Most samples were obtained from commercial producers; however, leafy vegetables and tomatoes were obtained from residential gardens because commercial growers could not be located.

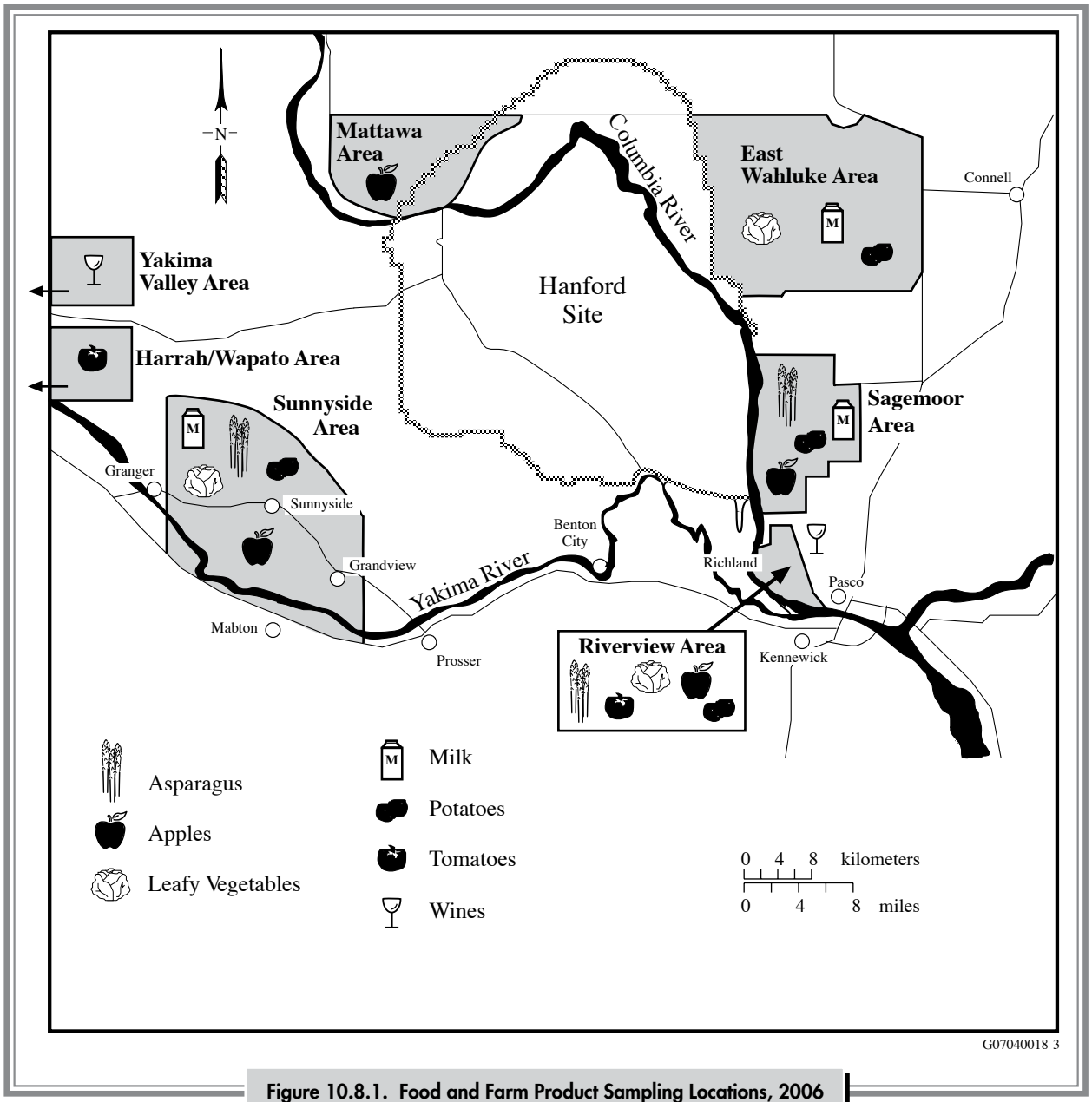


Figure 10.8.1. Food and Farm Product Sampling Locations, 2006

10.8.2 Milk

During 2006, milk samples were obtained quarterly from three dairies in the East Wahluke sampling area (two dairies in the second quarter of the calendar year), one dairy in the Sunnyside sampling area, and two dairies in the Sagemoor area (one dairy in the first quarter). The Sagemoor and East Wahluke sampling areas are located near the Hanford Site perimeter and could potentially be affected by airborne contaminants from the site. The Sunnyside area is a reference location generally upwind of the site. If milk was obtained from more than one dairy within a sampling area, the milk samples were combined and the combined (composite) sample was analyzed. All samples were analyzed for gamma-emitting radionuclides, strontium-90, and tritium. Milk sampling was conducted because Hanford Site-produced radionuclides have the potential to move through the air-pasture-cow-milk or water-pasture-cow-milk

Table 10.8.1. Sampling Locations, Frequencies, and Analyses Performed for Food and Farm Products Sampled Around the Hanford Site, 2006[a]

	Number of Locations			Types of Analyses and Number of Samples Analyzed			
Product	Upwind	Downwind	Sampling Frequency	^{3}H	Gamma	^{90}Sr	U
Apples	2	2	TE	0	4	4	0
Asparagus	1	2	A	0	3	3	3
Leafy vegetables	0	1	A and BE	0	1	1	0
Milk	1	2	Q and SA	14	14	14	0
Potatoes	1	2	A and TE	0	3	3	0
Tomatoes	1	1	A	2	2	2	0
Wine	2	2	A	8	8	0	0

(a) Products may include multiple varieties for each category.
A = Annually.
BE = Biennially.
Q = Quarterly.
SA = Semiannually.
TE = Triennially.

food chains to humans. However, in recent years, levels of Hanford Site-produced radiological contaminants in milk samples have diminished, and concentrations in samples obtained from dairies located downwind of the site are now similar to levels measured in samples obtained from the dairy located generally upwind of the site.

Strontium-90 – Strontium-90 was not detected in any of the milk samples collected in 2006.

Tritium – Tritium was detected in all milk samples collected in 2006. Concentrations ranged from a maximum of 621 pCi/L (23 Bq/L) in a Sunnyside area sample to 23.8 pCi/L (0.9 Bq/L) in an East Wahluke area sample. Annual average concentrations for the three sampling areas were 158 pCi/L (5.8 Bq/L) for Sagemoor (n=6); 215 pCi/L (8.0 Bq/L) for East Wahluke (n=4); and 262 pCi/L (9.7 Bq/L) for Sunnyside (n=4). These concentrations are within the range of concentrations historically measured in these areas. While there is no standard for tritium in milk, the health-based standard for tritium in drinking water is an annual average of 20,000 pCi/L (740 Bq/L).

Cesium-137 – There were no manmade gamma emitters (including cesium-137) detected in milk samples collected and analyzed in 2006 (PNNL-16623, APP. 1).

Potassium-40 – Potassium-40 was detected in all milk samples collected in 2006. Potassium-40 is a naturally occurring radionuclide found in soil and in fertilizers applied to soil. It is the predominant radionuclide in foods and human tissues (Eisenbud 1987). Concentrations ranged from a maximum of 1,410 pCi/L (52 Bq/L) in a Sunnyside area sample to a minimum of 1,060 pCi/L (39 Bq/L) in a Sunnyside area sample. Annual average concentrations for the individual areas were 1,250 pCi/L (46 Bq/L) for the Sagemoor area; 961 pCi/L (35 Bq/L) for the East Wahluke area; and 1,217 pCi/L (45 Bq/L) for the Sunnyside area.

10.8.3 Asparagus

Asparagus-shoot samples were collected in the spring from commercial fields in the Riverview, Sagemoor, and Sunnyside sampling areas (Figure 10.8.1). Samples were analyzed for gamma-producing radionuclides, strontium-90, and uranium isotopes (Table 10.8.1). Uranium-234 was the only radionuclide detected in the samples with a possible Hanford Site origin. This radionuclide was found in a low concentration (0.00411 pCi/g [0.00015 Bq/g]) in one sample collected in the Riverview area. The only other radionuclide detected in the samples was naturally occurring potassium-40. Concentrations of potassium-40 in all samples were less than 3 pCi/g (0.11 Bq/g) wet weight.

10.8.4 Apples

Apple samples were collected in the fall from the Riverview, Sagemoor, East Wahluke, Mattawa, and Sunnyside sampling areas (Figure 10.8.1). Samples were analyzed for gamma-producing radionuclides and strontium-90 (Table 10.8.1). The only radionuclide found in measurable quantities was naturally occurring potassium-40. Concentrations of potassium-40 in all samples were low (<1 pCi/g [0.037 Bq/g] wet weight).

10.8.5 Leafy Vegetables

A single leafy vegetable sample was collected during the summer from the East Wahluke sampling area (Figure 10.8.1). Sampling personnel also attempted to collect leafy vegetables in the Riverview, Sunnyside, and Sagemoor areas but sources could not be located. Leafy plants are sampled to monitor the potential deposition of airborne contaminants on agricultural food products. The Riverview area is also sampled because crops in this area are irrigated with Columbia River water withdrawn from places downstream of the Hanford Site. The sample from the East Wahluke area was analyzed for gamma-producing radionuclides and strontium-90 (Table 10.8.1). Naturally occurring potassium-40 was the only radionuclide detected in the sample (<5 pCi/g [0.2 Bq/g] wet weight).

10.8.6 Potatoes and Tomatoes

Potato and tomato samples were collected from both upwind and downwind sampling areas (Figure 10.8.1) during the growing season. All samples were analyzed for gamma-emitting radionuclides and strontium-90. Tomato samples were also monitored for tritium (Table 10.8.1). The only radionuclide detected in the samples was naturally occurring potassium-40. Concentrations of potassium-40 in all samples were less than 5 pCi/g [0.1 Bq/g] wet weight.

10.8.7 2006 Wines

Red and white wine samples were obtained in December 2006 from a winery in the vicinity of Pasco and a winery near Yakima. The wines were produced from 2006 vintage grapes that were harvested in the fall from vineyards located just north of Pasco (downwind of the site) and just east of Yakima (generally upwind of the site) (Figure 10.8.1). Each wine was divided (split) into two samples and all eight samples were analyzed for gamma-emitting radionuclides and tritium (Table 10.8.1).

Cesium-137 – There were no manmade gamma emitters (including cesium-137) detected in wine samples collected and analyzed in 2006 (PNNL-16623, APP. 1).

Potassium-40 – Potassium-40, a naturally occurring gamma emitter, was measured in all wine samples collected in 2006. Concentrations in all samples ranged from 716 to 1,250 pCi/L (26 to 46 Bq/L). The average concentration for all samples was 954 pCi/L (35 Bq/L).

Tritium – Low levels of tritium were measured in all wine samples analyzed in 2006. Concentrations in all samples ranged from 28.8 to 447 pCi/L (1.1 to 16.5 Bq/L). The average concentration for all samples was 148 pCi/L (5.5 Bq/L). When summarized by region, the tritium average for the Yakima area wines was 78 pCi/L (2.9 Bq/L), and the average for the Pasco area wines was 218 pCi/L (8.1 Bq/L). While there is no health-based standard for tritium in wine, the standard for tritium in drinking water is 20,000 pCi/L (740 Bq/L).

10.8.8 2005 Wines

All wine samples collected in 2005 were analyzed for gamma-producing radionuclides and tritium. A discussion of the gamma analyses results was included in the 2005 Hanford Site environmental report (PNNL-15892). Tritium data were received from the analytical laboratory too late to include in the 2005 report and are summarized here.

Samples of a red wine and a white wine were obtained in December 2005 from two separate wineries near Yakima and from one winery in the vicinity of Pasco. The wines were produced from 2005 vintage grapes that were harvested in the fall. Each wine was split into two samples and all eight samples were analyzed. Tritium was measured in all wine samples at low levels. Concentrations ranged from 12.2 to 103 pCi/L (0.4 to 3.8 Bq/L), and the average for all eight samples was 48 pCi/L (1.8 Bq/L). When summarized by region, the tritium average for the Yakima area wines was 28 pCi/L (1 Bq/L), and the average for the Pasco area wines was 42 pCi/L (1.5 Bq/L).

10.9 Soil Monitoring

The following sections summarize soil monitoring efforts conducted in 2006 on and around the Hanford Site. Radiological monitoring of soil is conducted onsite near facilities and operations, onsite away from facilities and operations (site-wide), and offsite at perimeter and distant locations and in nearby communities. Contaminant concentration data are used for the following:

- Determining the effectiveness of effluent monitoring and controls within facilities
- Assessing the adequacy of containment at waste-disposal sites
- Detecting and monitoring unusual conditions
- Providing information on long-term radionuclide contamination trends in soil at undisturbed locations.

Soil samples have been collected on and around the Hanford Site for more than 50 years. Consequently, a large amount of data exists documenting onsite and offsite levels of man-made radionuclides in Hanford Site soil. These data provide a baseline against which unplanned releases can be compared. For further information about these monitoring efforts, the programs that support them, and their purposes, see Section 10.0 and DOE/RL-91-50, Rev. 3.

10.9.1 Soil Monitoring Near Hanford Site Facilities and Operations

C. J. Perkins

Soil samples are collected near facilities and operations to evaluate long-term trends in the environmental accumulation of radioactive materials, and to detect potential migration and deposition of facility emissions. Soil contamination can occur as the result of direct deposition from facility emissions, resuspension and movement of contaminants from radiologically contaminated surface areas, uptake of contaminants into plants whose roots contact belowground waste, or translocation of buried waste by intruding animals.

10.9.1.1 Soil Sampling Near Hanford Site Facilities and Operations

Soil samples were collected on or adjacent to waste-disposal sites, and from locations downwind and near or within the boundaries of operating facilities and remedial action sites. The number and locations of soil samples collected during 2006 are summarized in Table 10.9.1. Only radionuclides with concentrations consistently above analytical detection

Table 10.9.1. Number and Locations of Soil Samples Collected Near Hanford Site Facilities and Operations, 2006

Number of Samples	Operational Area								
	100-D	100-F	100-K	100-N	200-West[a]	200-East[b]	600[b]	300[b]	400
97	4	9	2	7	27	15	16	16	1

(a) Includes one sample collected at the Environmental Restoration Disposal Facility.
(b) Number of samples includes one or more replicate samples.

limits are discussed in this section. A comprehensive presentation of the analytical data from these samples can be found in PNNL-16623, APP. 2.

Each 1-kilogram (2.2-pound) soil sample represented a composite of five plugs of soil, each 2.5 centimeters (1 inch) deep and 10 centimeters (4 inches) in diameter. Soil samples were sieved in the field to remove rocks and plant debris, and dried in the laboratory prior to analysis to remove residual moisture.

Hanford Site samples were analyzed for radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides [Appendix F, Table F.1], strontium-90, uranium isotopes, and/or plutonium isotopes). The analytical results from Hanford Site samples were compared to concentrations of radionuclides measured in samples collected offsite in previous years at various sampling locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin Counties (Figure 10.9.1). These comparisons were used to differentiate concentrations of Hanford Site-produced contaminants from levels resulting from natural sources and worldwide fallout.

Soil sampling results can be compared to the accessible soil concentrations (WHC-SD-EN-TI-070) developed specifically for use at the Hanford Site. These concentration values for radionuclides 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 consumption of foods, including animal products. The accessible soil concentration values are based on a radiation-dose estimate scenario (WHC-SD-EN-TI-070) in which an individual would have to spend 100 hours per year in direct contact with the contaminated soil. The conservatism inherent in pathway modeling assures the required degrees of protection are in place. These concentrations apply specifically to the Hanford Site with respect to onsite waste-disposal operations and cleanup, decontamination, and decommissioning activities. A partial listing of these values is presented in Table 10.9.2 (see PNNL-16623, APP. 2 for a complete listing of concentrations).

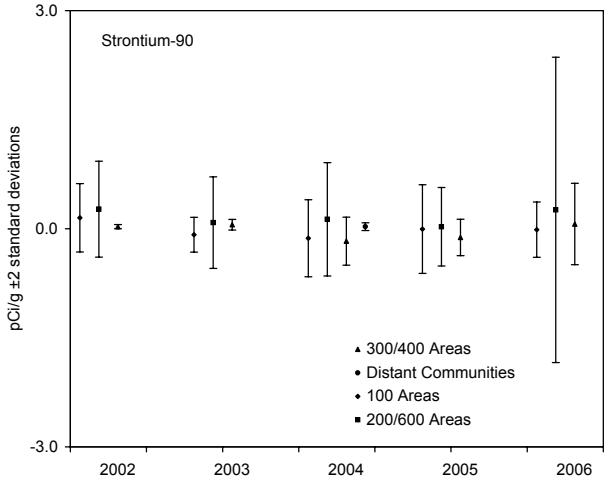
10.9.1.2 Analytical Results for Soil Samples Collected Near Hanford Site Facilities and Operations

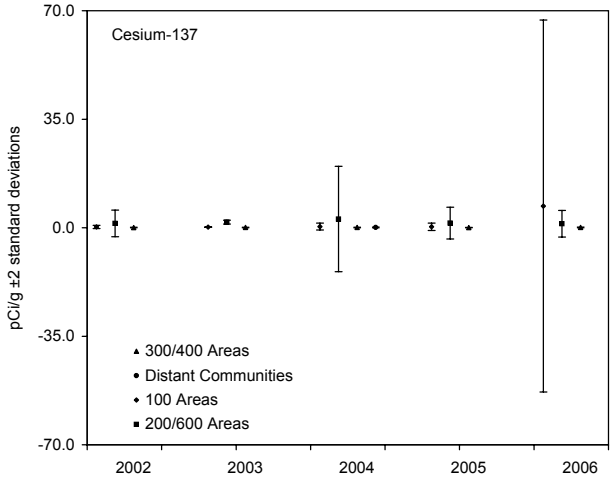
Some degree of variability is always associated with the collection and analysis of environmental samples. Therefore, variations in sample concentrations from year to year are expected. In general, radionuclide concentrations in soil samples collected from or adjacent to waste-disposal facilities in 2006 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 in 2006 were higher within different operational areas when compared to concentrations measured in distant communities in previous years. Generally, the predominant radionuclides detected were activation and fission products in the 100-N Area, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas.

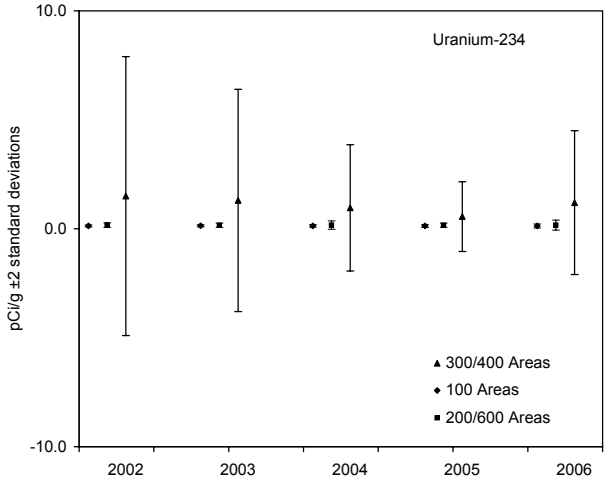
Cesium-134, cesium-137, plutonium-239/240, and uranium were detected consistently in the samples taken in 2006. Concentrations of these radionuclides were elevated near and within facility boundaries when compared to historical concentrations measured offsite at distant communities. Figure 10.9.1 shows the average concentrations of selected radionuclides in soil samples collected during 2006 and the preceding 4 years. Some individual levels demonstrate a high degree of variability, although overall trends are stable.

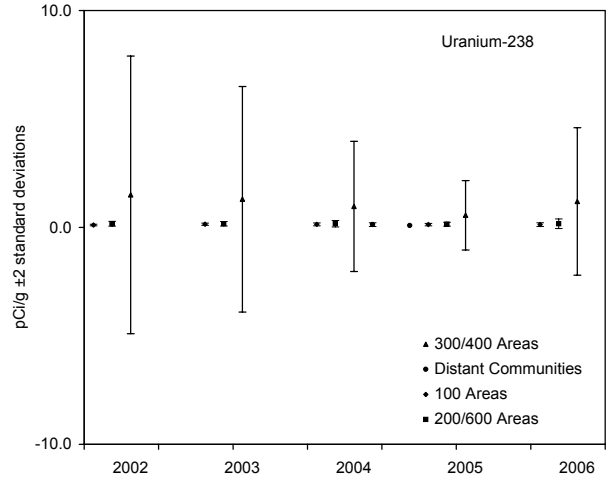
Table 10.9.3 provides a summary of selected analytical results for near-facility soil samples collected and analyzed in 2006. The average and maximum results are reported for five operational areas, along with comparative data for the preceding 5 years. Complete listings of radionuclide concentrations for all soil samples collected during 2006, as well as sampling location maps, can found in PNNL-16623, APP. 2.

Samples were collected from 15 locations in the 200-East Area in 2006. Average concentrations were comparable or somewhat lower than results reported for the previous years. Radionuclide levels for strontium-90, cesium-137, plutonium-238, plutonium-239/240, and uranium-238 were greater than those measured off the Hanford Site in previous years.









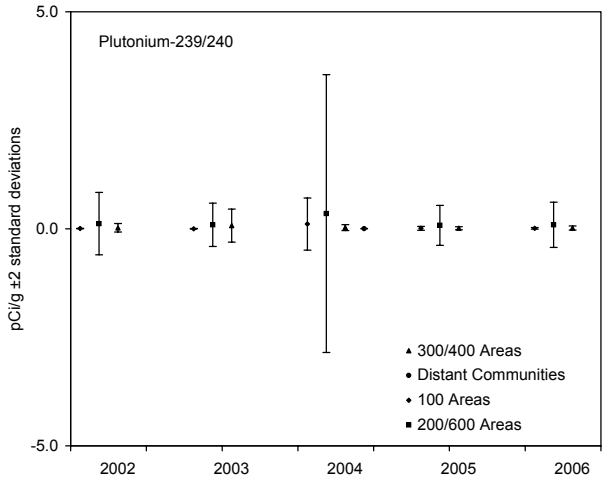


Figure 10.9.1. Average Concentrations of Selected Radionuclides in Soil Samples Collected on the Hanford Site Near Facilities and Operations Compared to Those Collected in Distant Communities, 2002 Through 2006. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

Table 10.9.2. Accessible Soil Concentration Limits (pCi/g[a] dry wt.) for Selected Radionuclides

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	$^{239/240}$Pu
Accessible soil[b] concentration limits (WHC-SD-EN-TI-070)	7.1	2,800	30	630	170	370	190

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) Hanford Site soil that is not behind security fences.

Twenty-seven locations were sampled in the 200-West Area in 2006. Of these, a single sample was collected at the Environmental Restoration Disposal Facility near the 200-West Area to determine the effectiveness of contamination controls (Table 10.9.1). Values reported for all radionuclides were comparable to historical ranges. Again, concentrations of strontium-90, cesium-137, plutonium-238, plutonium-239/240, and uranium-238 were greater than those measured at distant communities in previous years.

Soil samples were collected from 16 locations in the 300 Area. Concentrations of uranium-234, uranium-235, and uranium-238 isotopes in 300 Area samples were comparable to concentrations measured in previous years. These uranium concentrations did remain higher than those measured in the 100 and 200 Areas. The higher uranium levels were expected due to uranium releases to the environment during past fuel-fabrication operations in the 300 Area.

A single soil sample is collected annually from the 400 Area. The concentrations of cesium-137 and uranium-234, uranium-235, and uranium-238 measured in 2006 were comparable to average concentrations measured in prior years.

A total of 16 soil samples were collected from the 600 Area, which consists of locations on the plateau surrounding the 200-East and 200-West Areas. Average results reported for all radionuclides were comparable to averages reported for previous years and were greater than those measured off the Hanford Site.

One routine soil sample (location Y608) was collected near the 116-N-3 waste-disposal facility in the 100-N Area in 2006. The average radionuclide concentrations detected in the sample collected from the 100-N Area are presented in Table 10.9.4. Cobalt-60, cesium-134, and cesium-137 averages were somewhat higher than in preceding years, while averages for other radionuclides remained comparable.

For non-routine soil sampling in support of the environmental restoration contractor projects in 2006 and early 2007, four soil samples were collected at the field remediation project in the 100-D Area, nine at the 100-F Area field remediation project (collected during two sampling events), two at the 118-KR-1 field remediation project (in the 100-K Area), and six at the 100-NR-1 field remediation project (collected at three locations during two sampling events). Analytical results from each of these locations were comparable to those observed at other near-facility sampling locations at the Hanford Site. Table 10.9.4 provides a summary of selected analytical results for samples from these sites. A complete listing of the data is provided in PNNL-16623, APP. 2.

10.9.1.3 Investigations of Radioactive Contamination in Soil Near Hanford Site Facilities and Operations

S. M. McKinney and R. C. Roos

Investigations for radioactive contamination in soil were conducted in and near operational areas to monitor the presence or movement of radioactive materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. All samples collected during investigations were field surveyed for alpha and beta/gamma radiation. Generally, the predominant radionuclides in samples from the 100 and 200 Areas have been strontium-90, cesium-137, and plutonium-239/240. Uranium-234, uranium-235, and uranium-238 have been routinely found in 300 Area samples.

During 2006, there were 25 instances of radiological contamination in soil samples collected during investigations. Of the 25, 12 were identified as speck contamination, and 22 were cleaned up and disposed of onsite in burial grounds. At the remaining locations, the contamination levels did not exceed the radiological control limits for the sites and

Table 10.9.3. Concentrations of Selected Radionuclides (pCi/g dry wt.)[a] in Near-Facility Soil Samples, 2006 Compared to Previous Years

		2006				2001-2005			
		Number of				Number of			
Radionuclide	Hanford Area	Samples	Detections[b]	Average[c]	Maximum[d]	Samples	Detections[b]	Average[c]	Maximum[d]
Cobalt-60	200-E	15	0	0.0014 ± 0.0063	0.0067 ± 0.0087	72	0	0.00010 ± 0.0081	0.0099 ± 0.0076
	200-W[e]	27	0	0.000059 ± 0.0097	0.0098 ± 0.012	138	3	0.0015 ± 0.031	0.18 ± 0.020
	300	16	0	-0.0017 ± 0.0069	0.0048 ± 0.011	70	0	-0.0011 ± 0.0028	0.0083 ± 0.0063
	400[f]	1	0	Not applicable	0.0052 ± 0.0069	5	0	0.00048 ± 0.0045	0.0036 ± 0.0061
	600	16	0	-0.0015 ± 0.0053	0.0041 ± 0.0063	82	1	0.00015 ± 0.0097	0.013 ± 0.013
Cesium-137	200-E	15	15	2.1 ± 7.1	13.0 ± 2.2	72	71	2.3 ± 7.4	17 .0± 3.0
	200-W[e]	27	27	1.2 ± 2.5	4.9 ± 0.88	138	136	1.8 ± 4.2	13.0 ± 2.4
	300	16	15	0.098 ± 0.14	0.21 ± 0.038	70	62	0.069 ± 0.13	0.23 ± 0.040
	400[f]	1	1	Not applicable	0.027 ± 0.011	5	5	0.037 ± 0.084	0.12 ± 0.022
	600	16	16	0.69 ± 2.1	4.0 ± 0.64	82	79	1.2 ± 13.0	61.0 ± 9.7
Plutonium-238	200-E	15	0	0.0021 ± 0.020	0.028 ± 0.042	72	1	0.0049 ± 0.034	0.047 ± 0.039
	200-W[e]	27	1	0.016 ± 0.047	0.10 ± 0.048	138	6	0.0057 ± 0.047	0.22 ± 0.066
	300	16	0	0.0064 ± 0.022	0.021 ± 0.032	70	2	0.0032 ± 0.047	0.16 ± 0.061
	400[f]	1	0	Not applicable	0.011 ± 0.038	5	0	0.0013 ± 0.018	0.011 ± 0.021
	600	16	0	0.0028 ± 0.021	0.022 ± 0.033	82	3	0.019 ± 0.18	0.77 ± 0.22
Plutonium-239/240	200-E	15	7	0.012 ± 0.023	0.046 ± 0.023	72	26	0.014 ± 0.030	0.064 ± 0.029
	200-W[e]	27	19	0.18 ± 0.73	1.8 ± 0.47	138	117	0.15 ± 0.68	2.4 ± 0.48
	300	16	5	0.019 ± 0.050	0.072 ± 0.030	70	21	0.035 ± 0.19	0.73 ± 0.15
	400[f]	1	0	Not applicable	0.0036 ± 0.0072	5	0	0.0034 ± 0.0043	0.0075 ± 0.010
	600	16	9	0.025 ± 0.055	0.10 ± 0.036	82	44	0.24 ± 2.7	12.0 ± 3.1
Strontium-90	200-E	15	4	0.29 ± 0.75	1.3 ± 0.32	72	25	0.20 ± 0.73	1.9 ± 0.38
	200-W[e]	27	4	0.35 ± 3.1	8.1 ± 1.6	138	51	0.21 ± 0.94	3.8 ± 0.76
	300	16	1	0.063 ± 0.58	1.0 ± 0.35	70	2	-0.032 ± 0.15	0.30 ± 0.23
	400[f]	1	0	Not applicable	0.10 ± 0.20	5	0	-0.075 ± 0.35	0.18 ± 0.13
	600	16	2	0.099 ± 0.35	0.45 ± 0.22	82	13	0.047 ± 0.51	1.1 ± 0.25

Table 10.9.3. (contd)

Radionuclide	Hanford Area	2006 Number of Samples	2006 Number of Detections[b]	2006 Average[c]	2006 Maximum[d]	2001-2005 Number of Samples	2001-2005 Number of Detections[b]	2001-2005 Average[c]	2001-2005 Maximum[d]
Uranium-234	200-E	15	15	0.21 ± 0.36	0.84 ± 0.28	72	72	0.17 ± 0.11	0.36 ± 0.083
	200-W[e]	27	27	0.16 ± 0.17	0.51 ± 0.14	138	138	0.17 ± 0.10	0.47 ± 0.10
	300	16	16	1.3 ± 3.4	5.3 ± 1.4	70	70	1.1 ± 4.4	12.0 ± 2.3
	400[f]	1	1	Not applicable	0.16 ± 0.056	5	5	0.14 ± 0.072	0.20 ± 0.052
	600	16	16	0.16 ± 0.095	0.32 ± 0.093	82	82	0.18 ± 0.18	0.84 ± 0.23
Uranium-235	200-E	15	9	0.013 ± 0.011	0.026 ± 0.016	72	43	0.014 ± 0.015	0.037 ± 0.020
	200-W[e]	27	17	0.016 ± 0.021	0.054 ± 0.024	138	83	0.014 ± 0.014	0.035 ± 0.021
	300	16	14	0.086 ± 0.21	0.35 ± 0.10	70	55	0.066 ± 0.22	0.65 ± 0.16
	400[f]	1	0	Not applicable	0.012 ± 0.013	5	3	0.013 ± 0.015	0.024 ± 0.014
	600	16	11	0.017 ± 0.018	0.045 ± 0.023	82	53	0.016 ± 0.020	0.056 ± 0.027
Uranium-238	200-E	15	15	0.20 ± 0.33	0.77 ± 0.26	72	72	0.18 ± 0.11	0.38 ± 0.087
	200-W[e]	27	27	0.17 ± 0.18	0.53 ± 0.15	138	138	0.18 ± 0.11	0.43 ± 0.099
	300	16	16	1.3 ± 3.5	5.3 ± 1.4	70	70	1.1 ± 4.4	12.0 ± 2.3
	400[f]	1	1	Not applicable	0.15 ± 0.053	5	5	0.15 ± 0.088	0.22 ± 0.057
	600	16	16	0.16 ± 0.088	0.29 ± 0.087	82	82	0.18 ± 0.15	0.68 ± 0.19

(a) 1 pCi = 0.037 Bq.
(b) Number of samples with measurable concentrations of contaminant.
(c) Average ± two standard deviations of all samples analyzed.
(d) Maximum ± analytical uncertainty.
(e) Includes one sample collected at the Environmental Restoration Disposal Facility.
(f) Average cannot be calculated from a single sample.

Table 10.9.4. Radionuclide Concentrations (pCi/g[a] dry wt.)[b] in Environmental Restoration Contractor Field Remediation Projects' Soil Samples, 2006

Site	Sample Location[c]	Sample Date	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-238	Plutonium-239/240
ERDF	D146	05/30/2006	0.0074 ± 0.0084	0.021 ± 0.014	0.024 ± 0.18	0.15 ± 0.049	0.17 ± 0.054	0.0096 ± 0.0094
100-D Area	D147	11/16/2006	0.0094 ± 0.0092	0.32 ± 0.29	0.39 ± 0.067	0.16 ± 0.056	0.16 ± 0.056	0.021 ± 0.016
	D171	11/16/2006	0.0084 ± 0.0085	0.046 ± 0.28	0.64 ± 0.11	0.12 ± 0.043	0.14 ± 0.049	0.015 ± 0.016
	D172	11/16/2006	0.001 ± 0.0065	-0.19 ± 0.26	0.15 ± 0.03	0.097 ± 0.036	0.097 ± 0.036	0.011 ± 0.012
	D173	11/16/2006	-0.0033 ± 0.0088	-0.035 ± 0.29	0.097 ± 0.021	0.11 ± 0.038	0.085 ± 0.031	0.0076 ± 0.0095
100-F Area	D155	06/01/2006	0.0022 ± 0.012	0.23 ± 0.26	0.14 ± 0.033	0.092 ± 0.037	0.086 ± 0.034	0.011 ± 0.011
	D168	06/01/2006	0.0055 ± 0.0075	-0.072 ± 0.22	0.15 ± 0.03	0.11 ± 0.04	0.11 ± 0.04	0.0088 ± 0.0081
	D169	06/01/2006	0.0035 ± 0.0051	-0.27 ± 0.27	0.23 ± 0.038	0.14 ± 0.05	0.12 ± 0.048	0.0095 ± 0.0081
	D170	06/01/2006	-0.0038 ± 0.0071	0.029 ± 0.25	0.032 ± 0.013	0.15 ± 0.053	0.14 ± 0.049	0.0018 ± 0.0018
	D154	01/04/2007	-0.84 ± 4.9	-0.021 ± 0.21	140 ± 26	0.15 ± 0.054	0.1 ± 0.04	0.017 ± 0.013
	D155	01/04/2007	0.0033 ± 0.007	-0.11 ± 0.26	0.1 ± 0.02	0.32 ± 0.099	0.29 ± 0.093	0.021 ± 0.016
	D168	01/04/2007	-0.0031 ± 0.01	-0.081 ± 0.25	0.098 ± 0.028	0.099 ± 0.04	0.13 ± 0.048	0.015 ± 0.015
	D169	01/04/2007	0.0035 ± 0.0076	-0.19 ± 0.21	0.18 ± 0.035	0.084 ± 0.034	0.11 ± 0.042	0.013 ± 0.013
	D170	01/04/2007	-0.0065 ± 0.012	0.075 ± 0.26	0.1 ± 0.025	0.13 ± 0.048	0.17 ± 0.058	-0.0039 ± 0.0096
118-K-1 (100-K Area)	D166	02/13/2006	-0.004 ± 0.0098	-0.058 ± 0.19	0.16 ± 0.032	0.14 ± 0.052	0.14 ± 0.05	0.0093 ± 0.010
	D167	02/13/2006	0.034 ± 0.011	0.12 ± 0.24	0.47 ± 0.081	0.16 ± 0.06	0.13 ± 0.052	0.014 ± 0.010
100-N Area	D156	01/11/2006	0.053 ± 0.011	-0.012 ± 0.12	0.22 ± 0.038	0.15 ± 0.054	0.14 ± 0.051	0.0024 ± 0.024
	D158	01/11/2006	0.051 ± 0.011	0.28 ± 0.46	0.17 ± 0.03	0.12 ± 0.045	0.11 ± 0.041	0.0018 ± 0.011
	D159	01/11/2006	0.16 ± 0.021	0.2 ± 0.49	0.88 ± 0.15	Not reported	0.098 ± 0.039	0.0019 ± 0.011
	D156	06/06/2006	0.019 ± 0.0089	-0.13 ± 0.26	0.079 ± 0.018	0.1 ± 0.038	0.078 ± 0.031	-0.0037 ± 0.0074
	D158	06/06/2006	0.1 ± 0.014	-0.24 ± 0.27	0.17 ± 0.032	0.13 ± 0.044	0.11 ± 0.04	0.0058 ± 0.010
	D159	06/06/2006	0.11 ± 0.016	0.24 ± 0.29	1.7 ± 0.27	0.14 ± 0.048	0.16 ± 0.053	0.015 ± 0.012
	Y608	06/06/2006	16 ± 1.5	-0.41 ± 0.41	3.5 ± 0.58	0.11 ± 0.04	0.12 ± 0.043	0.044 ± 0.022
Accessible Soil Concentration[d]			7.1	2,800	30	630	370	190

(a) 1 pCi = 0.037 Bq.
(b) ± total analytical uncertainty.
(c) Sampling location code. See PNNL-16623, APP. 2.
(d) Hanford Site soil that is not behind security fences.
ERDF = Environmental Restoration Disposal Facility (200-West Area).

the soil was left in place. None of the soil samples were submitted for radioisotopic analysis. The number of soil investigation contamination incidents and range of radiation dose levels in 2006 were generally within historical values (WHC-MR-0418).

The number and general locations of soil contamination incidents investigated during 2006 are summarized in Table 10.9.5. The number of contamination incidents investigated in 2006 and during the previous 9 years are provided in Table 10.9.6.

10.9.2 Soil Monitoring at Hanford Site-Wide and Offsite Locations

B. G. Fritz

Soil monitoring provides information on long-term contamination trends and baseline environmental radionuclide activities at undisturbed locations both on and off the Hanford Site (DOE/RL-91-50, Rev. 3). Soil samples have been collected on and around the Hanford Site for more than 50 years. Consequently, a large database exists that documents onsite and offsite levels of manmade radionuclides in soil at specific locations. This database contains baseline data against which analysis results from unplanned contaminant releases from the Hanford Site can be compared. Routine radiological monitoring of soil at site-wide (onsite away from facilities and operations) and offsite locations was last conducted in 2004 (Section 8.9 in PNNL-15222) and is scheduled to be done again in 2009.

Table 10.9.5. Number and Locations of Soil Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 2006

Locations	Number of Incidents
200-East Area	
tank farms	8
burial grounds	0
cribs, ponds, and ditches	0
fence lines	0
roads and railroads	1
unplanned release sites	2
underground pipelines	1
miscellaneous	2
200-West Area	
tank farms	7
burial grounds	0
cribs, ponds, and ditches	0
fence lines	0
roads and railroads	0
unplanned release sites	0
underground pipelines	1
miscellaneous	0
Cross-site transfer line	1
200-BC cribs and trenches	0
200-North Area	0
100 Areas	1
300 Area	0
400 Area	0
600 Area	1
Former 1100 Area	0
Total	**25**

Table 10.9.6. Annual Number of Soil Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 1997 Through 2006

Year	Number of Incidents	Year	Number of Incidents
1997	51	2002	22
1998	41	2003	30
1999	42	2004	19
2000	25	2005	20
2001	20	2006	25

10.10 Vegetation Monitoring

Vegetation monitoring and control activities conducted on and around the Hanford Site in 2006 are summarized in the following sections. The sections include discussions on the following:

- Surveying and monitoring Hanford Site plant populations
- Monitoring contaminants in perennial vegetation growing near facilities and operations on the site
- Controlling contaminated or unwanted vegetation on the site.

Surveys and monitoring of plant populations are conducted to assess the abundance, vigor or condition, and distribution of populations and species. These data can be integrated with contaminant monitoring results and used to help characterize potential risks or impacts to biota. Radiological monitoring of vegetation near onsite facilities and operations is done to determine the effectiveness of effluent monitoring and controls within facilities, to assess the adequacy of containment at waste-disposal sites, and to detect and monitor unusual conditions. Site-wide and offsite vegetation samples (not collected in 2006 but scheduled for collection in 2009) are analyzed for information on atmospheric deposition of contaminants, around onsite operational areas, and in uncultivated areas offsite. These data provide a baseline against which unplanned releases can be compared. Vegetation management activities help to prevent, limit, or clean up contaminated plants or undesirable plant species. For further information about these monitoring and control activities, their purposes, and the programs that support them, see Section 10.0 in this report or DOE/RL-91-50, Rev. 3.

10.10.1 Plant Communities and Population Surveys on the Hanford Site

J. L. Downs, M. R. Sackschewsky, and M. A. Chamness

The Hanford Site contains biologically diverse shrub-steppe plant communities that have been protected from most disturbances (except for fire) for more than 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 the Hanford Site. Surveys and mapping efforts have documented the occurrence and extent of rare-plant populations and plant community types on the Hanford Site (PNL-8942; PNNL-13688; Soll et al. 1999). Plant populations monitored on the site include taxa listed by Washington State as endangered, threatened, or sensitive (Section 10.12), and species 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 on the Hanford Site to develop baseline information and to monitor any changes resulting from site operations. The data provide information that is used for site-planning processes and land-use policy development.

10.10.1.1 Vegetation Cover Types and Habitats

Monitoring of the plant communities and cover types on the Hanford Site focuses on two main objectives: 1) mapping the distribution and extent of major plant cover types on

uplands and riparian areas on the site; and 2) conducting periodic surveys to assess whether community composition and structure are changing. Mapping the distribution and extent of vegetation on the site provides important information on potential and existing habitats of sensitive or rare species, as well as information regarding the presence of receptor species. The spatial data for upland habitats were updated to reflect changes in vegetation following the 24 Command Wildland Fire in 2000 (DOE/RL-2000-63). Spatial information for the riparian vegetation-cover types was updated during 2003 and 2004 to provide a continuous map of the Benton County shoreline of the Hanford Reach. During 2005, further work was conducted to update the vegetation-cover type information for the 100 Areas, 200 Areas, and 300 Area to better describe the current status of vegetation within the area boundaries. Numerous activities associated with cleanup including excavation, remediation, and restoration have influenced the vegetation inside the areas and at their fenced boundaries. Information from these surveys is also used to update maps depicting areas with highly valued biological resources (for detailed information, see the website at http://www.pnl.gov/ecomon/Veg/Veg.html). Periodic surveys of the frequency, cover, and number of species found on permanent monitoring plots provide information on trends or changes in species diversity, presence of invasive and key species, and the overall condition of the plant community and available habitat (PNNL-15892). Work during 2006 focused on developing a computer model to map shrub-canopy cover using field measured shrub-canopy cover, and texture data derived from aerial imagery. A shrub-canopy cover map will be available in 2007.

10.10.1.2 Rare-Plant Monitoring

More than 100 plant populations of 53 different taxa listed by the Washington Natural Heritage program as endangered, threatened, sensitive, or on the review or watch list are found at the Hanford Site (for additional information, see PNNL-13688 and the following website: http://www.pnl.gov/ecomon/Veg/Habitat.html). The U.S. Fish and Wildlife Service has designated 4 of these 53 taxa as species of concern in the Columbia River Basin ecoregion: Columbia milkvetch (*Astragalus columbianus*), gray cryptantha (*Cryptantha leucophaea*), Hoover's desert parsley (*Lomatium tuberosum*), and persistent sepal yellowcress (*Rorippa columbiae*). Two species, Umtanum buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Lesquerella tuplashensis*) (for additional information, see the website at http://www.dnr.wa.gov/nhp/refdesk/lists/plantrnk.html) are proposed as candidates for federal listing as endangered and threatened, respectively. 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 listed by Washington State. These are areas that potentially support populations of rare annual forbs.

During May 2006, surveys for rare annual species were conducted within specific areas inside these special habitat types as part of compliance review activities for firebreak construction and maintenance. Several populations of the Washington State sensitive taxa Suksdorf monkeyflower (*Mimulus suksdorfii*) that were seen in previous surveys in the habitat north of Gable Mountain were found again in 2006. Individuals and/or populations of Piper's daisy (*Erigeron piperianus*), Columbia milkvetch, and gray cryptantha were also located. Populations of loeflingia (*Loeflingia squarrosa var. squarrosa*) and rosy pussypaws (*Calyptridium roseum*) previously identified in the same vicinity were not found in 2006.

During September 2006, monitoring transects originally established in 1994 to examine the condition and status of persistent sepal yellowcress were revisited along the Columbia River shoreline near the 100-F Area. Surveys were also conducted on three Hanford Reach islands (Locke Island [Island 6], Island 18, and Island 16, Figure 10.10.1) in an attempt to relocate populations previously seen at those sites. The number of plants (stems) counted during 2006 at a 100-F Area beach was higher than the number seen in 2005 at the same location (Table 10.10.1). No specimens were located along the original 100-F Area transects (monitored from 1994 through 2001). Monitoring along the shoreline in 2005 and 2006 was accomplished downstream and up the river bank from the original population, and more than 600 stems were counted. Surveys of the islands in the downstream stretch of the Hanford Reach did not locate any persistent sepal yellowcress plants. On Hanford Reach Islands 16 (located just downstream of Wooded Island [Island 14]) and 18 (located near the 300 Area), it appears that the cobble habitats that previously supported persistent

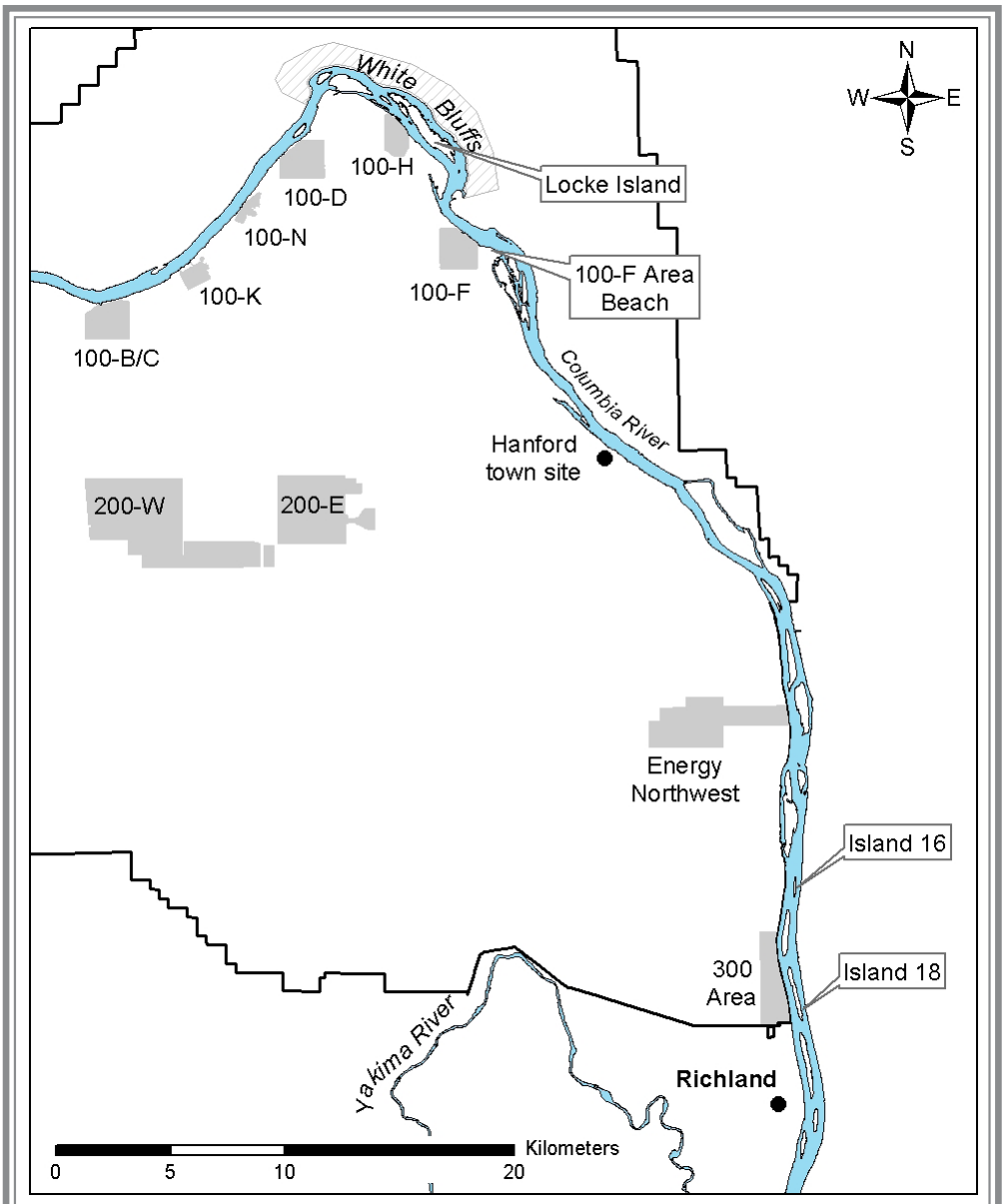


Figure 10.10.1. Survey Locations for Yellowcress (Rorippa columbiae) Monitoring Along the Hanford Reach

sepal yellowcress, have been covered with silt. This change in the substrate may be affecting persistent sepal yellowcress occurrence and/or survival. Data that describe trends in plant numbers and the timing of growth for this species are of interest because large variations in population numbers have been observed. These variations are believed to be linked to natural and Priest Rapids Dam related river-level fluctuations that inundate habitat for this species during a large part of the growing season.

10.10.2 Vegetation Monitoring Near Hanford Site Facilities and Operations

C. J. Perkins

Vegetation samples were collected on, or adjacent to, waste-disposal sites and from locations downwind and near or

Table 10.10.1. Numbers of Rorippa Columbiae[a] Stems Counted Along the Hanford Reach of the Columbia River in Surveys Conducted from 1994 Through 2006 (High river flows in 2002 and 2003 precluded surveys for Rorippa columbiae along the shoreline.)

Survey Location	1994 Counts	1998 Counts	1999 Counts	2000 Counts	2001 Counts	2004 Counts	2005 Counts	2006 Counts
100-F Area beach	>15,000	70	94	196	17	Not surveyed[b]	130	639
Locke Island	>10,000	117	Not surveyed[b]	1,038	1,793	1,800	Not surveyed[b]	2,220
Island 18[c]	>10,000	0	Not surveyed	19	0	Not surveyed[b]	Not surveyed[b]	0

(a) Persistent sepal yellowcress.
(b) High water levels prevented access to populations.
(c) Located in the Columbia River near the 300 Area.

within the boundaries of operating facilities and remedial-action sites. Samples were collected to evaluate long-term trends in environmental accumulation and potential migration of radioactive material. Contamination in vegetation can occur as the result of surface deposition of radioactive materials from other radiologically contaminated sources and/or by absorption of radionuclides by the roots of vegetation growing on or near former waste-disposal sites.

The number and location of vegetation samples collected near facilities and operations during 2006 are summarized in Table 10.10.2. Only those radionuclides with concentrations consistently above analytical detection limits are discussed in this section. A comprehensive presentation of the analytical data from these samples can be found in PNNL-16623, APP. 2.

10.10.2.1 Vegetation Sampling Near Hanford Site Facilities and Operations

Each sample (approximately 500 grams [16.1 ounces]) consisted of new-growth leaf cuttings taken from the available brushy, deep-rooted species (e.g., sagebrush and/or rabbitbrush) at a sampling location. Often, the sample consisted of a composite of several like members of the sampling-site plant community to avoid decimation of any individual plant through over-harvesting. Vegetation samples were dried prior to analyses and analytical results were reported on a dry weight basis.

Samples were analyzed for the radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides [cobalt-60 and cesium-137], strontium-90, uranium isotopes, and/or plutonium isotopes). Selected analytical results were compared to concentrations in samples collected during 2004 by Pacific Northwest National Laboratory personnel at offsite sampling locations in Yakima, Benton, and Franklin Counties (PNNL-15222). Comparisons can be used to determine the differences between contributions from site operations and remedial action sites, and contributions from natural sources and worldwide fallout.

10.10.2.2 Analytical Results for Vegetation Samples Collected Near Hanford Site Facilities and Operations

Some degree of variability is always associated with the collection and analysis of environmental samples. Therefore, variations in sample concentrations from year to

Table 10.10.2. Number and Locations of Vegetation Samples Collected Near Hanford Site Facilities and Operations in 2006

Number of Samples	Operational Area					
	100-N	200-East	200-West[a]	300[a]	400	600[a]
69	4	10	23	15	1	16

(a) Number of samples indicates one or more replicate samples.

year are expected. In general, radionuclide concentrations in vegetation samples collected from, or adjacent to, waste-disposal facilities in 2006 were higher than 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 in 2006 were higher within different operational areas when compared to concentrations measured in past years in distant communities. Generally, the predominant radionuclides were activation and fission products in the 100-N Area, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas.

Uranium was detected consistently, and strontium-90, cesium-137, plutonium-238, plutonium-239/240 were detected occasionally in samples taken in 2006. Concentrations of these radionuclides were elevated near and within facility boundaries compared to concentrations measured at distant communities. Figure 10.10.2 shows the average concentrations in vegetation samples collected near Hanford Site facilities and operations during 2006 and the preceding 5 years, and results for 2004 at distant communities. The results demonstrate a high degree of variability.

Table 10.10.3 provides a summary of selected radionuclides, which were detected in vegetation samples collected and analyzed in 2006 and in previous years. The average and maximum results are reported for the six primary waste facility/operational areas of interest, along with comparative data for the preceding 5 years. A complete listing of 2006 radionuclide concentrations, as well as sampling location maps, is provided in PNNL-16623, APP. 2.

Four vegetation samples were collected at locations in the 100-N Area in 2006. Analytical results from these samples were comparable to those observed in 100-N Area samples collected in previous years. The levels of strontium-90 in 100-N Area samples were higher than levels found in samples from the 200, 300, and 400 Areas. The radionuclide levels measured in 100-N Area vegetation in 2006 were greater than those measured in samples from distant communities in 2004.

Samples were collected from ten locations in the 200-East Area in 2006. Analytical results were comparable to results reported for the previous years. Radionuclide levels for strontium-90, cesium-137, plutonium-239/240, and uranium-238 were greater than those measured off the Hanford Site in 2004.

Twenty-three locations were sampled in the 200-West Area in 2006. Values reported in 2006 for most radionuclides were comparable to historical ranges. One sample collected near the 216-U-10 pond showed high concentrations of plutonium-238 and plutonium-239/240. Measured concentrations of strontium-90, cesium-137, plutonium-238, plutonium-239/240, and uranium-238 were greater than those measured at distant communities.

Vegetation samples were collected from 15 locations in the 300 Area. Concentrations of uranium-234 and uranium-238 were somewhat lower than historical data and higher than those measured in the 100 and 200 Areas. Additionally, the average values reported for uranium-234 and uranium-238 in the 300 Area were higher than the maximum site-wide value reported by the Pacific Northwest National Laboratory for the 2004 vegetation samples (see Section 8.10.3 in PNNL-15222). The higher uranium levels were expected due to uranium releases to the environment during past fuel-fabrication operations in the 300 Area.

A single vegetation sample is collected annually from the 400 Area. In 2006, only plutonium-239/240 and uranium-238 were detected and the concentrations were within the ranges of historical data.

A total of 16 vegetation samples were collected from the 600 Area, which consists of locations on the 200 Areas plateau surrounding the 200-East and 200-West Areas. The 2006 results were similar to historical levels and greater than those measured off the Hanford Site in 2004.

10.10.2.3 Investigations of Radioactive Contamination in Vegetation Near Hanford Site Facilities and Operations

S. M. McKinney and R. C. Roos

Investigations for radioactive contamination in vegetation were conducted in and near operational areas to monitor the presence or movement of radioactive materials around areas of known or suspected contamination or to verify

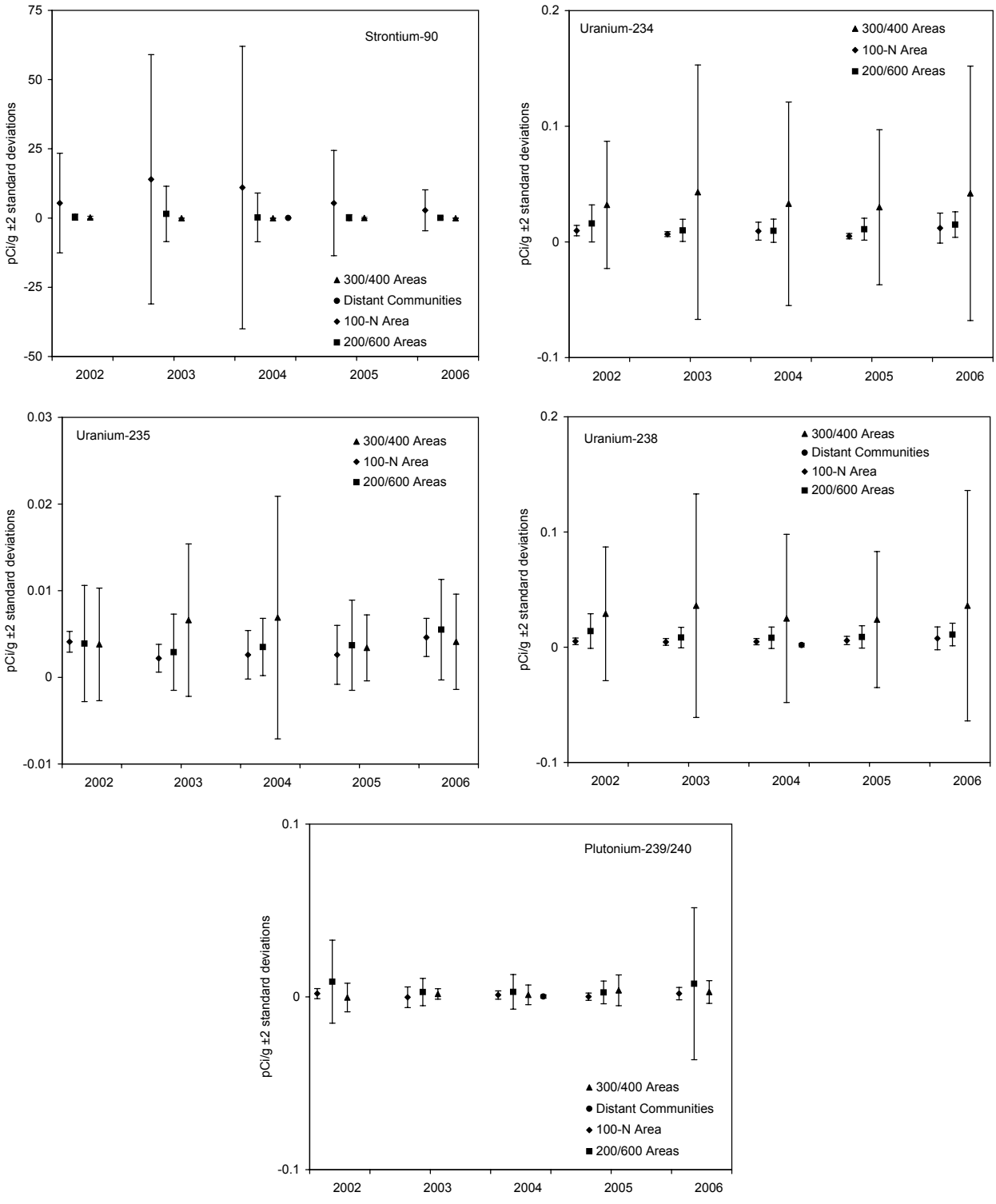


Figure 10.10.2. Average Concentrations of Selected Radionuclides in Vegetation Samples Collected Near Hanford Site Facilities and Operations Compared to Those Collected in Distant Communities, 2002 Through 2006. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

Table 10.10.3. Concentrations of Selected Radionuclides (pCi/g dry wt.)[a] in Near-Facility Vegetation Samples, 2006 Compared to Previous Years

		2006				2001-2005			
		Number of				Number of			
Radionuclide	Hanford Area	Samples	Detections[b]	Average[c]	Maximum[d]	Samples	Detections[b]	Average[c]	Maximum[d]
Cobalt-60	100-N	4	0	0.0020 ± 0.042	0.025 ± 0.053	27	8	0.18 ± 1.4	3.8 ± 0.33
	200-East	10	0	-0.023 ± 0.085	0.029 ± 0.077	47	0	0.0039 ± 0.059	0.098 ± 0.24
	200-West	23	0	0.0073 ± 0.075	0.10 ± 0.11	116	1	0.0095 ± 0.14	0.72 ± 3.1
	300	15	0	-0.049 ± 0.30	0.032 ± 0.041	67	0	-0.0011 ± 0.034	0.041 ± 0.044
	400	1	0	0.0083 ± 0.0	-0.0083 ± 0.045	4	0	-0.0028 ± 0.011	0.0051 ± 0.019
	600	16	0	-0.014 ± 0.20	0.060 ± 0.075	78	0	0.0028 ± 0.048	0.095 ± 0.077
Cesium-137	100-N	4	0	0.018 ± 0.064	0.046 ± 0.050	27	7	0.095 ± 0.35	0.71 ± 0.16
	200-East	10	4	0.031 ± 0.15	0.16 ± 0.066	47	15	0.076 ± 0.27	0.80 ± 0.30
	200-West	23	0	0.012 ± 0.095	0.10 ± 0.11	116	44	0.16 ± 1.3	6.0 ± 4.3
	300	15	0	-0.086 ± 0.58	0.072 ± 0.085	67	1	-0.00072 ± 0.041	0.053 ± 0.045
	400	1	0	-0.022 ± 0.0	-0.022 ± 0.043	4	0	-0.0015 ± 0.022	0.0088 ± 0.020
	600	16	1	0.14 ± 0.84	1.7 ± 2.2	78	13	0.035 ± 0.14	0.44 ± 0.10
Plutonium-238	100-N	4	0	0.0047 ± 0.014	0.012 ± 0.024	27	0	0.0016 ± 0.017	0.018 ± 0.015
	200-East	10	0	0.00033 ± 0.015	0.011 ± 0.019	47	1	-0.00034 ± 0.017	0.016 ± 0.010
	200-West	23	1	0.0039 ± 0.029	0.064 ± 0.029	116	2	0.00040 ± 0.015	0.020 ± 0.016
	300	15	1	0.0037 ± 0.018	0.026 ± 0.016	67	2	0.0029 ± 0.017	0.050 ± 0.017
	400	1	0	0.0023 ± 0.0	0.0023 ± 0.0041	4	0	0.0023 ± 0.0068	0.0051 ± 0.015
	600	16	0	0.0029 ± 0.016	0.020 ± 0.017	78	1	0.0017 ± 0.018	0.026 ± 0.016
Plutonium-239/240	100-N	4	0	0.0019 ± 0.0036	0.0035 ± 0.0042	27	4	0.0040 ± 0.021	0.055 ± 0.018
	200-East	10	1	0.00067 ± 0.0058	0.0054 ± 0.0050	47	4	0.0019 ± 0.0057	0.0091 ± 0.0062
	200-West	23	8	0.015 ± 0.061	0.15 ± 0.045	116	45	0.0087 ± 0.025	0.10 ± 0.027
	300	15	1	0.0023 ± 0.0057	0.0082 ± 0.0055	67	7	0.0018 ± 0.0070	0.016 ± 0.010
	400	1	1	0.0098 ± 0.0	0.0098 ± 0.0063	4	0	0.00048 ± 0.0017	0.0012 ± 0.0024
	600	16	0	0.0011 ± 0.0038	0.0042 ± 0.0059	78	17	0.0046 ± 0.018	0.052 ± 0.017
Strontium-90	100-N	4	2	2.8 ± 7.4	9.0 ± 1.4	27	16	7.1 ± 33.0	68.0 ± 8.2
	200-East	10	2	0.16 ± 0.77	1.3 ± 0.26	47	24	0.78 ± 3.9	12.0 ± 1.8
	200-West	23	1	0.037 ± 0.30	0.36 ± 0.13	116	43	0.62 ± 8.6	25.0 ± 3.8
	300	15	0	-0.049 ± 0.13	0.12 ± 0.14	67	17	0.058 ± 0.42	0.88 ± 0.18
	400	1	0	-0.031 ± 0.0	-0.031 ± 0.11	4	1	0.088 ± 0.19	0.17 ± 0.14
	600	16	3	0.084 ± 0.30	0.56 ± 0.17	78	22	0.25 ± 1.4	4.8 ± 0.72

Table 10.10.3. (contd)

Radionuclide	Hanford Area	2006 Number of Samples	2006 Number of Detections[b]	2006 Average[c]	2006 Maximum[d]	2001-2005 Number of Samples	2001-2005 Number of Detections[b]	2001-2005 Average[c]	2001-2005 Maximum[d]
Uranium-234	100-N	4	2	0.012 ± 0.013	0.021 ± 0.011	27	16	0.0081 ± 0.0068	0.016 ± 0.085
	200-East	10	10	0.020 ± 0.0077	0.026 ± 0.012	47	36	0.011 ± 0.0089	0.022 ± 0.011
	200-West	23	20	0.015 ± 0.010	0.026 ± 0.012	116	96	0.015 ± 0.017	0.054 ± 0.017
	300	15	15	0.044 ± 0.12	0.24 ± 0.067	67	64	0.052 ± 0.19	0.54 ± 0.11
	400	1	0	0.0069 ± 0.0	0.0069 ± 0.0068	4	3	0.011 ± 0.0070	0.016 ± 0.0083
	600	16	15	0.014 ± 0.011	0.028 ± 0.013	78	60	0.012 ± 0.014	0.036 ± 0.013
Uranium-235	100-N	4	2	0.0046 ± 0.0022	0.0061 ± 0.0052	27	2	0.0029 ± 0.0035	0.0077 ± 0.0073
	200-East	10	7	0.0070 ± 0.0073	0.016 ± 0.0093	47	5	0.0027 ± 0.0041	0.0071 ± 0.0070
	200-West	23	10	0.0047 ± 0.0040	0.0088 ± 0.0063	116	27	0.0036 ± 0.0045	0.015 ± 0.0078
	300	15	3	0.0042 ± 0.0056	0.0099 ± 0.0069	67	28	0.0060 ± 0.012	0.033 ± 0.013
	400	1	0	0.0021 ± 0.0	0.0021 ± 0.0029	4	1	0.0027 ± 0.0027	0.0043 ± 0.0039
	600	16	5	0.0057 ± 0.0061	0.012 ± 0.0076	78	18	0.0038 ± 0.0060	0.013 ± 0.0084
Uranium-238	100-N	4	2	0.0077 ± 0.0099	0.014 ± 0.0081	27	14	0.0052 ± 0.0050	0.013 ± 0.0071
	200-East	10	9	0.013 ± 0.0092	0.023 ± 0.011	47	33	0.0097 ± 0.010	0.024 ± 0.011
	200-West	23	17	0.0097 ± 0.011	0.021 ± 0.010	116	104	0.013 ± 0.016	0.048 ± 0.016
	300	15	13	0.037 ± 0.10	0.21 ± 0.059	67	59	0.047 ± 0.19	0.57 ± 0.11
	400	1	1	0.0098 ± 0.0	0.0098 ± 0.0067	4	4	0.0061 ± 0.0044	0.0090 ± 0.0057
	600	16	13	0.010 ± 0.0075	0.018 ± 0.010	78	55	0.0094 ± 0.012	0.025 ± 0.012

(a) 1 pCi = 0.037 Bq.
(b) Number of samples with measurable concentrations of contaminants.
(c) Average ± two standard deviations.
(d) Maximum ± analytical uncertainty.

radiological conditions at specific project sites. All samples collected during investigations were field surveyed for alpha and beta/gamma radiation.

During 2006, radiological contamination was found in 75 vegetation samples collected during investigations. Seventy-four samples were tumbleweeds (Russian thistle) or tumbleweed fragments, and one sample was listed as moss. None of the samples were analyzed for specific radionuclides and were disposed of onsite in burial grounds.

The number and general locations of vegetation contamination incidents investigated during 2006 are summarized in Table 10.10.4. The numbers of contamination incidents investigated in 2006 and during the previous 9 years are provided in Table 10.10.5. A discussion of vegetation control efforts at the Hanford Site during 2006 is provided in Section 10.10.4.

Table 10.10.4. Number of Vegetation Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 2006

Location	Number of Incidents
200-East Area	
tank farms	30
burial grounds	8
cribs, ponds, and ditches	3
fence lines	6
roads and railroads	1
unplanned release sites	2
underground pipelines	3
miscellaneous	2
200-West Area	
tank farms	5
burial grounds	1
cribs, ponds, and ditches	7
fence lines	0
roads and railroads	0
unplanned release sites	2
underground pipelines	0
miscellaneous	0
Cross-site transfer line	0
200-BC cribs and trenches	2
200-North Area	0
100 Areas	3
300 Area	0
400 Area	0
600 Area	0
Former 1100 Area	0
Total	**75**

Table 10.10.5. Annual Number of Vegetation Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 1997 Through 2006

Year	Number of Incidents	Year	Number of Incidents
1997	46	2002	16
1998	51	2003	32
1999	85	2004	60
2000	66	2005	66
2001	31	2006	75

10.10.3 Vegetation Monitoring at Hanford Site-Wide and Offsite Locations

B. G. Fritz

Monitoring of rabbitbrush and sagebrush leaves and stems provides information on atmospheric deposition of radioactive materials in uncultivated areas and at site-wide locations that could potentially be affected by contaminants from Hanford Site operations. Vegetation samples have been collected from and around the Hanford Site for more than 50 years. Data from these samples are maintained in a database to document onsite and offsite levels of manmade radionuclides in vegetation at specific locations. This database holds baseline data against which data from unplanned contaminant releases from the Hanford Site can be compared. Collection of vegetation samples at site-wide and offsite locations was last conducted in 2004 (Section 8.10 in PNNL-15222) and is scheduled to be done again in 2009.

10.10.4 Vegetation Control Activities

A. R. Johnson, R. C. Roos, J. G. Caudill, J. M. Rodriguez, and R. A. Schieffer

Vegetation control at the Hanford Site consists of cleaning up contaminated plants that can be a threat to workers or the public (i.e., either safety, health, or radiation protection), controlling or preventing the growth or re-growth of plants in contaminated or potentially contaminated areas on the site, and monitoring and removing unwanted (noxious) plant species.

10.10.4.1 Waste Site Remediation and Revegetation During 2006

Small sites with recurring radioactive contamination events caused by deep-rooted vegetation or burrowing animals were covered with Biobarrier® to prevent further invasion by biota.[(a)] Biobarrier® is an engineered fabric impregnated with herbicide used to stop root penetration and serve as a physical barrier to burrowing insects. It was installed at four sites in 2006 that totaled approximately 1,100 square meters (approximately 10,000 square feet). Tests at the Hanford Site have shown this barrier is effective in preventing the spread of contamination. This brings the total number of sites at Hanford covered with Biobarrier® since 1999 to 36, with a total area of approximately 14,000 square meters (140,000 square feet).

Larger areas, including entire waste sites, were reseeded with bunchgrass to inhibit the growth of deep-rooted vegetation (e.g., tumbleweed). There were approximately 280 hectares (770 acres) overseeded with bunchgrass seed in 2006, including the 200-BC Cribs Area; 216-A-30, 216-A-37-1, 216-A-37-2, 216-A-42, and 216-A-8 cribs; and 216-B-3 Pond.

10.10.4.2 Noxious Weed Control

Noxious weeds are controlled on the Hanford Site (between State Highway 240 and the Columbia River and along the paved road to the top of Rattlesnake Mountain) to prevent their spread and eliminate populations. A noxious weed is a legal and administrative category designated by federal or state regulatory agencies (e.g., U.S. Department of Agriculture or Washington State Department of Agriculture). Noxious weeds are non-native, aggressively invasive, and hard to control. Noxious weeds alter native plant communities and degrade ecosystems unless control measures are taken. Control measures can be mechanical, chemical, cultural, or biological; approximately 3,000 hectares (8,000 acres) on the Hanford Site were so treated in 2006.

Ten plant species are on a high-priority list for control at the Hanford Site. These species are described in the following paragraphs along with a summary of 2006 control activities.

Yellow Starthistle (*Centaurea solstitialis*). Yellow starthistle represents the most rapidly expanding weed infestation in the western United States. Since 1995, yellow starthistle has been the highest priority weed for the Hanford Site noxious-weed control program because starthistle has the potential to invade the entire site, and have a dramatic impact on the ecology of the site and neighboring lands.

Control measures for starthistle have included spot treatments and broadcast herbicide applications by ground equipment and aerial sprayers, biological control, and hand-weeding in critical locations. Major populations near the Hanford town site have been reduced to scattered individual plants, mostly near live trees where aerial herbicide applications were not made. In 2006, approximately 405 hectares (1,000 acres) were treated for yellow starthistle infestation south of the Hanford town site, both on the east and west side of Route 2 South.

Yellow starthistle seeds are known to remain viable for 10 years in the soil. The small number of seedlings that are found over much of the area of infestation indicates that the seed bank is being exhausted. Careful control efforts over the next few years should see yellow starthistle on the Hanford Site changed from a major infestation to a monitoring and eradication effort.

Biological control agents for yellow starthistle are widely distributed across the infested area. They have been highly effective during the early part of the flowering season. However, the adult phase of the control agent's annual life cycle is completed before the end of the flowering season. Consequently, flowers opening late in the season are largely spared the effects of insect predation.

Rush Skeletonweed (*Chondrilla juncea*). Rush skeletonweed is scattered over large areas on the Hanford Site. Areas of dense rush skeletonweed infestation have largely been eliminated. Nevertheless, considerable rush skeletonweed remains as scattered individual plants. Populations of rush skeletonweed have increased on some areas burned in the 24 Command Wildland Fire in June 2000.

In 2006, control of rush skeletonweed focused on individuals scattered from the Volpentest Hazardous Materials

(a) Biobarrier is a registered trademark of Fiberweb plc, Old Hickory, Tennessee.

Management and Emergency Response (HAMMER) Training and Education Center, north to the 400 Area. Over 1,214 hectares (3,000) acres were treated to remove an infestation that was becoming dense in many areas.

The deep and extensive root system of rush skeletonweed makes it very difficult to eliminate. The area north of the HAMMER facility has been treated with herbicides in the past, and will continue to be monitored for sprouts emerging from roots remaining in the ground. It is expected that additional aerial applications will be needed to reduce the population of rush skeletonweed to the level that ground applications will be able to control the infestation.

Biological control agents are commonly found in rush skeletonweed on the Hanford Site. However, they have not significantly reduced plant populations.

Medusahead (*Taeniatherum asperum*). No plants of medusahead were discovered in 2006. The Hanford Site will continue to be monitored for several years to assure that the seed bank has been eradicated.

Babysbreath (*Gypsophila paniculata*). Efforts to control babysbreath in 2006 concentrated on the main infestation (about 30 hectares [75 acres]) at the Hanford town site. Babysbreath is resistant to control by herbicides; however, the aboveground portion of the plant can be killed by some herbicides. Using these herbicides, flowering and population growth can be prevented. It is hoped these plants will ultimately be eradicated by continually removing the top portions through herbicide use.

Dalmatian Toadflax (*Linaria genistifolia ssp. Dalmatica*). Control of dalmatian toadflax focused on a small population at the 100-B/C Area. The species at the Hanford Site has yielded to previous control efforts. Few plants continue to sprout. Sprouts and seedlings of the long-lived perennial plant will be eliminated as they are identified. No biological controls have been released at the Hanford Site for dalmatian toadflax.

Spotted Knapweed (*Centaurea maculosa*). Spotted knapweed at the Hanford Site has been controlled so that sprouts or seedlings are rare. Only two sprouts or seedlings were found in 2006. The site will continue to be monitored for several years to be sure that viable seeds and roots have been eliminated from the soil. Cooperative efforts with neighboring landowners continue to eliminate spotted knapweed near the Hanford Site. No biological controls have been released specifically for spotted knapweed. Most biological controls for diffuse knapweed are also effective for spotted knapweed.

Diffuse Knapweed (*Centaurea diffusa*). Aerial applications for control of diffuse knapweed have been effective in the past. Spot treatment of scattered individuals continues. The population of diffuse knapweed near the high-water mark of the Columbia River has not actively been controlled by herbicides due to the biological sensitivity of the area. Biological controls are established and monitored to observe their effectiveness in controlling the weed.

Russian Knapweed (*Acroptilon repens*). Biological controls for Russian knapweed are limited, and their success has been poor in the arid climate of the Hanford Site. Chemicals and other control techniques are being developed that promise to be effective with this difficult-to-control species.

Saltcedar (*Tamarix spp.*). Several individual plants of saltcedar are found on the Hanford Site. Most are remaining from ornamental plantings near homes in the early part of the previous century. A few populations are the result of natural seed dispersal. Most individual plants south and west of the Columbia River have been eliminated. Those remaining alive continue to be treated with herbicide and will be monitored until they are eradicated.

Purple Loosestrife (*Lythrum salicaria*). The Columbia River riverbank and islands on the Hanford Site are monitored for purple loosestrife. Populations are found on many islands and along the north and east bank of the river. Individual plants are found along the south and west bank of the river. Limited treatment took place in 2006. Herbicide applications using backpack sprayers are planned for the 2007 season if changing herbicide regulations allow such applications.

Under good ecological conditions, biological controls are effective for eradicating purple loosestrife; however, rapidly fluctuating water levels along the Columbia River kill the control organisms that overwinter on the ground in the weed populations. Winter mortality prevents an effective population of control agents from developing. Hanford Site officials are working with neighboring land managers along the Columbia River to identify effective controls for purple loosestrife along the Hanford Reach.

10.11 Fish and Wildlife Monitoring

The following sections summarize wildlife-related monitoring activities conducted on and around the Hanford Site in 2006. The sections include discussions on the following:

- Surveys and monitoring of Hanford Site animal populations
- Selected species that occur at the site and are protected by state and federal laws and regulations
- Results of activities to measure levels of site-produced contaminants in fish and wildlife tissues
- Activities to manage organisms that might affect workers or have become radiologically contaminated.

Wildlife populations at the Hanford Site are monitored to assess the abundance, condition, and distribution of populations of selected species. Data collection and analyses are integrated with contaminant-monitoring activities, and analytical results may be used to help characterize potential risks or impact to biota. Results may also be used to support objectives for completing Hanford Site's waste management and environmental restoration missions. Information on threatened, endangered, and sensitive wildlife species is collected so the DOE can determine site compliance with requirements of applicable state and federal laws and regulations.

This section provides current information on ecological monitoring of key animal species and populations found on the Hanford Site as well as results of contaminant monitoring. Population monitoring (Section 10.11.1) focuses on species of interest, including fish and wildlife potentially hunted offsite and used for food, as well as special-status species listed by Washington State or the U.S. Fish and Wildlife Service as threatened or endangered. Habitat and species characterization activities (Section 10.11.2) target the near-shore and riparian areas along the Columbia River. These habitats are important because of the potential for exposure to groundwater contaminants that are intersecting the Columbia River. A third area of interest includes ecological and contaminant monitoring of animal and plant populations on 35 long-term monitoring plots (Section 10.11.3) spread across the Hanford Site. Data collected from surveys of these plots are used to evaluate both spatial and temporal site-wide population trends.

Fish and wildlife that inhabit the Columbia River and Hanford Site are routinely monitored for contaminants (Section 10.11.4) because they could potentially be exposed to site-produced materials and be adversely affected; subsequently, contaminated animals could be harvested and consumed by the public.

When discovered, pest organisms are removed and disposed of to eliminate possible impacts to worker safety and health and to control the spread of radioactive contamination (Section 10.11.5).

For further information about these monitoring and pest control activities and the programs that support them, see Section 10.0 of this report or DOE/RL-91-50, Rev. 3.

10.11.1 Population Monitoring

Four fish and wildlife species on the Hanford Site are monitored annually by the Ecological Monitoring and Compliance Project: fall Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), bald eagles (*Haliaeetus leucocephalus*), and mule deer (*Odocoileus hemionus*). These species are of special interest to the public and to stakeholders. Monitoring consists of estimating

numbers of fall Chinook salmon redds, surveying for steelhead redds, assessing bald eagle nesting, and conducting an inventory of mule deer. The species are monitored to assess abundance, condition, and distribution. All have the potential to be impacted by Hanford Site operations and yearly monitoring provides baseline data for ecological assessments.

10.11.1.1 Chinook Salmon

R. P. Mueller

Chinook salmon are an important resource in the Pacific Northwest; they are caught commercially and for recreation. Salmon are also of cultural importance to local Native American tribes. Today, the most important natural spawning area in the mainstem Columbia River for the fall Chinook salmon is found in the Hanford Reach (Dauble and Watson 1997). In the early years of the Hanford Site, only a few spawning nests (redds) were found in the Hanford Reach. Between 1943 and 1973, several dams were constructed on the Columbia River and the formation of reservoirs behind these dams eliminated most mainstem spawning areas. These changes resulted 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 increased number of salmon redds found in the Hanford Reach.

The number of fall Chinook salmon redds in the Hanford Reach is estimated by aerial surveys. Over the years, the number of redds has increased from less than 500 in the early 1950s to nearly 8,800 in 1989 (Figure 10.11.1). In the early 1990s, redd estimates declined to approximately one-third of the 1989 peak. The number of redds peaked again in 1996 and 1997 and then declined before starting to rise again in 2001. This trend continued though 2003 when an estimated 9,400 redds were counted, which was the highest count since monitoring began in 1948.

The peak redd count for fall Chinook salmon in the Hanford Reach during the fall of 2006 was estimated at 6,190 (Figure 10.11.1). This count was lower than the 2005 count of 7,891 and below the 5-year average for 2001 to 2005 of 8,023. The main spawning areas were located similarly to those observed last year and in the following order of abundance; Vernita Bar (Area 10), Locke Island complex (Areas 4 and 5), Islands 8-10 (Areas 2 and 3), Island 2

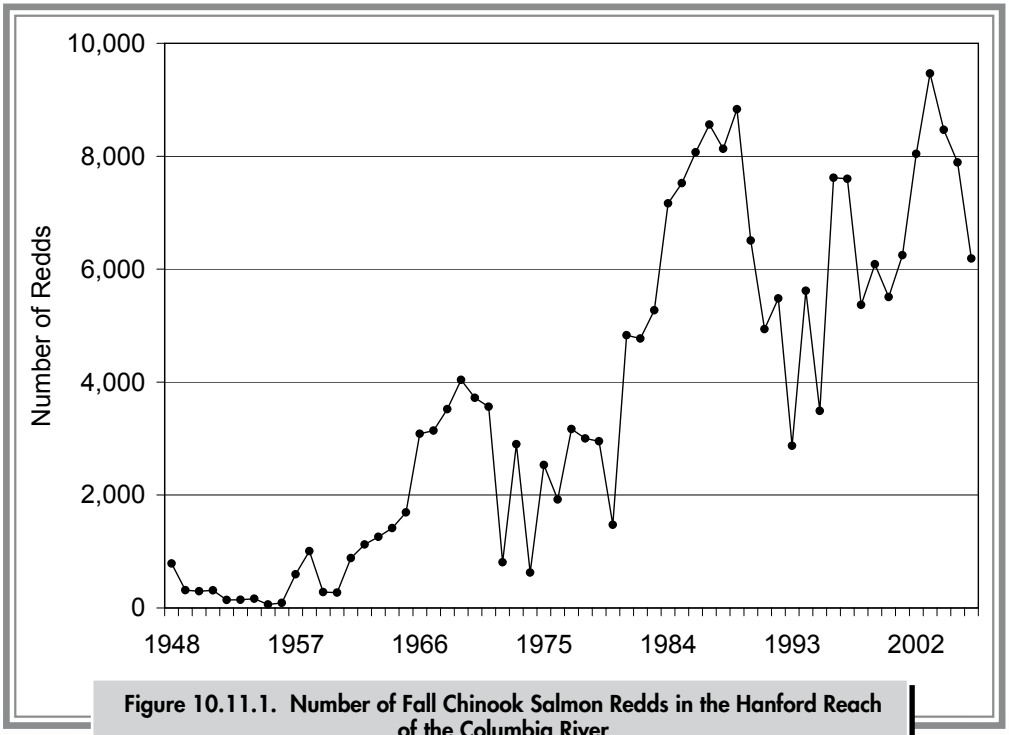


Figure 10.11.1. Number of Fall Chinook Salmon Redds in the Hanford Reach of the Columbia River

(Area 7), and the Ringold Area (Area 1) (Figure 10.11.2). The general locations of the spawning areas have not changed significantly over the past few years.

Aerial surveys do not yield absolute salmon redd counts because environmental conditions such as water depth, water turbidity, and sun angle vary. In addition, the number of redds in high-density locations cannot be counted with absolute accuracy while flying. However, redd survey data are highly correlated with adult salmon escapement estimates (that portion of the fish population that survives natural mortality and harvest to reach the spawning grounds) obtained by state and federal agencies within the Columbia River Basin by using an expansion factor (1 redd = 7 to 8 adult fish) (for additional information, see the website at http://www.streamnet.org/).

10.11.1.2 Steelhead

R. P. Mueller

Steelhead within the Hanford Reach are considered part of the upper Columbia River Evolutionarily Significant Unit, and are listed as endangered under the *Endangered Species Act*. In March 2006, one aerial survey was conducted along the Columbia River from north Richland to the Vernita Bridge. During the survey, one possible region of disturbance near Locke Island (north of Area 4, Figure 10.11.2) was observed to have characteristics indicative of steelhead spawning. A follow-up survey was conducted in this region on March 28, 2006, and the possible spawning redds were visually inspected from a boat. Based on this inspection, the disturbed areas were not believed to be steelhead redds.

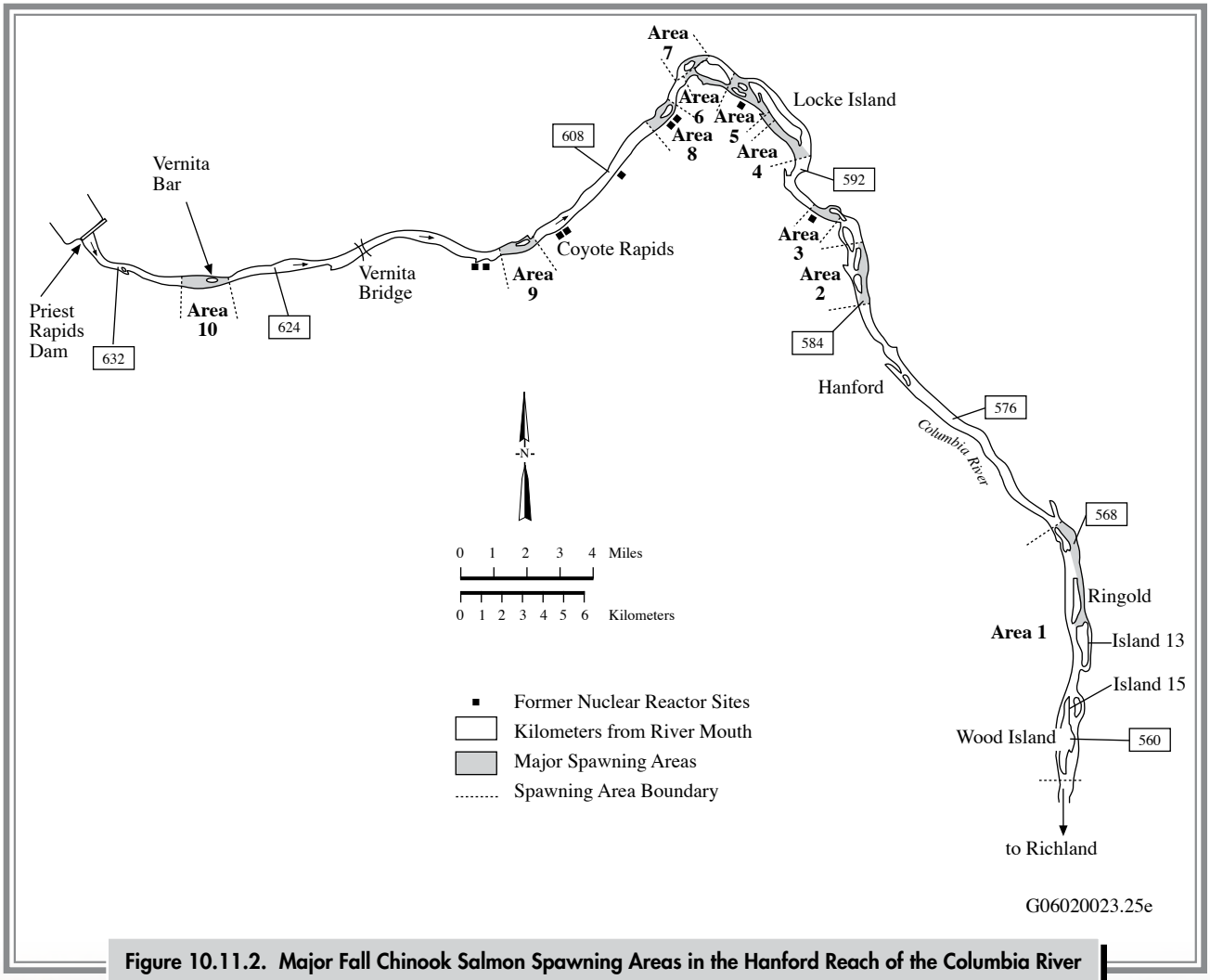


Figure 10.11.2. Major Fall Chinook Salmon Spawning Areas in the Hanford Reach of the Columbia River

An excavation of one of the areas also did not produce any evidence of fish eggs. No other areas within the survey area were identified as having characteristics associated with steelhead redds.

10.11.1.3 Bald Eagle Protection

R. E. Durham and M. R. Sackschewsky

Bald eagles have wintered along the Hanford Reach for many years. In accordance with the DOE's *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (DOE/RL-94-150, Rev. 0), annual protective measures have been put in place from November 15 through March 15 since 1994. While these dates generally encompass the arrival and departure times of wintering bald eagles, nest-tending activities and territorial displays have been observed as early as October with nest occupancy continuing as late as August. Current protective measures include limited-access road closures within 800 meters (875 yards) of major perching and roost sites, or within 400 meters (437 yards) when road access to these sites is out of line-of-sight. Nest-site protection is achieved with a no-access area closure not less than 800 meters (875 yards) surrounding the nest. Nest-area closures are not subject to the same time constraints described above but remain in effect until nest-site abandonment has been confirmed.

A pair of adult bald eagles returned during November 2006 to occupy the historical nest site in the vicinity of the former White Bluffs town site. As of March 15, 2007, bald eagles were still being observed at the town site; however, it was determined the historical nest site was no longer occupied by the bald eagle pair.

Primary causes of eagle nest abandonment may include 1) adverse weather, 2) food availability, 3) human activity near the nest site, and 4) avian predator interactions (such as hazing and harassment by magpies and ravens). The causes of eagle nest abandonment along the Hanford Reach have not been determined.

10.11.1.4 Bald Eagle Roosting Surveys

C. A. Duberstein

Four historical night-roosting sites are delineated in the *Hanford Site Biological Resources Management Plan* (DOE/RL-94-150, Rev. 0; DOE/RL-96-32, Rev. 0). These sites (management zones) include one location adjacent to the 100-K Area, two locations upstream of the 100-H Area, and one location north of the Hanford town site (Figure 10.11.3). These sites were selected based on data collected in the early 1990s. Since then, roost trees have been lost through fire, wind damage, and old age. Surveys were conducted in early 2007 to reevaluate the current distribution of night roosts and assess rates of roost use (number of eagles, frequency of use) along the Hanford Reach shoreline from the Vernita Bridge downstream to the 300 Area. Observers conducted visual observations at all historical roost locations within the current management restrictions, as well as at additional suspected roost sites. The surveys took place within an hour of sunrise or sunset for 13 days from January 3 to February 28, 2007. Thirty-six bald eagles were observed utilizing roosts. Although many of these observations may have been the same eagle seen on subsequent visits, 13 individual eagles were counted between the 100-D and 100-H Areas during a single visit on January 3, and over half (52%) of the roost sites were occupied by at least one eagle. However, eagles were also observed using roost sites outside the management zones including roosts near Wooded Island, north of the 300 Area, within the Hanford town site, adjacent to the 100-D Area, and at the active nest site at the White Bluffs boat launch (Figure 10.11.3).

10.11.1.5 Mule Deer

K. D. Hand and J. A. Stegen

Population characteristics of mule deer on the Hanford Site have been monitored since 1994. Roadside surveys are conducted from mid-November to mid-January to assess age and sex ratios and the frequency of testicular atrophy in males. The survey route extends from near the 300 Area in the south to the 100-B/C Area in the north and is divided at the Hanford town site into northern and southern regions. Tiller and Poston (2000) found that is little overlap in the home ranges of deer occupying these two regions.

Five surveys were conducted between mid-November 2006 and early-January 2007. A combined total of 439 deer observations were made over the five repeated surveys, which included multiple observations of the same animals in some

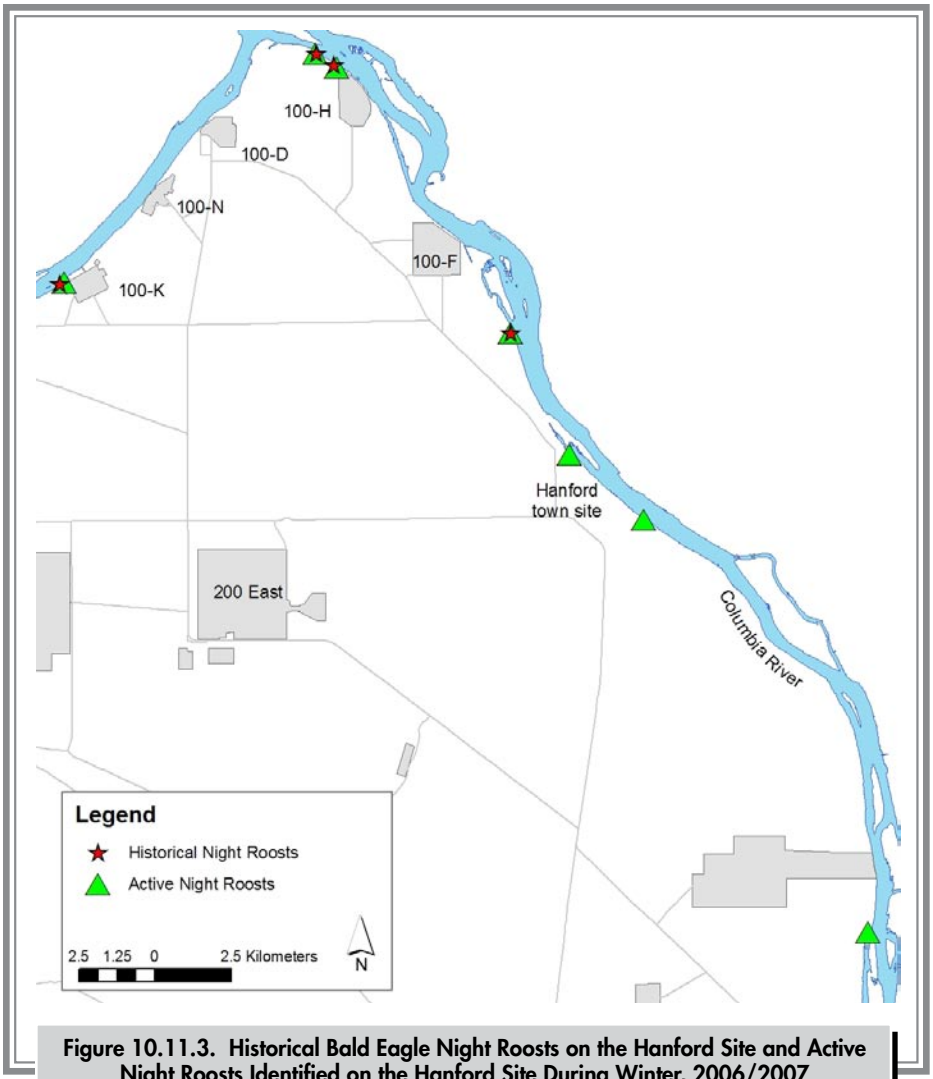


Figure 10.11.3. Historical Bald Eagle Night Roosts on the Hanford Site and Active Night Roosts Identified on the Hanford Site During Winter, 2006/2007

cases. Individual animals were identified according to sex and age class (fawn or adult). For male deer, the presence of misshapen, velvet-covered antlers was used as an indicator of testicular atrophy.

Trends in the ratios of fawns to does over time can be used to monitor changes in mule deer population size and health. Data from the 2006 to 2007 surveys show a pattern of fawn-to-doe ratios that was similar to that observed in 2003. In 2006, the northern region fawn-to-doe mean estimate was 45 fawns per 100 does while the southern region mean estimate was 47 fawns per 100 does (Figure 10.11.4). These estimates were higher than those reported for the last two years and are similar to the 2003 estimates. In 2003, the mean estimates were 47 and 56 fawns per 100 does for the northern and southern regions, respectively, while in the last 2 years, the estimates have ranged from 20 to 27 fawns per 100 does. Hanford fawn-to-doe ratios for all survey years (1994 through 2006) are weighted averages, using the total number of fawns and does seen per survey as the weighting factors.

In the early 1990s, testicular atrophy and sterility were observed in some male mule deer on the Hanford Site (Tiller et al. 1997; PNNL-11518). Extensive investigation found no relationships between the presence of testicular atrophy and contaminant levels, diet, disease, or natural conditions such as aging or genetics (Tiller et al. 1997). Testicular atrophy in male mule deer is associated with abnormal antler growth manifest as misshapen, velvet-covered antlers, which

can be observed in field surveys. The observed frequency of misshapen antlers in mule deer has ranged from a high of 17% in 1998 to a low of 0% in 2003 (Figure 10.11.5). The decrease from 1998 through 2003 was reversed in 2004 with 12.5% of the northern region and 5% of the southern region male deer affected. Data from the 2005 surveys showed a decrease with only 2.9% of observed male deer in both the northern and southern regions affected. This trend was repeated for the present surveys where only a single affected male deer was observed. However, because small sample sizes may not fully reflect population conditions, these frequency estimates need to be interpreted with caution.

10.11.2 Habitat and Species Characterizations

Another aspect of Hanford Site ecological monitoring involves characterizing habitats and associated species. This information is used to evaluate the biological resources on the Hanford Site and provide the data necessary to identify critical and priority habitats for special status species or communities, and establish mitigation criteria. These data can be integrated with contaminant monitoring data to assess potential impacts of Hanford Site contaminants to individuals and populations. Characterization work in 2006 focused on an inventory of amphibian breeding habitats. Surveys were also conducted to identify the distribution of native snails and clams along the Hanford Reach of the Columbia River. Identification of all the specimens was not completed at the time of this report.

10.11.2.1 Amphibians

J. M. Becker and B. F. Miller

Toads and frogs (anurans) may serve as key indicators of aquatic environmental health in ecological assessments (Lannoo 2005). Before 2003, relatively little information was available on anurans along the Hanford Reach of the Columbia River, so Ecological Monitoring and Compliance project staff began monitoring anurans and their potential breeding sites along the Hanford Reach. In 2006, call surveys to listen for all toad and frog breeding vocalizations were conducted from February through September at ephemeral pools, sloughs, and riverside locations along the Benton County shoreline of the Hanford Site (Figure 10.11.6).

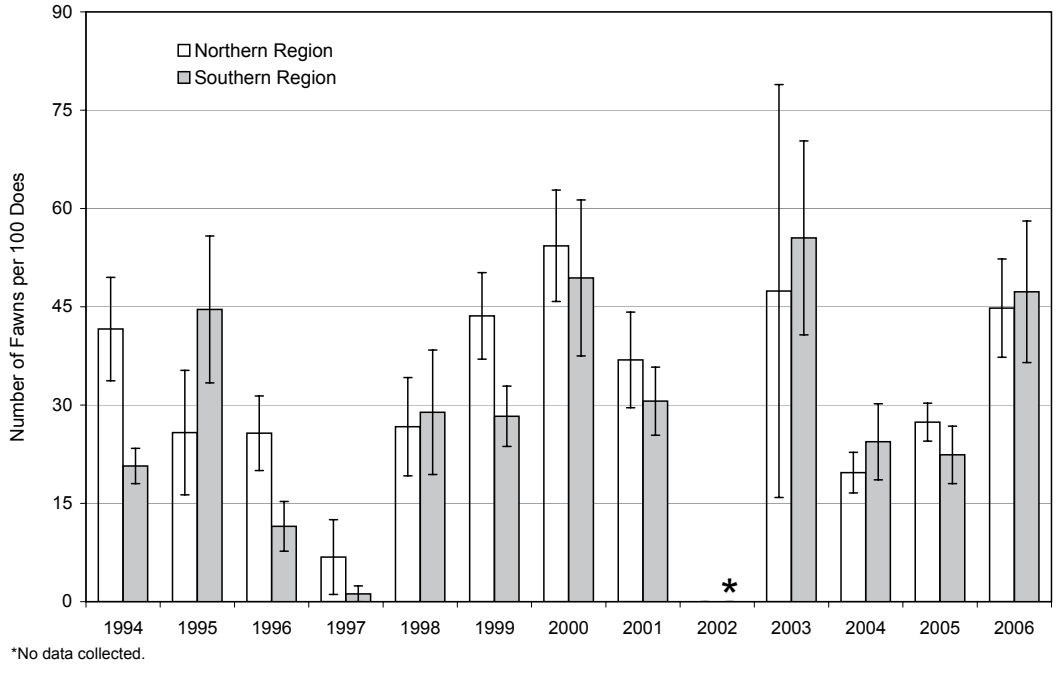


Figure 10.11.4. Estimates of the Number of Fawns per 100 Mule Deer Does in the Post-Hunting Period (Winter) on the Hanford Site from 1994 Through 2006 (mean ±1 standard error)

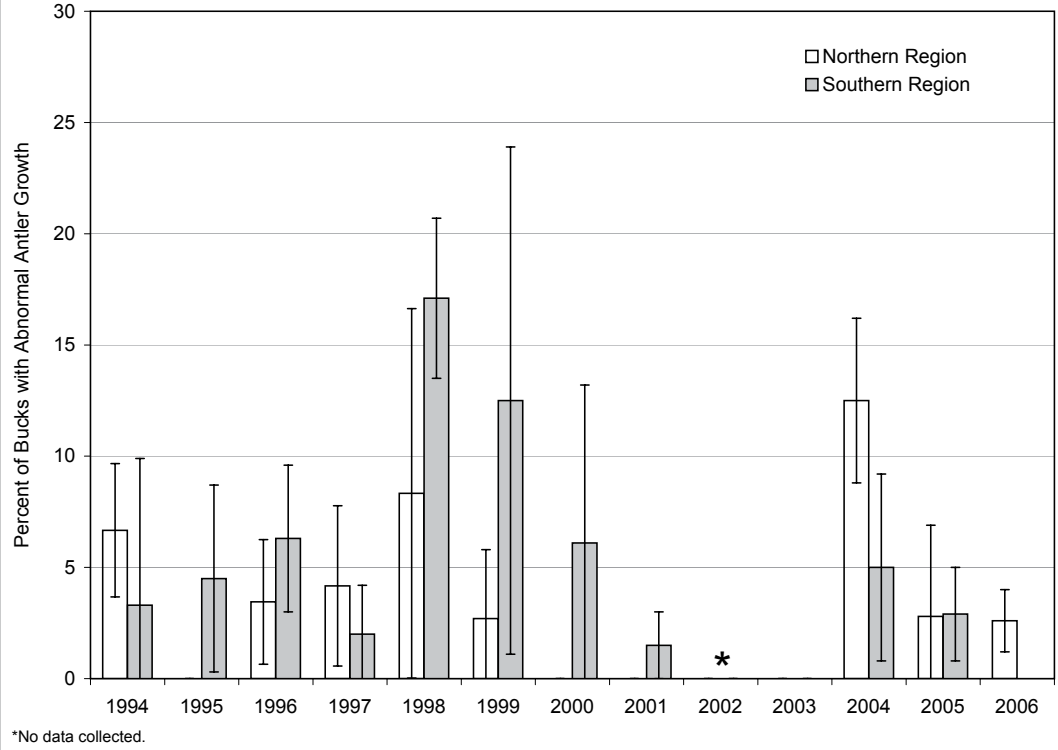


Figure 10.11.5 Percent of Male Mule Deer on the Hanford Site from 1994 Through 2006 Showing Signs of Abnormal Antler Growth (mean ±1 standard error)

Surveys in previous years were conducted to document tadpoles in available slow-water habitats and along the Hanford Reach. Surveys for tadpoles in available habitat and limited call surveys were conducted during May, June, and July.

The purpose of conducting call surveys in 2006 was to provide estimates of the relative abundance of the species using the Columbia River shoreline, characterize use of the shoreline environment, and identify species-specific breeding chronologies. Call survey information was compared to Hanford Site Meteorological Station precipitation and temperature data, and U.S. Army Corps of Engineers daily river-flow data below Priest Rapids Dam to evaluate whether weather and river flow affect breeding patterns. Tadpole survey data from 2003 through 2006 were combined with U.S. Army Corps of Engineers flow data and inundation thresholds (the flow at which an ephemeral pool begins to fill with river water due to overland flow) to describe the implications of changing river flows on tadpole survival.

In 2006, anurans were heard calling at 8 of the 11 ephemeral pools, 3 of the 5 sloughs, and 1 of the 5 riverside locations (Table 10.11.1). The Great Basin spadefoot (*Spea intermontana*) and Woodhouse's toad (*Bufo woodhousii*) were the most abundant species comprising 44% and 42%, respectively, of the 1,301 total recorded individuals. The bullfrog (*Rana catesbeiana*) was the least abundant, represented by 14% of the calls. Bullfrogs called almost exclusively at the four pools with the largest concentrations of Great Basin spadefoot and Woodhouse's toads (Table 10.11.1). Sixty-nine percent of bullfrogs called at two of the four pools that contain water year-round and thus permit completion of the 2-year requirement for metamorphosis in this species. The bullfrog's breeding period followed that of the Great Basin spadefoot and Woodhouse's toad by 2 to 4 weeks. The collocation of bullfrogs with the Great Basin spadefoot and Woodhouse's toad and juxtaposition of breeding periods may facilitate opportunistic feeding of bullfrogs on toad larvae.

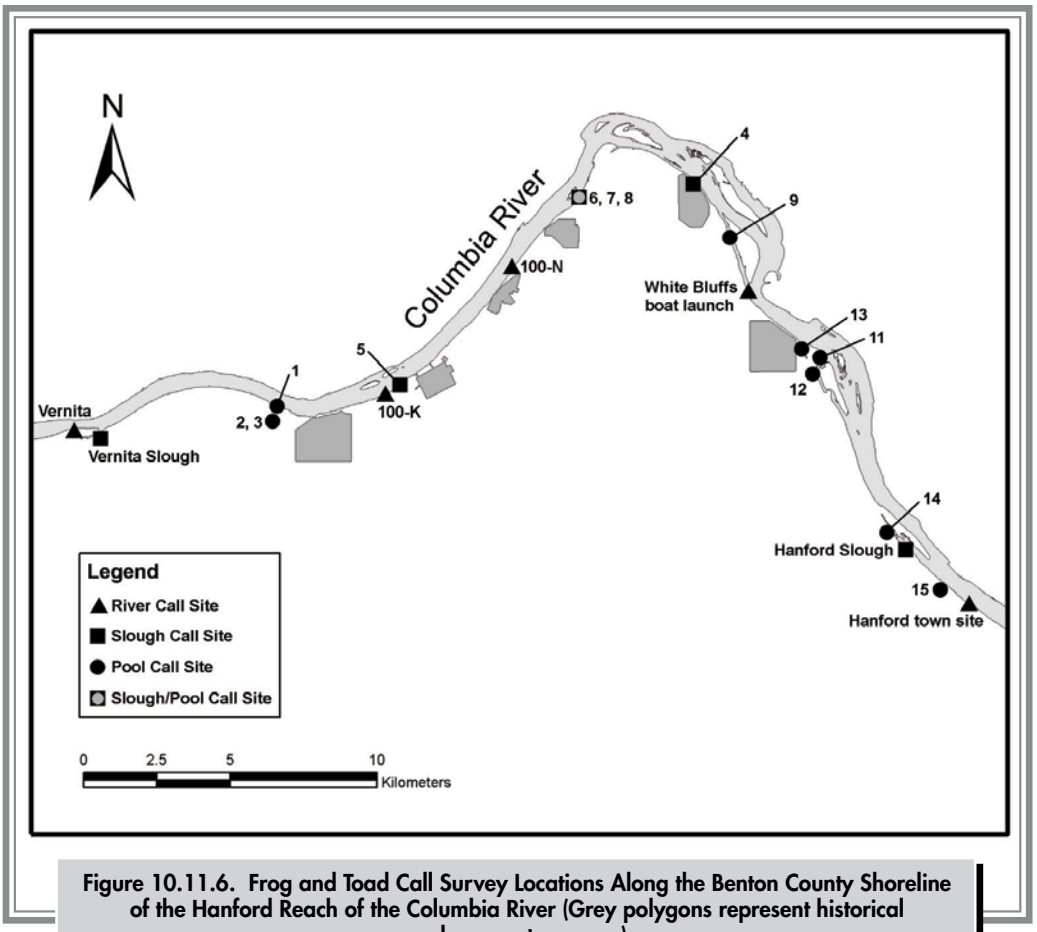


Figure 10.11.6. Frog and Toad Call Survey Locations Along the Benton County Shoreline of the Hanford Reach of the Columbia River (Grey polygons represent historical nuclear reactor areas.)

Peak Columbia River flows, mostly at or above 5,663 cubic meters (200,000 cubic feet) per second, were strongly correlated with the onset of chorusing and the timing of subsequent peak chorusing events in all three species. Precipitation and air temperature, however, did not appear to be related to the timing of breeding. Forty percent of all calling anurans used one pool (#13) that became inundated at the highest flows. There was successful reproduction in this pool in 2003 and 2006, but reproduction failed in 2004 and 2005 due to inundation that was either delayed until too late in the breeding season or was too infrequent. The timing, distribution, and success of anuran reproduction in this regulated river environment depends upon several factors including the dynamic process of pool creation and duration, which is subject to the amount and frequency of water released upstream at Priest Rapids Dam.

10.11.2.2 Mollusks

R. P. Mueller

Mollusks were collected in August 2006 at three Columbia River shoreline springs in the 300 Area as part of shoreline characterization activities. Three snail species were identified: prairie fossaria (*Fossaria bulimoides*), ash gyro (*Gyraulus parvus*), and springsnail (*Pyrgulopsis* new species 6). All of these have been previously found in the Hanford Reach. The prairie fossaria is commonly found throughout the Columbia River system. The ash gyro is widespread throughout North America and common to lakes and large, slow-moving rivers. The springsnail has a short but complex history in the Columbia River system. It was first described in 1988 by U.S. Fish and Wildlife Service personnel in deep pools (24 to 27 meters [80 to 90 feet]) near Bonneville Dam. Since

Table 10.11.1. Number of Chorusing Great Basin Spadefoot Toads, Woodhouse's Toads, and Bullfrogs Recorded at Survey Sites Between February and September 2006

Type	Call Survey Site	Great Basin Spadefoot Toad	Woodhouse's Toad	Bullfrog
Pool	1	0	11	0
	2 and 3	65	14	47
	7	0	0	0
	8	0	0	0
	9	54	134	34
	11	1	4	8
	12	0	2	0
	13	323	183	12
	14	114	143	78
	15	0	0	0
River	Vernita	0	0	0
	100-K Area	0	0	0
	100-N Area	0	0	0
	White Bluffs boat launch	0	0	3
	Hanford town site	0	0	0
Slough	Vernita Slough	3	25	0
	5	0	4	0
	6	0	0	0
	4	0	0	0
	Hanford Slough	15	24	0
Total (percent)		**575 (44)**	**544 (42)**	**182 (14)**

then, the springsnail has been found at 12 lower Columbia River sites in shallower depths (1.8 meters [6 feet]) extending from the river mouth to Rufus, Oregon. In the Hanford Reach, this species was not found in surveys conducted by Neitzel and Frest (PNL-8229) or by The Nature Conservancy in 1998 (Newell 2003). This species was found in surveys conducted by Pacific Northwest National Laboratory personnel in 2003 and 2004 (PNNL-15222). The springsnail is widespread in North America; it is a cold-water species and appears to be expanding its range into the Hanford Reach. The shell morphology and some anatomical features are similar to those of the Idaho springsnail (*Pyrgulopsis idahoensis*), a species that is currently being delisted under the *Endangered Species Act of 1973*, which has caused some confusion. In an attempt to clarify the status of the springsnail (*Pyrgulopsis* new species 6), the U.S. Fish and Wildlife Service has recently sponsored genetic work on the *Pyrgulopsis* genus.

10.11.3 Ecological Monitoring on Long-Term Plots

J. L. Downs

Long-term monitoring plots, established as part of the *Hanford Site Biological Resources Management Plan* (DOE/RL-96-32, Rev. 0), are surveyed periodically to determine the status of biological populations and resources on the Hanford Site. Thirty original plots, each with outside dimensions of 1 kilometer (0.62 mile) by 200 meters (0.12 mile) were initially surveyed during 1996 to characterize vegetation and bird use. Since 1996, five additional plots have been added to address particular habitats, such as riparian areas and abandoned fields. Surveys also have been conducted on selected long-term monitoring plots to provide data to evaluate changes in plant and animal communities

after fires, and to measure the abundance and diversity of small mammals in priority habitats. As part of ongoing monitoring activities, selected plots on the Hanford Central Plateau were surveyed during 2005 (PNNL-15892). No data were collected on long-term monitoring plots during 2006 because of a funding reduction.

10.11.4 Monitoring of Fish and Wildlife for Hanford Site-Produced Contaminants

J. A. Stegen, R. E. Durham, M. A. Simmons, and K. D. Hand

In 2006, several types of wildlife and fish were collected at locations on and around the Hanford Site (Figure 10.11.7) as part of routine monitoring for site-produced contaminants. Samples from these organisms were analyzed for selected radionuclides and metals that are suspected or known to be present on the Hanford Site (Table 10.11.2). Samples were also collected at locations that are distant from the site to obtain reference (background) contaminant measurements.

Fish and wildlife samples collected on or near the Hanford Site for routine human-exposure pathway assessments are obtained annually, but specific species are only sampled every 2 or 3 years. Samples obtained at locations believed to be unaffected by Hanford Site effluent and emissions are collected approximately every 5 years.

In 2006, all fish and wildlife samples collected were monitored for strontium-90 contamination and were analyzed by gamma spectrometry to detect a number of gamma emitters (Appendix F), including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples.

Strontium-90 is chemically similar to calcium; consequently, it accumulates in hard tissues rich in calcium such as bones and antlers. Strontium-90 has a biological half-life in hard tissue of 14 to 600 days (PNL-9394). Hard-tissue concentrations may profile an organism's lifetime exposure to strontium-90. However, strontium-90 generally does not contribute much to human dose because it does not accumulate in edible portions of fish and wildlife. Strontium-90 is present in the Hanford Site environs as a result of atmospheric fallout from nuclear weapons testing, and past operating and waste-disposal practices. Currently, contaminated groundwater entering the Columbia River via shoreline springs in the 100-N and 100-H Areas is the primary source of site-produced strontium-90 measurable in the Columbia River; however, the current contaminant contribution relative to historical fallout from atmospheric weapons testing is small (<2%) (PNL-8817).

Cesium-137 is particularly important to the human food-chain because it is chemically similar to potassium and is found in the muscle tissues of fish and wildlife. Having a relatively short biological half-life (<200 days in muscle and <20 days in the gastrointestinal tract [PNL-9394]), cesium-137 is an indicator of recent exposure to radioactive materials. Cesium-137 is present in the environment as a result of past Hanford Site operating and waste-disposal practices, as well as from historical worldwide fallout resulting from nuclear weapons testing.

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 were below levels that could be detected by the analytical laboratory.

Monitoring various biota for uptake and exposure to radionuclides both near and distant from Hanford Site operations continues to assure regulatory agencies that the consumption of fish and wildlife obtained from the site environs does not pose a threat to humans. Monitoring also provides long-term contamination trends in selected components of the ecosystem.

Several trace metals associated with Hanford Site operations have the potential to accumulate in certain fish and wildlife tissues. These metals are potential contaminants of concern (e.g., chromium, cadmium, lead, and mercury), particularly along Hanford's Columbia River shoreline where contaminated groundwater flows into the river (PNNL-14295). The suite of metals analyzed for in the 2006 biota samples is consistent with the contaminants of potential concerns identified in the 100 Areas and 300 Area

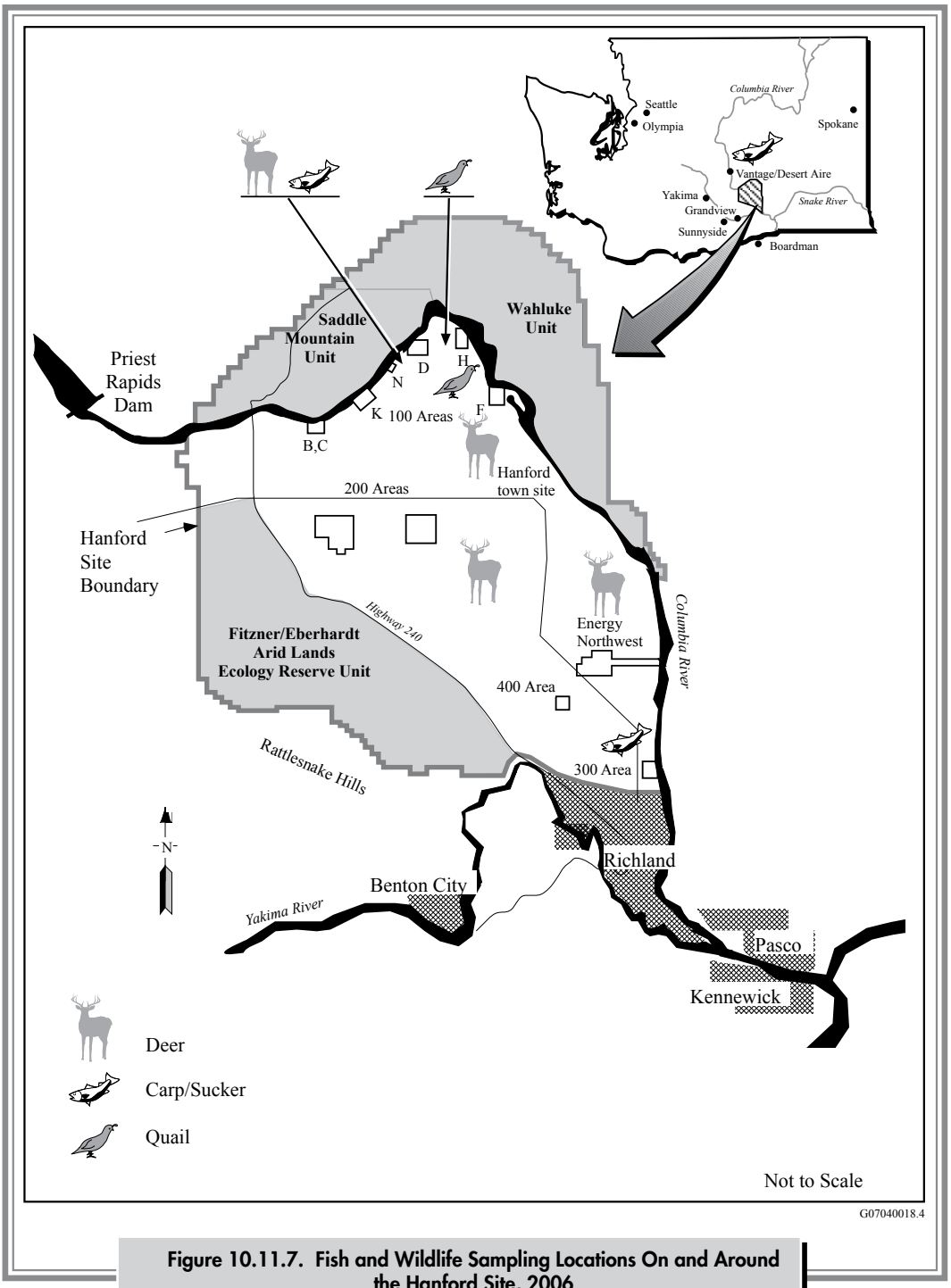


Figure 10.11.7. Fish and Wildlife Sampling Locations On and Around the Hanford Site, 2006

Table 10.11.2. Site-Wide and Offsite Fish and Wildlife Sampling Locations and Analyses, 2006

Biota	No. of Reference Locations	No. of Onsite Locations	No. of Analyses		
			Gamma	Strontium-90	Trace Metals
Fish (carp and sucker)	1[a]	2	15	15	15
Upland game (California quail and pheasant)	0	2	6	6	5
Big game (deer)	0	2	11	11	2

(a) Collected near Desert Aire/Vantage, Washington.

sampling and analysis plan (DOE/RL-2005-42, Rev. 1) and associated data-quality objective summary report (BHI-01757). Historical operations at the Hanford Site resulted in the production of both radiological and non-radiological wastes, including metals, in various forms. Liquid and solid wastes were placed in various disposal sites at the site, including trenches, cribs, ditches, ponds, and underground storage tanks (PNNL-13487). Fly ash (ash produced from burning coal) from coal-fired steam/power plants that were associated with each reactor was released to the atmosphere. The fly ash contained trace metals and natural radionuclides that may have deposited on the soil around the reactor areas. Other sources for metals related to Hanford Site operations include metals used in the treatment of water used in the reactors (e.g., chromium used to deal with corrosion in the pipes; iron or aluminum flocculants for removing dissolved solids before the water was used in the reactors), metals released from burning offsite, and metals released from studies conducted at the sites (e.g., animal testing in the 100-F Area). In addition to trace metals associated with past Hanford Site operations, other sources of contamination have impacted the site. Trace metals generated from upriver mining and smelting activities have been transported down the Columbia River (Johnson et al. 1990) and into the Hanford Reach. Also, contaminants associated with past and present agricultural practices have contributed to the metals inventory at the Hanford Site (Yokel and Delistraty 2003). For example, arsenic is likely associated with historical applications of lead arsenate on fruit orchards prior to World War II. Lead arsenate was once the most commonly used insecticide in fruit orchards and studies that examined the extent of arsenic contamination in pre-World War II orchard soil near the 100 Areas showed elevated levels of arsenic compared to levels in soil from background locations (Yokel and Delistraty 2003).

Organisms can accumulate metals through incidental soil ingestion, by drinking contaminated water, and by consuming contaminated foods. The spatial variability of concentrations of metals in the environment is influenced by the contributions of both natural sources and industrial contaminants. Thus, concentrations of metals and organism exposures can vary between locations. This variability can produce some uncertainty in the source of the metals within the sampled organism. To determine the Hanford Site's contribution to levels of metals in biota collected onsite or in the Hanford Reach, samples were also collected from the Columbia River upstream of the site and from background areas distant from the site. A comparison of concentrations of metals in upstream and background samples with concentrations in Hanford Reach or Hanford Site samples may provide information on increases in concentrations of metals potentially due to activities on the site.

Fish and wildlife sampled and analyzed during 2006 for radionuclides and trace metals included sucker (*Catostomus* species), common carp (*Cyprinus carpio*), California quail (*Callipepla californica*), and mule deer; data results are summarized in the following sections. Individual results and their associated analytical uncertainties are provided in PNNL-16623, APP. 1.

10.11.4.1 Analytical Results for Fish Samples

Fishing is a popular activity along the Hanford Reach of the Columbia River. Fish, such as carp and suckers, are occasionally harvested for food and could potentially contribute to human exposure. Sucker and carp are both bottom feeders that are likely moving up and down the Hanford Reach. They may be exposed to metals and persistent radionuclides in the Columbia River environment. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site continues to be important to track the extent and long-term trends of contamination in the Hanford Reach environment. When possible, carp were sampled; however, when carp could not be collected, suckers were collected instead. During 2006, one carp and nine suckers were collected from two locations in the Hanford Reach: five from the region between the 100-N and 100-D Areas, and five from near the 300 Area (Figure 10.11.7). Additionally, five suckers were collected at an upstream background location near Desert Aire, Washington, in 2006. Fillets and the eviscerated remains (carcasses) of the fish were analyzed for a variety of radiological contaminants, and liver samples were analyzed for 17 trace metals.

Cesium-137. Cesium-137 results were below the analytical detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) in all of the fish-fillet samples collected in 2006. These results are consistent with results reported throughout the past 10 years that indicated a gradual decline in cesium-137 levels in fish found both at background locations and near the Hanford Site.

Strontium-90. Strontium-90 was measured above the analytical detection limit in four of the five fish carcass samples collected between the 100-N and 100-D Areas and in four of the five fish carcass samples collected near the 300 Area. The maximum strontium-90 concentrations in fish carcass samples between the 100-N and 100-D Areas (0.029 pCi/g [0.0011 Bq/g] wet weight) and near the 300 Area (0.021 pCi/g [0.00077 Bq/g] wet weight) were similar to the maximum background concentration of strontium-90 measured in background samples (0.023 pCi/g [0.00085 Bq/g] wet weight). The median level of strontium-90 in carcass tissues collected from the region between the 100-N and 100-D Areas (0.013 pCi/g [0.00048 Bq/g] wet weight) was similar to the median level observed in fish from the 300 Area (0.015 pCi/g [0.00055 Bq/g] wet weight) and similar to median levels recorded in the preceding 10-year period (Figure 10.11.8).

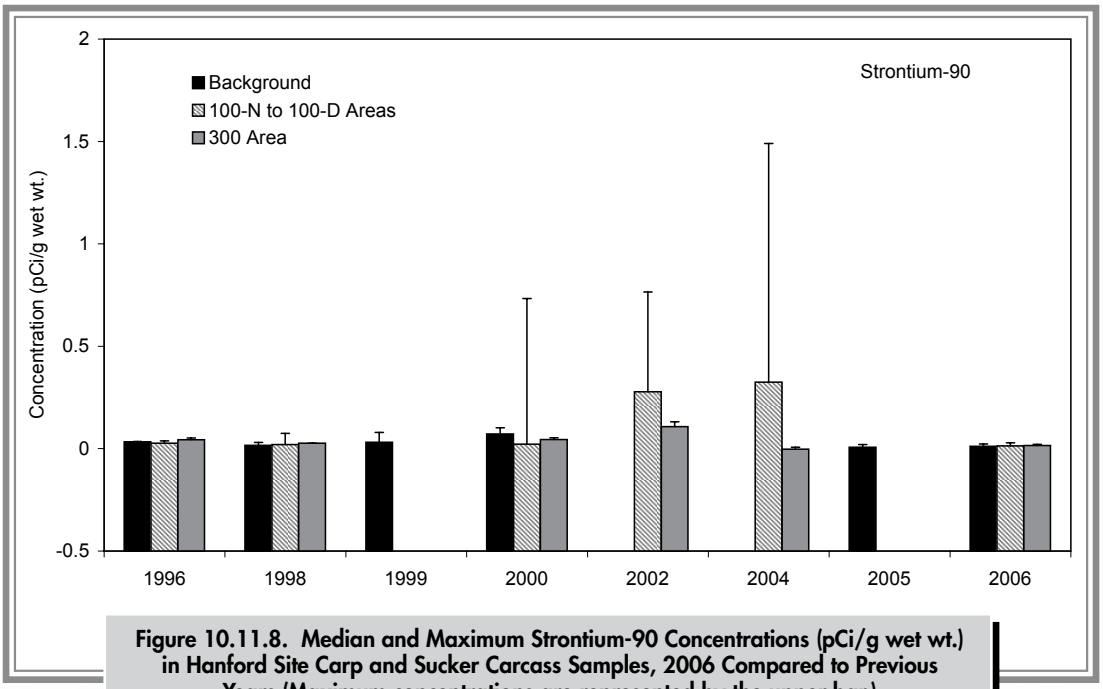


Figure 10.11.8. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site Carp and Sucker Carcass Samples, 2006 Compared to Previous Years (Maximum concentrations are represented by the upper bar.)

Trace Metals. Liver samples from five suckers collected near the 300 Area, and four suckers and one carp collected between the 100-N and 100-D Areas on the Hanford Reach, were analyzed for 17 trace metals during 2006. Liver samples from five suckers collected at a reference location upstream of Priest Rapids Dam near Desert Aire, Washington, were also analyzed in 2006. Trace metals concentrations measured in samples collected in the Hanford Reach in 2006 were compared to concentrations in sucker samples collected at the reference site in 2006 as well as in 2002 (Appendix C, Table C.12; PNNL-14295, APP. 1). For most trace metals, concentrations in samples collected at the Hanford Site were the same as or below concentrations in samples collected at the reference location near Desert Aire, Washington, in 2006 and 2002. Beryllium was the only trace metal not detected above the analytical detection limit (0.02 µg/g dry weight) in carp in 2006 (Appendix C, Table C.12). The median and maximum concentrations of mercury, antimony, and lead in liver samples from fish collected between the 100-N and 100-D Areas were elevated, compared to concentrations in liver samples from fish collected from the reference location in 2006.

The maximum concentrations of manganese in the fish collected between the 100-N and 100-D Areas (69 µg/g dry weight) and near the 300 Area (73 µg/g dry weight) were higher than the maximum concentration of manganese in carp livers collected at the same locations in 2004 (PNNL-15222, Appendix C), the upstream reference location in 2006 (29 µg/g dry weight), and the upstream reference location in 2002 (12 µg/g dry weight) (Appendix C, Table C.12; PNNL-14295, APP. 1). The median concentration of manganese in fish collected between the 100-N and 100-D Areas was less than the median concentration reported from reference samples collected upstream in 2006. However, the median concentration was higher in fish collected near the 300 Area in 2006 compared to median concentrations in fish collected near the 300 Area in 2004, and at upstream reference locations near Vantage, Washington, in 2002 and Desert Aire, Washington, in 2006.

The maximum and median uranium concentrations were elevated in carp and suckers collected between the 100-N and 100-D Areas and in the 300 Area compared to the maximum and median concentrations of uranium in carp and suckers collected at the upstream reference location in 2006 and 2002 (Appendix C, Table C.12; PNNL-14295, APP. 1). The levels measured in fish in 2006 were consistent with the concentrations measured in carp liver samples collected between the 100-N and 100-D Areas and in the 300 Area in 2004 (PNNL-15222, APP. 1).

The maximum concentrations of nickel in fish collected between the 100-N and 100-D Areas (1.25 µg/g dry weight) and in fish collected near the 300 Area (1.69 µg/g dry weight) were higher than the maximum nickel concentration in samples collected at the same locations in 2004 (PNNL-15222, APP. 1), the upstream reference location in 2006 (0.447 µg/g dry weight), and the upstream reference location in 2002 (0.14 µg/g dry weight) (Appendix C, Table C.12). The median concentration of nickel in fish collected between the 100-N and 100-D Areas was similar to the median concentration reported from reference samples collected upstream in 2006. However, the median concentration was higher in fish collected in the 300 Area compared to the median concentrations in fish collected in the 300 Area in 2004 and at the reference location in 2002 and 2006.

The surveillance dataset for metals in fish near the Hanford Site is relatively small and results are variable; therefore, it is difficult to draw conclusions. In addition, no established state or federal adverse-affects values (i.e., benchmark criteria) are available for metals concentrations in fish tissue. However, Washington State has developed acute and chronic aquatic-life criteria for ambient surface water. Both Columbia River and river shoreline spring water samples have been collected near Hanford Site facilities for several years. Data for these spring water samples collected in 2006 are presented in Sections 10.4 and 10.5. With the exception of chromium in riverbank spring water, concentrations of measured metals in Columbia River and riverbank spring water samples were less than the Washington State ambient surface-water quality acute and chronic criteria for the protection of aquatic life (Table 10.5.3; Appendix C, Table C.7). Average concentrations of most metals in Hanford Reach sediment samples collected during 2006 were lower than concentrations in sediment collected at the Priest Rapids Dam upstream of the Hanford Site (see Section 10.4 for discussion). There were slightly elevated concentrations of uranium in near-shore Columbia River water samples, and values exceeded the drinking water standard (30 µg/L)

for some riverbank spring water samples collected near the 300 Area in 2006. Uranium concentrations at the 300 Area were only slightly elevated compared to the concentrations measured in sediment collected near Priest Rapids Dam (see Sections 10.4 and 10.5 for discussion).

10.11.4.2 Analytical Results for Upland Game Samples

California quail are one of the most prevalent upland game birds found on the Hanford Site. Most quail that reside onsite are found along the Columbia River where trees and shrubs provide shelter. Quail forage for seeds, other plant parts, and grit in grassy and weedy places not far from cover. Ordinarily, quail do not travel far from where they hatch. Individual birds on the Hanford Site may spend their entire lives near one of the retired reactors. Quail can be exposed to metals and persistent radionuclides when they forage on materials from plants that have roots in contact with contaminated groundwater or soil, drink contaminated water, or ingest contaminated grit. Six California quail were collected in the region between the 100-H and 100-F Areas and in the region between the 100-D and 100-H Areas on the Hanford Site in the fall of 2006. Radionuclide levels found in muscle and bone samples analyzed during 2006 were compared to levels measured in upland game samples collected onsite during the previous 10-year period, and to levels found in upland game samples collected from reference locations in 2000 and 2004.

Cesium-137. Cesium-137 was below the analytical detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) in the two quail muscle samples collected between the 100-H and 100-F Areas, and in the four samples collected between the 100-D and 100-H Areas. The number of samples reported at or below the analytical detection limit from 1996 through 2006 (44 of 44 collectively) reflects the continued downward trend in worldwide levels of cesium-137 fallout resulting from materials released to the atmosphere during the nuclear weapons testing era (1950s through the 1970s).

Strontium-90. One bone sample from a quail collected onsite between the 100-D and 100-H Areas had a strontium-90 concentration above the analytical detection limit (0.08 pCi/g [0.0030 Bq/g] wet weight). Results from all other bone samples collected onsite were below the analytical detection limit. These results were consistent with results obtained in past years and do not indicate elevated levels of strontium-90 in upland game (Figure 10.11.9).

Trace Metals. One liver sample from quail collected between the 100-H and 100-F Areas and four liver samples from quail collected between the 100-D and 100-H Areas were analyzed for 17 trace metals during 2006. For most trace metals, concentrations in samples collected on the Hanford Site were the same as or below concentrations in samples collected at a reference location near Grandview, Washington, in 2004 (Appendix C, Table C.13).

Beryllium, silver, and uranium were not detected above analytical detection limits in any of the upland game bird liver samples collected on the Hanford Site in 2006. The median and maximum concentrations of aluminum, cadmium, copper, manganese, and selenium were elevated in liver samples collected between the 100-D and 100-H Areas compared to the median and maximum concentrations measured in liver samples from the reference location in 2004. The results for cadmium, copper, manganese, and selenium are consistent with levels measured in quail collected between the 100-D and 100-H Areas in 2004 (PNNL-15222). Copper, manganese, and selenium concentrations in the liver sample collected between the 100-H and 100-F Areas were also elevated compared to reference area samples collected in 2004 (Appendix C, Table C.13).

10.11.4.3 Analytical Results for Deer Samples

Studies of mule deer populations residing on the Hanford Site indicate their division into three relatively distinct groups (Tiller and Poston 2000): 1) deer that live near the retired reactors in the 100 Areas are designated the northern-area population; 2) deer that reside from the Hanford town site south to the 300 Area are designated the southern-area population; and 3) by default, deer living around the 200 Areas, away from the Columbia River, are designated the central-area population. The central-area population has decreased significantly with the eliminations of Gable Mountain Pond and B Pond. Deer can be exposed to metals and persistent radionuclides when they forage on plants that grow in places where plant roots have access to contaminated groundwater or soil, drink contaminated

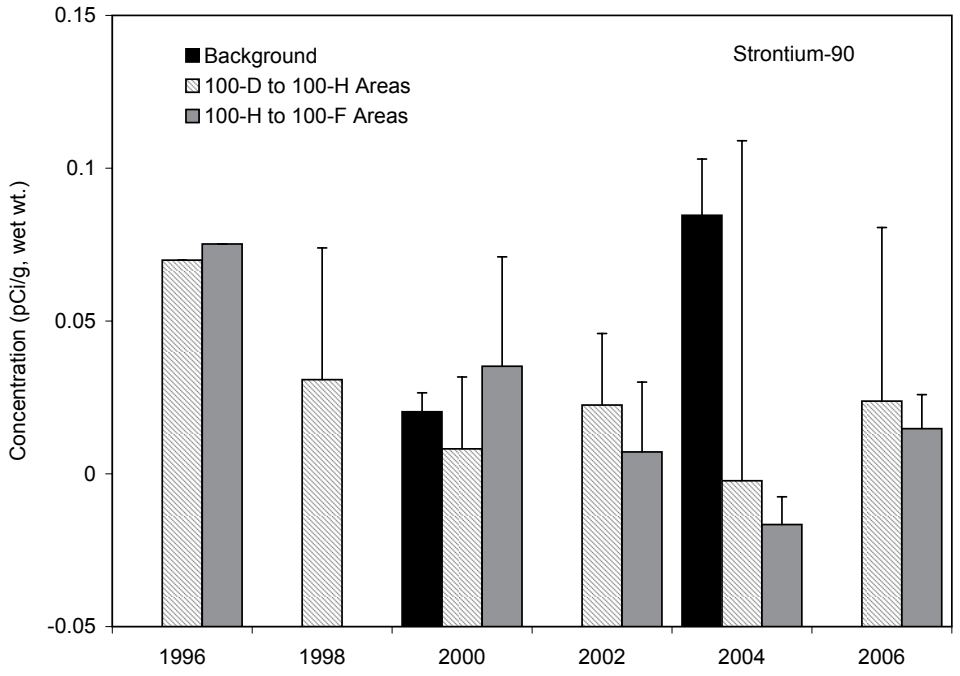


Figure 10.11.9. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Game Bird Bone Samples, 2006 Compared to Previous Years (Maximum concentrations are represented by the upper bar.)

water, or incidentally ingest contaminated soil. Deer hunting is not allowed above the high water mark on the Benton County side of the Columbia River (on the Hanford Site), but the river is not a barrier to deer movements. Deer captured and tagged on the Hanford Site have been legally killed by hunters on the Hanford Reach shoreline below the high water mark and across the Columbia River in Franklin County.

Radionuclide levels in 11 deer collected on the Hanford Site in 2006 were compared to levels in deer collected in previous years from reference locations that are distant from the site and to results reported for the preceding 10-year period. Four deer were from the northern-area population and seven were from the southern-area population. In 2002 and 2004, black-tail deer samples from Olympia, Washington, were donated by the Washington State Department of Health. Additionally, background samples were collected during 2000 from the lower Yakima Valley, near Sunnyside, Washington (see PNNL-13487, Section 4.5). Concentrations in a white-tailed deer that was co-sampled with the Washington State Department of Health during 1996 from Vail, Washington (see PNNL-12088, Section 4.5) were also used for comparison purposes. These comparisons with samples from distant locations are useful in evaluating the Hanford Site's relative contribution of radionuclides in deer. The deer collected in Vail, Washington, inhabited mountain regions that received more rainfall (and more atmospheric fallout) than the Hanford Site, increasing background levels of fallout radionuclides there (Tiller and Poston 2000). The climate and precipitation of the Sunnyside, Washington, region is similar to the Hanford Site.

Cesium-137. Cesium-137 was not detected (at or <0.03 pCi/g [0.001 Bq/g] wet weight) in any of the 11 deer muscle samples collected onsite in 2006. These results are consistent with a decline in cesium-137 levels in wildlife examined from the preceding 10 years. In this time period, the highest level of cesium-137 was measured in a background deer sample collected in 1996, from Vail, Washington.

Strontium-90. Strontium-90 was detected in all 11 deer bone samples collected onsite and analyzed in 2006, and continues to demonstrate the utility of this organism to

accumulate this radionuclide and to depict trends of strontium-90 contamination in the environment. Median levels of strontium-90 found in deer bone in 2006 were higher in deer from the northern area (0.325 pCi/g [0.012 Bq/g] wet weight) compared to deer collected from the southern-area population (0.182 pCi/g [0.0067 Bq/g] wet weight) (Figure 10.11.10). The highest concentration of strontium-90 (0.396 pCi/g [0.015 Bq/g] wet weight) obtained onsite during 2006 was obtained near the 100 Areas. Elevated levels of strontium-90 in deer bone samples from the northern-area population, compared to bone samples from the southern-area population, typically occurred in about one out of three deer samples collected from the northern-area population throughout the preceding 10-year period. The highest concentration of strontium-90 (20.8 pCi/g [0.77 Bq/g] wet weight) was reported during 1992 (see PNNL-13487, Section 4.5). The apparently higher concentrations reported in deer bone from the northern area may indicate some exposure to localized, low-level contamination in the 100-N Area. Previous background samples of deer bone indicate strontium-90 concentrations can be as high as 2.06 pCi/g (0.08 Bq/g) wet weight.

Trace Metals. Liver samples from one mule deer collected near the 100-N Area and one mule deer collected from the southern-area population were analyzed for trace metals in 2006. Concentrations measured in Hanford Site deer were compared to concentrations in black-tailed deer collected in 2002 and 2004 near Olympia, Washington (Appendix C, Table C.14) and in four mule deer samples collected in 1994 near Boardman, Oregon (PNNL-11518).

Most trace metal concentrations in liver samples collected from deer on the Hanford Site in 2006 were similar to or less than concentrations measured in samples from the reference locations (Appendix C, Table C.14). Uranium, beryllium, thallium, arsenic, aluminum, and antimony were not detected above analytical detection limits in samples collected on the Hanford Site in 2006.

Cadmium and selenium levels were elevated in samples collected onsite compared to concentrations in all reference samples. These results are consistent with deer samples collected onsite in 2004 near the 100-N Area (PNNL-15222, APP. 1). The maximum concentration of cadmium measured in the samples collected onsite was at least two times higher than the maximum concentrations measured in all reference samples (Appendix C, Table C.14; PNNL-11518). The maximum concentrations of selenium in samples collected onsite were slightly elevated compared to levels in

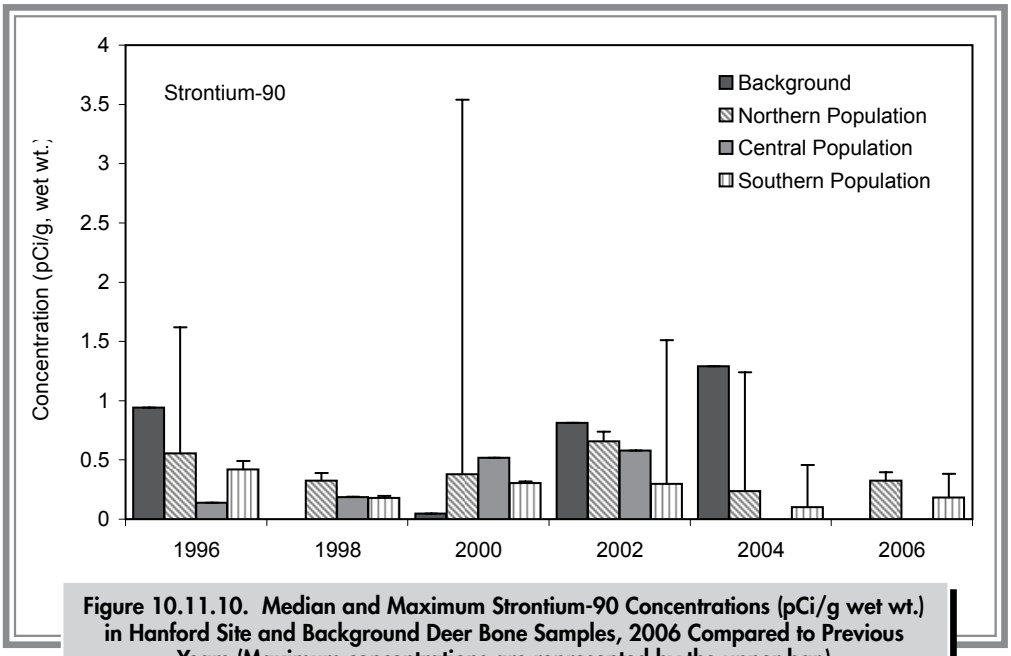


Figure 10.11.10. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Deer Bone Samples, 2006 Compared to Previous Years (Maximum concentrations are represented by the upper bar.)

samples collected near Boardman, Oregon (PNNL-11518) but were over four times higher than the concentration measured in the sample collected near Olympia, Washington. The zinc concentration measured in the deer liver collected from the southern population was approximately nine times higher than the concentration measured in all reference samples and previous onsite samples.

10.11.5 Control of Pests and Contaminated Biota

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Animal species such as the domestic pigeon (*Columbia livia*), Northern pocket gopher (*Thomomus talpoides*), house mouse (*Mus musculus*), and deer mouse (*Peromyscus maniculatus*) must be controlled when they become a nuisance, health problem, or contaminated with radioactivity. Biological control personnel responded to approximately 28,000 animal control requests (ranging from requests to remove animals within radioactive waste facilities to insect invasions of work areas) from Hanford Site employees in 2006. There were approximately 2,500 trap/bait stations used to control populations of animals in and near facilities and offices.

There were 21 contaminated animals or animal-related materials discovered during 2006. This is approximately 60% less than the peak number of 46 in 1999, and is one more than the total for 2005. Flying insects and insect-related materials (e.g., harvester ants and mud-dauber wasp nests) collected during operations on the Hanford Site are monitored for radiological contaminants. Only three of the contaminated animal samples collected in 2006 related to insects, and those were approximately 3-year-old inactive wasp nests found on equipment stored near the 100-N Area that had been relocated from the 100-H Area near where the wasps were building nests from contaminated mud exposed during the demolition of the 105-H Building in 2003 (PNNL-14687).

10.12 Endangered and Threatened Species at Hanford

M. R. Sackschewsky

This section provides information on federal and state endangered and threatened species, candidate or sensitive plant and animal species, and other species of concern potentially found on the Hanford Site. Endangered species are those in danger of extinction within all or a significant portion of their range. Threatened species are those likely to become endangered in the foreseeable future. Sensitive species are species that are vulnerable or declining and could become endangered or threatened without active management or removal of threats. The federal list of endangered and threatened species is maintained by the U.S. Fish and Wildlife Service in 50 CFR 17.11 and 50 CFR 17.12; the state lists are maintained by the Washington Natural Heritage Program (WNHP 2007) and the Washington Department of Fish and Wildlife (WDFW 2007).

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 endangered and threatened species, and 3) ensure that appropriate steps are taken to achieve the purposes of the treaties and conventions established under the act. Washington State also lists species as endangered and threatened, but such listing does not provide the protection of the federal *Endangered Species Act*. The National Oceanic and Atmospheric Administration Fisheries (NOAA 2007) has the responsibility for the federal listing of anadromous fish (i.e., fish such as steelhead and spring-run Chinook salmon that require both saltwater and freshwater to complete a life cycle). The U.S. Fish and Wildlife Service has responsibility for all other federally listed species on the Hanford Site. Species of plants and animals listed as endangered, threatened, sensitive, or candidate by either the federal or state governments that occur or potentially occur on the Hanford Site are listed in Table 10.12.1.

Two fish species (spring-run Chinook salmon and steelhead) on the federal list of endangered and threatened species are known to regularly occur on the Hanford Site (Table 10.12.1). The bald eagle, which occurs on the Hanford Site, was previously listed as a federal-threatened species but was delisted in June 2007. One additional fish species (bull trout) has been recorded on the Hanford Site but is believed to be transient. No plants or mammals known to occur on the Hanford Site are currently on the federal list of endangered and threatened species (50 CFR 17), but two species of plants, one species of mammal, and one species of bird are currently candidates for listing under the *Endangered Species Act* (Table 10.12.1). In addition, 12 plant species and 5 bird species have been listed as either endangered or threatened by Washington State. Numerous additional species of animals and plants are listed as candidate or sensitive species by Washington State. There are 28 state-level sensitive and candidate species of insects and animals, and 15 sensitive plant species occurring or potentially occurring on the Hanford Site (Table 10.12.1). The U.S. Fish and Wildlife Service also maintains an informal list of species of concern in the Columbia Basin (USFWS 2007), which includes species that are being monitored and may be considered for federal candidate status in the future; there are 14 species on this list that occur on the Hanford Site.

Washington State maintains additional lower-level lists of species, including a Monitor list for animals (WDFW 2007) and Review and Watch lists for plants (WNHP 2007). Species on the Washington State Monitor, Watch, and Review lists are not considered species of concern, but are monitored for status and distribution. These species are managed by the state as needed to prevent them from becoming endangered, threatened, or sensitive.

Table 10.12.1. Federal and Washington State Listed Endangered, Threatened, Sensitive, and Candidate Species Occurring or Potentially Occurring on the Hanford Site

Common Name	Scientific Name	Federal Status[a]	State Status[a]
Plants			
awned halfchaff sedge	*Lipocarpha (= Hemicarpha) aristulata*		Threatened
beaked spike-rush	*Eleocharis rostellata*		Sensitive
Canadian St. John's wort	*Hypericum majus*		Sensitive
Columbia milkvetch	*Astragalus columbianus*	Species of concern	Sensitive
coyote tobacco	*Nicotiana attenuata*		Sensitive
desert dodder	*Cuscuta denticulata*		Threatened
desert evening-primrose	*Oenothera caespitosa*		Sensitive
dwarf evening primrose	*Camissonia (= Oenothera) pygmaea*		Sensitive
fuzzytongue penstemon	*Penstemon eriantherus whitedii*		Sensitive
Geyer's milkvetch	*Astragalus geyeri*		Threatened
grand redstem	*Ammannia robusta*		Threatened
gray cryptantha	*Cryptantha leucophaea*	Species of concern	Sensitive
Great Basin gilia	*Gilia leptomeria*		Threatened
Hoover's desert parsley	*Lomatium tuberosum*	Species of concern	Sensitive
loeflingia	*Loeflingia squarrosa var. squarrosa*		Threatened
lowland toothcup	*Rotala ramosior*		Threatened
miner's candle	*Cryptantha scoparia*		Sensitive
mousetail	*Myosurus clavicaulis*		Sensitive
persistent sepal yellowcress	*Rorippa columbiae*	Species of concern	Endangered
Piper's daisy	*Erigeron piperianus*		Sensitive
rosy pussypaws	*Calyptridium roseum*		Threatened
small-flowered evening-primrose	*Camissonia (= Oenothera) minor*		Sensitive
Snake River cryptantha	*Cryptantha spiculifera (= C. interrupta)*		Sensitive
Suksdorf's monkey flower	*Mimulus suksdorfii*		Sensitive
Umtanum desert buckwheat	*Eriogonum codium*	Candidate	Endangered
White Bluffs bladderpod	*Physaria (= Lesquerella) tuplashensis*	Candidate	Threatened
white eatonella	*Eatonella nivea*		Threatened
Mollusks			
California floater	*Anodonta californiensis*	Species of concern	Candidate
great Columbia River spire snail	*Fluminicola columbiana*	Species of concern	Candidate
shortfaced lanx	*Fisherola nuttalli*		Candidate
Insects			
Columbia River tiger beetle[b]	*Cicindela columbica*		Candidate
silver-bordered fritillary	*Boloria selene atrocostalis*		Candidate
Fish			
bull trout[c]	*Salvelinus confluentus*	Threatened	Candidate
leopard dace[c]	*Rhinichthys flacatus*		Candidate
mountain sucker[c]	*Catastomus platyrhynchus*		Candidate
Pacific lamprey	*Lampetra tridentata*	Species of concern	
river lamprey[c]	*Lampetra ayresi*	Species of concern	Candidate
spring-run Chinook salmon	*Oncorhynchus tshawytscha*	Endangered	Candidate
steelhead	*Oncorhynchus mykiss*	Threatened	Candidate
Amphibians and Reptiles			
sagebrush lizard	*Sceloporus graciosus*	Species of concern	Candidate
striped whipsnake	*Masticophis taeniatus*		Candidate
western toad	*Bufo boreas*	Species of concern	Candidate

Table 10.12.1. (contd)

Common Name	Scientific Name	Federal Status[a]	State Status[a]
Birds			
American white pelican	*Pelecanus erythrorhynchos*		Endangered
bald eagle	*Haliaeetus leucocephalus*	[d]	Threatened
burrowing owl	*Athene cunicularia*	Species of concern	Candidate
common loon	*Gavia immer*		Sensitive
ferruginous hawk	*Buteo regalis*	Species of concern	Threatened
flamulated owl[c]	*Otus flammeolus*		Candidate
golden eagle	*Aquila chrysaetos*		Candidate
greater sage grouse	*Centrocercus urophasianus*	Candidate	Threatened
Lewis's woodpecker[c]	*Melanerpes lewisi*		Candidate
loggerhead shrike	*Lanius ludovicianus*	Species of concern	Candidate
merlin	*Falco columbarius*		Candidate
northern goshawk[c]	*Accipter gentilis*	Species of concern	Candidate
olive-sided flycatcher	*Contopus cooperi*	Species of concern	
peregrine falcon	*Falco peregrinus*	Species of concern	Sensitive
sage sparrow	*Amphispiza belli*		Candidate
sage thrasher	*Oreoscoptes montanus*		Candidate
sandhill crane	*Grus canadensis*		Endangered
western grebe	*Aechmorus occidentalis*		Candidate
Mammals			
black-tailed jackrabbit	*Lepus californicus*		Candidate
Merriam's shrew	*Sorex merriami*		Candidate
Townsend's ground squirrel	*Spermophilus townsendii*	Species of concern	Candidate
Washington ground squirrel[c]	*Spermophilus washingtoni*	Candidate	Candidate
white-tailed jackrabbit	*Lepus townsendii*		Candidate

(a) Endangered = Species in danger of extinction within all or a significant portion of its range.
Threatened = Species likely to become endangered in the foreseeable future.
Candidate = Species that are believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared.
Sensitive = Taxa that are vulnerable or declining and could become endangered or threatened without active management or removal of threats.
Species of concern = Species that are not currently listed or candidates under the *Endangered Species Act*, but are of conservation concern within specific U.S. Fish and Wildlife Service regions.
(b) Probable, but not observed, on the Hanford Site.
(c) Reported, but seldom observed, on the Hanford Site.
(d) Delisted in June 2007.

However, an abundance of these species may be indicative of an ecosystem with relatively high-native diversity. There are approximately 50 Washington State Monitor animal and insect species occurring or potentially occurring on the Hanford Site (Table 10.12.2) and 26 Watch or Review list plant species potentially found on the Hanford Site (Table 10.12.3).

Table 10.12.2. Washington State Monitor Species Occurring or Potentially Occurring on the Hanford Site

Common Name	Scientific Name
Mollusks	
Oregon floater	*Anodonta oregonensis*
western floater	*Anodonta kennerlyi*
western pearlshell	*Margaritifera falcata*
Insects	
Bonneville skipper	*Ochlodes sylvanoides bonnevilla*
canyon green hairstreak	*Callophrys sheridanii neoperplexa*
coral hairstreak	*Harkenclenus titus immaculosus*
juba skipper	*Hesperia juba*
Nevada skipper	*Hesperia nevada*
northern checkerspot	*Chlosyne palla palla*
Pasco pearl	*Phyciodes tharos pascoensis*
Persius' duskywing	*Erynnis persius*
purplish copper	*Lycaena helloides*
ruddy copper	*Lycaena rubida perkinsorum*
silver-spotted skipper	*Epargyreus clarus californicus*
viceroy	*Limenitis archippus lahontani*
Fish	
piute sculpin	*Cottus beldingi*
reticulate sculpin	*Cottus perplexus*
sand roller	*Percopsis transmontana*
Amphibians and Reptiles	
night snake	*Hypsiglena torquata*
short-horned lizard	*Phrynosoma douglassii*
tiger salamander	*Ambystoma tigrinum*
Woodhouse's toad	*Bufo woodhousii*
Birds	
Arctic tern[(a)]	*Sterna paradisaea*
ash-throated flycatcher[(a)]	*Myiarchus cinerascens*
black tern	*Chlidonias niger*
black-crowned night-heron	*Nycticorax nycticorax*
black-necked stilt	*Himantopus mexicanus*
bobolink[(a)]	*Dolichonyx oryzivorus*
Caspian tern	*Sterna caspia*
Clark's grebe	*Aechmophorus clarkii*
Forster's tern	*Sterna forsteri*
grasshopper sparrow	*Ammodramus savannarum*
gray flycatcher	*Empidonax wrightii*
great blue heron	*Ardea herodias*
great egret	*Ardea alba*
gyrfalcon[(a)]	*Falco rusticolus*
horned grebe	*Podiceps auritus*
lesser goldfinch	*Carduelis psaltria*
long-billed curlew	*Numenius americanus*
osprey	*Pandion haliaetus*
prairie falcon	*Falco mexicanus*
red-necked grebe[(a)]	*Podiceps grisegena*
snowy owl	*Nyctea scandiaca*
Swainson's hawk	*Buteo swainsoni*
turkey vulture[(a)]	*Cathartes aura*
western bluebird	*Sialia mexicana*
Mammals	
long-legged myotis	*Myotis volans*
northern grasshopper mouse	*Onychomys leucogaster*
pallid bat	*Antrozous pallidus*
sagebrush vole	*Lagurus curtatus*
small-footed myotis	*Myotis leibii*
western pipistrelle	*Pipistrellus hesperus*

(a) Reported, but seldom observed on the Hanford Site.

Table 10.12.3. Washington State Review and Watch List Plant Species Potentially Found on the Hanford Site

Common Name	Scientific Name	State Listing[a]
annual paintbrush	*Castilleja exilis*	Watch List
annual sandwort	*Minuartia pusilla var. pusilla*	Review Group 1
basalt milk-vetch	*Astragalus conjunctus var. rickardii*	Watch List
bristly combseed	*Pectocarya setosa*	Watch List
brittle prickly pear	*Opuntia fragilis*	Review Group 1
chaffweed	*Centunculus minimus*	Review Group 1
Columbia River mugwort	*Artemisia lindleyana*	Watch List
crouching milkvetch	*Astragalus succumbens*	Watch List
false pimpernel	*Lindernia dubia anagallidea*	Watch List
giant helleborine	*Epipactis gigantea*	Watch List
hedge hog cactus	*Pediocactus simpsonii var. robustior*	Review Group 1
Kittitas larkspur	*Delphinium multiplex*	Watch List
medic milkvetch	*Astragalus speirocarpus*	Watch List
pigmy-weed	*Crassula aquatica*	Watch List
porcupine sedge	*Carex hystericina*	Watch List
Robinson's onion	*Allium robinsonii*	Watch List
rosy balsamroot	*Balsamorhiza rosea*	Watch List
scilla onion	*Allium scilloides*	Watch List
shining flatsedge	*Cyperus bipartitus (rivularis)*	Watch List
small-flowered nama	*Nama densum var. parviflorum*	Watch List
smooth cliffbrake	*Pellaea glabella simplex*	Watch List
southern mudwort	*Limosella acaulis*	Watch List
stalked-pod milkvetch	*Astragalus sclerocarpus*	Watch List
Thompson's sandwort	*Arenaria franklinii thompsonii*	Review Group 2
vanilla grass	*Hierchloe odorata*	Review Group 1
winged combseed	*Pectocarya penicillata*	Watch List

(a) Review Group 1 - Taxa for which currently there are insufficient data available to support listing as threatened, endangered, or sensitive.
Review Group 2 - Taxa with unresolved taxonomic questions.
Watch List - Taxa that are more abundant and/or less threatened than previously assumed.

10.13 External Radiation Monitoring

C. J. Perkins

External radiation is defined as radiation originating from a source external to the body. In 2006, external radiation at the Hanford Site was monitored onsite in relative close proximity to known, suspected, or potential radiation sources. Sources of external radiation at the Hanford Site include waste materials associated with the historical production of plutonium for defense; residual nuclear inventories in former production and processing facilities; radioactive-waste handling, storage, and disposal activities; waste cleanup and remediation actions; atmospheric fallout from historical nuclear weapons testing; and natural sources such as cosmic radiation. During the 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 1975).

The Harshaw™ thermoluminescent dosimeter (TLD) system is used to measure external radiation at the Hanford Site. This system includes the Harshaw 8800-series dosimeter and the Harshaw 8800 reader. The Harshaw 8800-series environmental dosimeter consists of two TLD-700 chips and two TLD-200 chips, and provides both shallow- and deep-dose measurement capabilities using filters in the dosimeter. The two TLD-700 chips were used to determine the average total environmental dose at each location. The average daily dose rate was determined by dividing the average total environmental dose by the number of days the dosimeter was exposed. Daily dose equivalent rates (millirem per day) at each location were converted to annual dose equivalent rates (millirem per year) by averaging the daily dose rates and multiplying by 365 days per year. The two TLD-200 chips were included only to determine doses in the event of a radiological emergency and were not used during 2006. The TLDs were positioned approximately 1 meter (3.3 feet) above the ground and were collected and read quarterly.

Radiation surveys with portable instruments are conducted to monitor and detect contamination and to provide a coarse screening for external radiation fields. The types of areas surveyed in 2006 included underground radioactive materials areas, contamination areas, soil contamination areas, high-contamination areas, roads, and fence lines.

10.13.1 External Radiation Monitoring Near Hanford Site Facilities and Operations

C. J. Perkins

During 2006, external radiation fields were monitored with TLDs at 134 locations near onsite facilities and operations. The TLD results were used individually or averaged to determine dose rates in a given area for a particular sampling period. A comparison of 2006 and 2005 results for TLDs located near waste-handling facilities at the Hanford Site can be found in Table 10.13.1. Individual TLD results and detailed monitoring-location maps are provided in PNNL-16623, APP. 2.

10.13.1.1 External Radiation Measurements Onsite Near Facilities and Operations

100-B/C Area. At the former 116-B-11 and 116-C-1 liquid-waste disposal facilities (located in the 100-B/C Area), dose rate levels in 2006 were comparable to previous years.

(a) Harshaw is a trademark of Thermo Fisher Scientific, Waltham, Massachusetts.

Table 10.13.1. Thermoluminescent Dosimeter Results (mrem/yr)[a] Near Hanford Site Operations in 2005 and 2006

Hanford Site Locations	No. of Dosimeters	2005 Maximum[b]	2005 Average[c,d]	2006 Maximum[b]	2006 Average[c,d]	% Change[e]
100-B/C Area	4	94 ± 10	88 ± 10	90 ± 9	84 ± 8	-4
100-K Area	14	5,600 ± 3,600	1,270 ± 3,800	2,300 ± 5,800	483 ± 1,300	-51
100-KR-1	5	159 ± 55	113 ± 52	109 ± 46	98 ± 17	-13
100-N Area	11	229 ± 38	139 ± 96	176 ± 124	119 ± 59	-15
200-East Area	42	312 ± 151	114 ± 95	338 ± 275	113 ± 106	0
200-West Area	24	182 ± 13	105 ± 46	174 ± 120	104 ± 54	-1
200-North Area (212-R)[f]	1	3,100 ± 487	2,700 ± 710	2,200 ± 329	2,100 ± 207	-22
300 Area	8	113 ± 8	93 ± 23	113 ± 158	91 ± 24	-2
300 Area TEDF	6	91 ± 10	88 ± 4	87 ± 15	84 ± 4	-4
300-FF-2	4	101 ± 44	88 ± 13	93 ± 14	88 ± 10	3
400 Area	7	87 ± 5	84 ± 4	85 ± 9	81 ± 5	-2
CVDF	4	1,100 ± 916	560 ± 834	666 ± 939	337 ± 475	-39
ERDF	3	105 ± 51	100 ± 8	88 ± 16	86 ± 4	-13
IDF	1	90 ± 14	89 ± 2	93 ± 14	90 ± 5	1

(a) To convert to international metric system units, multiply mrem/yr by 0.01 to obtain mSv/yr.
(b) ± analytical uncertainty.
(c) ±2 standard deviations.
(d) Each dosimeter is collected and read quarterly.
(e) Numbers indicate a decrease (-) or increase from the 2005 mean.
(f) Maximum value represents highest quarterly value ± analytical uncertainty
CVDF = Cold Vacuum Drying Facility (100-K Area).
ERDF = Environmental Restoration Disposal Facility (200-West Area).
IDF = Integrated Disposal Facility (200-East Area).
TEDF = Treated Effluent Disposal Facility.

100-K Area. Cleanup activities at the 100-K Area fuel storage basins and adjacent retired reactor buildings continued in 2006, and overall average dose rates measured during the year decreased by approximately 50% relative to 2005 values. The 2006 decrease became noticeable during the last half of the year at nearly all monitoring locations near the K-East and K-West spent nuclear fuel storage basins and load-out stations.

The general decrease in dose rates observed at the K-East and K-West facilities was similarly observed at dosimeter monitoring sites around the 100-K Area Cold Vacuum Drying Facility and at the adjacent 100-KR-1 field remediation project. Overall annual dose rates at the Cold Vacuum Drying Facility decreased approximately 40% in 2006 compared to 2005, and by approximately 13% at the 100-KR-1 site.

In March 2006, three additional dosimeters were deployed at the 100-K Area to monitor the total dose during the transfer of radioactively contaminated basin sludge from the 105-KE fuel storage basin to the 105-KW fuel storage basin, and then to the Cold Vacuum Drying Facility (known as the Hose-in-Hose project). Two of the dosimeters were situated near the Columbia River shoreline, at the 183-KE and 183-KW water-intake structures. The third dosimeter was placed adjacent to a permanent fence line monitoring location east of the 105-KE facility. In October 2006, workers began pumping collected sludge from tanks in the K-East basin to tanks in the K-West Basin. Dose rates measured at the Columbia River shoreline locations were at typical, site baseline levels throughout 2006. Dose rates measured at the 105-KE fence line location were slightly higher than baseline levels until the fourth quarter of the year. During that period, dose rates increased noticeably, likely in conjunction with sludge transfer activities.

100-N Area. Average dose rates observed in the 100-N Area continued to decrease in 2006 and were approximately

15% lower than those measured in 2005. This notable reduction was directly attributable to the continued removal of contaminated materials from the retired 116-N-1 (also known as 1301-N) and 116-N-3 (also known as 1325-N) liquid-waste disposal trenches. Annual average dose rates at monitoring locations near the 116-N-1 trench showed a decrease of approximately 28% compared to levels measured at the same locations in 2005. The monitoring locations near the 116-N-3 facility that had shown significant dose rate decreases over the previous 2 years were removed in December 2005. Annual average TLD results for the entire 100-N Area from 1995 through 2006 are presented in Figure 10.13.1.

100-N Area Shoreline (N Springs). Dose rates were measured along the Columbia River shoreline in the 100-N Area (N Springs) to determine potential external radiation doses to onsite workers and to the public using the river. Continued cleanup activities at the retired 116-N-1 and 116-N-3 trenches (located near the Columbia River) have reduced the skyshine effect (i.e., radiation reflected by the atmosphere back to the Earth's surface) at the shoreline. The dose rates have decreased notably over the past few years (Figure 10.13.1). The 2006 dose rates were approximately 25% lower than the 2005 dose rates and averaged less than 100 mrem (1 mSv) per year.

200-East and 200-West Areas. Dose rates measured during 2006 in both the 200-East and 200-West Areas were very similar to 2005 and remained much lower than levels measured during peak waste-retrieval activities at the A Tank Farm (200-East Area) and at the S Tank Farm (200-West Area) during the second quarter of 2004 (Figure 10.13.1).

Average dose rates measured in 2006 at the Environmental Restoration Disposal Facility (located near the 200-West Area) were lower than 2005 levels, with a decrease of approximately 13% (Table 10.13.1).

200-North Area. One TLD monitoring site, located in the 200-North Area at the contaminated 212-R Railroad Car Disposition Area, showed a decrease in the annual average dose rate of 22% in 2006 compared to 2005. This TLD location was established in 2000 to monitor expected high radiation levels emitted from contaminated railroad cars staged in the immediate vicinity.

300 and 400 Areas. The average dose rates in the 300 Area, at the 300 Area Treated Effluent Disposal Facility, and in the 400 Area in 2006 were comparable to 2005 levels (Figure 10.13.1).

Dose rate measurements were reinitiated in September 2006 at four locations at the 300-FF-2 field remediation action site in the 300 Area. Dose rates were comparable to typical levels observed at the longer established locations in the 300 and 400 Areas (i.e., approximately 90 mrem [0.9 mSv] per year).

10.13.1.2 Radiological Surveys at Active and Inactive Waste-Disposal Sites

S. M. McKinney

During 2006, 515 environmental radiological surveys were conducted at active and inactive waste-disposal sites and the terrain surrounding them to detect and characterize radioactive surface contamination. Vehicles equipped with radiation detection devices and global positioning systems were used to accurately measure the extent of contamination. Area measurements were entered into the Hanford Geographical Information System, a computer database maintained by Fluor Hanford, Inc. Routine radiological survey locations included former waste-disposal cribs and trenches, retention basin 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. These sites were posted as underground radioactive materials areas, contamination areas, and soil contamination areas. It was estimated that the external dose rate at 80% of the outdoor contamination areas was less than 1 mrem (0.01 mSv) per hour, though direct-dose rate readings from isolated radioactive specks could have been higher.

Underground radioactive materials areas are areas where radioactive materials occur 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. These areas are surveyed at least annually to assess the effectiveness of the barriers.

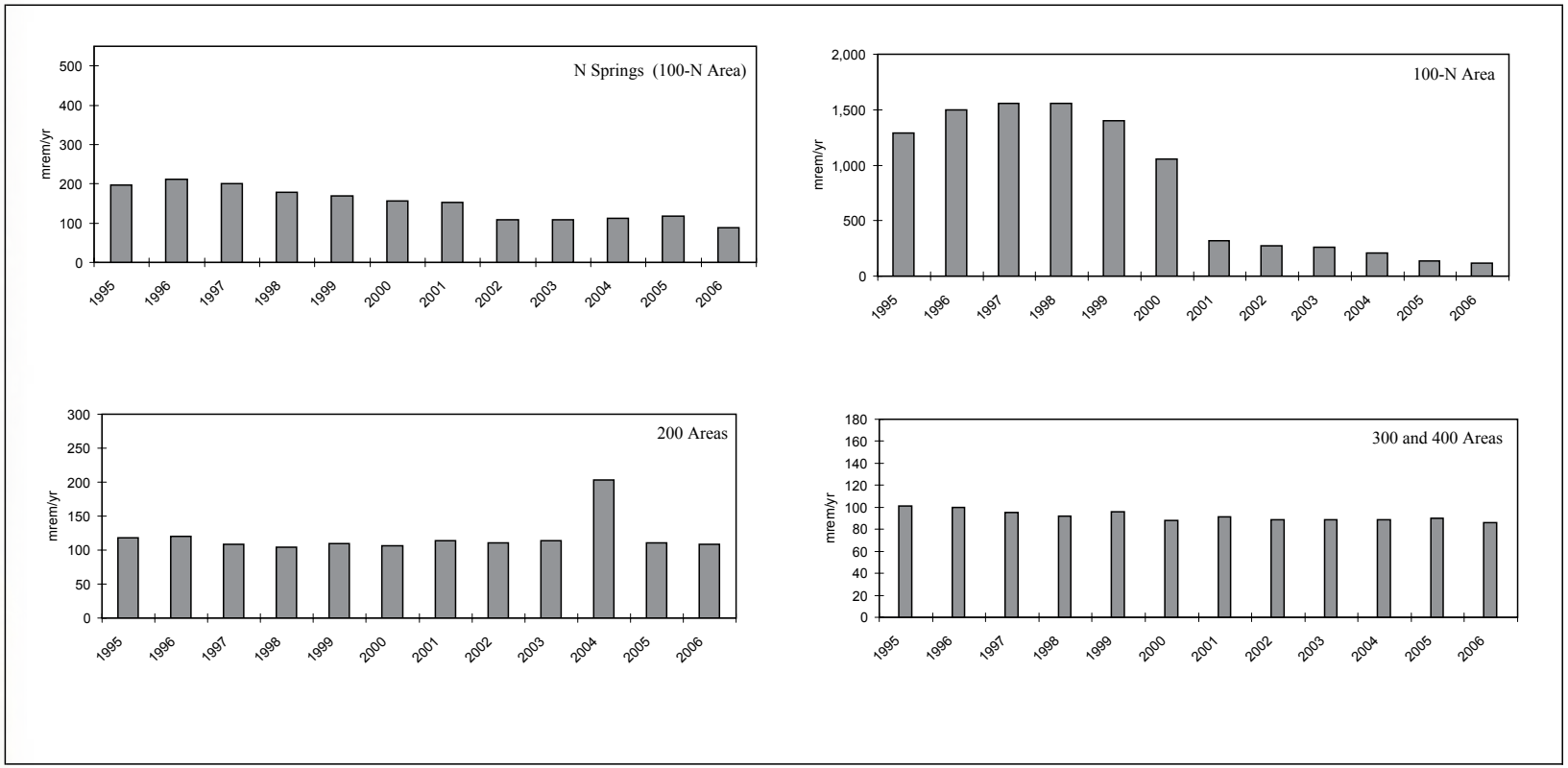

Figure 10.13.1. Annual Average Dose Rates Determined with Thermoluminescent Dosimeters in Selected Operations Areas at the Hanford Site

Contamination areas and soil contamination areas may or may not be associated with an underground structure containing radioactive material. A breach in the surface 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 sources 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 or with materials from unplanned releases (e.g., contaminated tumbleweeds and animal feces).

All contaminated areas may be susceptible to contaminant migration and are surveyed at least annually to assess their current radiological status (locations of posted contamination areas are illustrated in PNNL-16623, APP. 2). In addition, onsite paved roadways are surveyed annually and the intersections along the Environmental Restoration Disposal Facility haul routes are surveyed quarterly.

During 2006, the Hanford Site had approximately 3,583 hectares (8,853 acres) of outdoor contaminated areas of all types and approximately 600 hectares (1,482 acres) that contained underground radioactive materials, not including active facilities. A list of contamination areas, underground radioactive materials areas, interim-closed waste sites, their status, and their general locations is provided in Table 10.13.2. No new areas of significant size were discovered during 2006. Waste sites are "interim closed" and released from radiation posting when the remedial actions meet the operable unit's record of decision cleanup requirements. During 2006, approximately 13 hectares (32 acres) of previously posted contamination and/or underground radioactive materials areas underwent remediation action and were interim closed. Table 10.13.3 summarizes the change in status of outdoor contamination areas during 2006.

Table 10.13.2. Status of Outdoor Contamination Areas at the Hanford Site, 2006

Area	Contamination Areas,[a] ha (acres)		Underground Radioactive Materials Areas,[b] ha (acres)		Interim Closed, ha (acres)	
100-B/C	0	(0)	35	(86)	11	(27)
100-D/DR	0	(0)	22	(54)	6	(15)
100-F	0	(0)	13	(32)	9	(22)
100-H	0	(0)	7	(17)	7	(17)
100-K	5	(12)	45	(111)	20	(49)
100-N	2	(5)	16	(40)	25	(62)
200-East[c]	71	(175)	141	(348)	0	(0)
200-West[c]	27	(67)	224	(554)	0	(0)
300	0	(0)	42	(104)	22	(54)
400	0	(0)	0	(0)	0	(0)
600[d]	3,478	(8,594)	55	(136)	0	(0)
Totals	**3,583**	**(8,853)**	**600**	**(1,482)**	**100**	**(246)**

(a) Includes areas posted as contamination/soil contamination or as radiologically controlled and areas that had both underground radioactive material and contamination/soil contamination.
(b) Includes areas with only underground contamination.
(c) Includes tank farms.
(d) Includes 200-BC Crib Area, Environmental Restoration Disposal Facility, and waste-disposal facilities outside the 200-East and 200-West Areas boundaries.

Table 10.13.3. Change in Status of Outdoor Contamination Areas at the Hanford Site, 2006

Areas	Changes	Area, ha (acres)	
100	CA/URM to interim closed[a]	5	(12)
200-East	None to report	0	(0)
200-West	None to report	0	(0)
300	CA/URM to interim closed[a]	8	(20)
400	None to report	0	(0)
600	None to report	0	(0)

(a) Changes due to remediation activities.
CA = Contamination/soil contamination area.
URM = Underground radioactive material area.

10.13.2 External Radiation Monitoring at Hanford Site-Wide and Offsite Locations

R. W. Hanf

External radiation monitoring and radiation surveys at site-wide, offsite, and Columbia River shoreline locations were

discontinued by the Pacific Northwest National Laboratory at the end of calendar year 2005 because of funding reductions. Data collected at these locations for many years indicate that current radiation levels are at or near background levels, and are stable or decreasing as onsite cleanup activities progress. Readers interested in reviewing measurement and survey readings obtained in 2005 or earlier years should refer to previous Hanford Site environmental reports and their data appendices (see the website at http://hanford-site.pnl.gov/envreport).

10.14 Potential Radiological Doses from 2006 Hanford Site Operations

E. J. Antonio and K. Rhoads

During 2006, potential radiological doses to the public and biota from Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. Potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, liquid effluent from operating wastewater treatment facilities, contaminated groundwater seeping into the Columbia River, and fugitive emissions from contaminated soil areas and facilities. The methods used to calculate the potential doses are detailed in Appendix E.

The radiological impacts of 2006 Hanford Site operations were assessed in terms of the following:

- Dose to a hypothetical, maximally exposed individual at an offsite location, evaluated by using a multimedia pathway assessment (DOE Order 5400.5; Section 10.14.1)
- Collective dose to the population residing within 80 kilometers (50 miles) of Hanford Site operating areas (Section 10.14.2)
- Doses for air pathways, evaluated by using EPA methods, for comparison to the *Clean Air Act* standards in 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (Section 10.14.3)
- Dose to a worker consuming drinking water on the site (Section 10.14.4.2)
- Inhalation dose associated with measured radionuclide concentrations in air (Section 10.14.4.3)
- Doses from non-DOE industrial sources on and near the Hanford Site (Section 10.14.5)
- Absorbed dose received by animals exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies (Section 10.14.6).

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations. However, amounts of most radioactive materials released in 2006 from Hanford Site sources were generally too small to be measured directly after they were dispersed in the offsite environment. For many of the radionuclides present in measurable amounts, it was difficult to separate the contributions due to Hanford Site sources from the contributions due to fallout and naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using *GENII - The Hanford Environmental Radiation Dosimetry Software System*, Version 1.485 (PNL-6584) and the Hanford Site-specific parameters listed in Appendix E and in PNNL-16623, APP. 1.

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 2006, tritium and two uranium isotopes were found in the Columbia River downstream of the Hanford Site at greater levels than predicted based on direct discharges from the 100-K Area (Section 10.4 and Appendix C). All other radionuclide concentrations in river water were lower than those predicted from known releases. Columbia River shoreline spring water containing radionuclides is known to enter the river along the portion of the site shoreline extending from the 100-B/C Area downstream to the 300 Area (Sections 10.5 and 10.7). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported during 2006.

10.14.1 Maximally Exposed Individual Dose (Offsite Resident)

The maximally exposed individual is a hypothetical person who lives at a particular location and has a lifestyle that makes it unlikely that any member of the public would have received a higher radiological dose from Hanford Site releases during 2006. 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 exposures to radioactive materials is highly unlikely to apply to any single individual.

The location of the hypothetical, maximally exposed individual varies depending on the relative contributions of the several sources of radioactive emissions released to the air and liquid effluents released to the Columbia River from Hanford Site facilities (Figure 10.14.1). During 2006, the dose assessment determined that the maximally exposed individual was located across the Columbia River (east of the Hanford Site) at Sagemoor (Figure 10.14.1). For the calculation, it was assumed this individual:

- Inhaled and was surrounded by airborne radionuclides
- Received external exposure to radionuclides deposited on the ground
- Consumed locally grown food products
- Used the Columbia River near the Hanford Site for recreational purposes, resulting in direct exposure from radionuclides in water and radionuclides deposited on the shoreline
- Consumed locally caught Columbia River fish.

Doses were calculated using Hanford Site air emissions and effluent data (Tables 10.1.1 and 10.3.2) and the calculated quantities of radionuclides assumed to be present in the Columbia River from shoreline spring discharges along the site shoreline. The estimated radionuclide releases to the Columbia River from these sources were derived from the difference between the upstream and downstream radionuclide concentrations in river water. These radionuclides were assumed to originate from historical releases of contaminants to the ground in the 100 and 200 Areas, and to have entered the Columbia River through shoreline groundwater springs between the 100-B/C Area and the 300 Area.

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, and food) that maximize a hypothetical individual's offsite exposure to Hanford's radiological effluent 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 the 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 may be different. However, the estimated doses from both methods have historically been significantly lower than health-based exposure criteria.

Recently, the DOE has allowed private businesses to locate their activities and personnel on the Hanford 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 food, water, and air pathways and is calculated for the population residing within 80 kilometers (50 miles) of the Hanford Site operating areas. The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population.

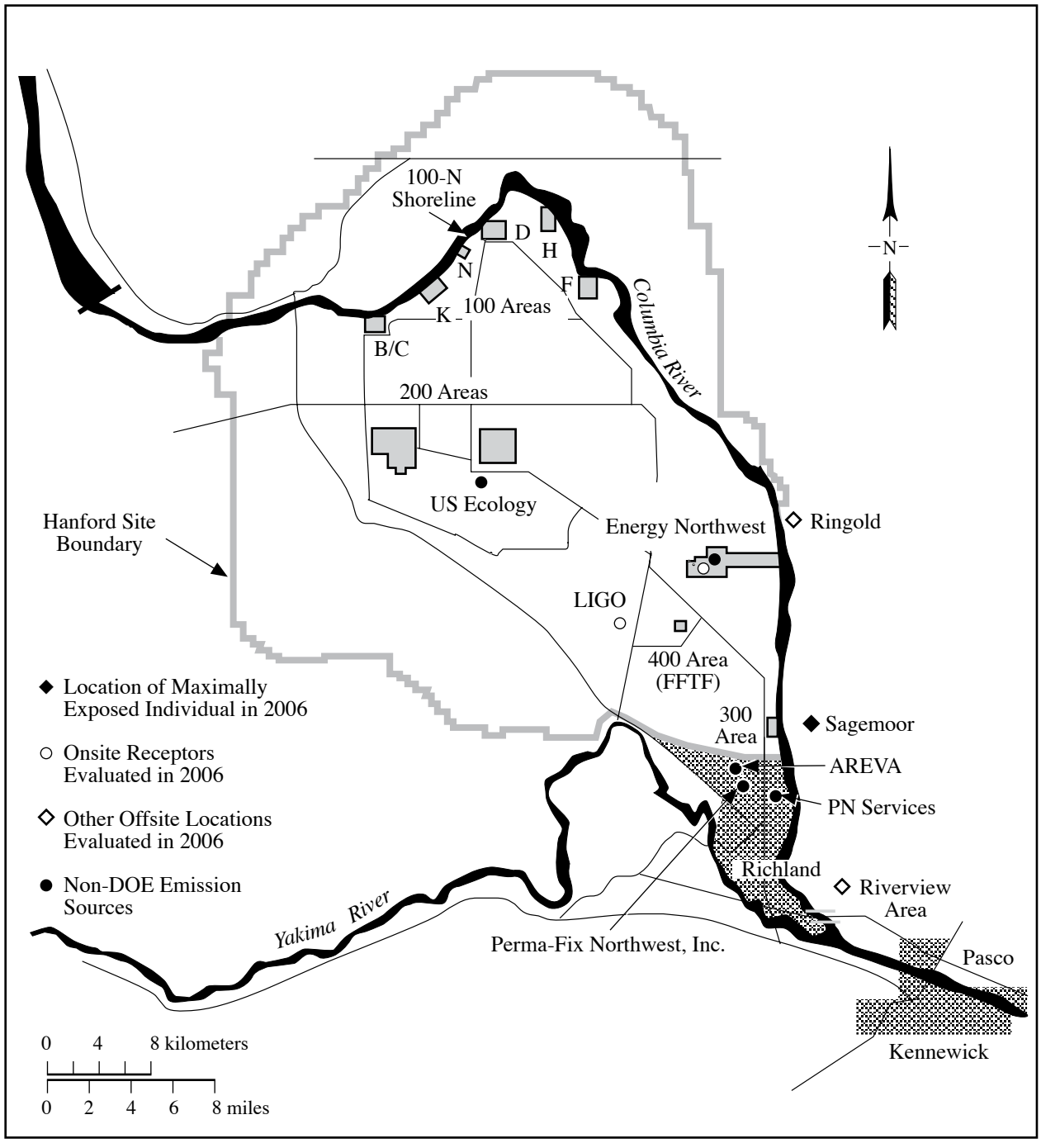

Figure 10.14.1. Locations Important to Dose Calculations at the Hanford Site, 2006

During 2006, the total dose to the maximally exposed individual at Sagemoor (Figure 10.14.1) was calculated to be 0.068 mrem (0.68 µSv) per year (Table 10.14.1). This dose was 0.068% of the 100-mrem (1-mSv) per-year standard specified in DOE Order 5400.5 (Figure 10.14.2.). The primary pathways (Appendix E, Tables E.1, E.2, and E.4) contributing to this dose (and the percentage of all pathways) were as follows:

- The inhalation of air downwind of the Hanford Site (11%) and the consumption of food products grown downwind of the site (approximately 81%), resulting in exposure to airborne releases of tritium and radon from the 300 Area.
- The consumption of foods irrigated with Columbia River water withdrawn downstream of the Hanford Site (4%) and the consumption of fish from the Columbia River (3%), resulting in exposure to tritium and uranium isotopes in the river.

10.14.2 Collective Dose

Collective dose is defined as the sum of doses to all individual members of the public within 80 kilometers (50 miles) of Hanford Site operating areas. The regional collective dose from 2006 Hanford Site operations was estimated by calculating the radiological dose to the population residing within an 80-kilometer (50-mile) radius of onsite operating areas. During 2006, the collective dose calculated for the population was 0.65 person-rem (0.0065 person-Sv) per year (Table 10.14.2; Figure 10.14.3), which is about 40% higher than the 2005 collective dose (0.46 person-rem [0.0046 person-Sv]) per year (Appendix E, Tables E.5 to E.10).

Primary pathways contributing to the 2006 collective dose (and the percentage of all pathways) included the following:

- Inhalation of radionuclides that were released to the air, principally tritium and radon from the 300 Area and iodine-129 from the 200 Areas (17%), and consumption of food grown downwind of the Hanford Site (approximately 62%).
- The consumption of water withdrawn from the Columbia River downstream of the Hanford Site (20%) and foods irrigated with water withdrawn from the Columbia River downstream of the site (approximately 0.5 %) containing principally tritium, uranium-234, and uranium-238.

Collective doses reported for 2006 are based on population data from the 2000 census. The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population. Between 1990 and 2000, the population within 80 kilometers (50 miles) of the major Hanford Site operating areas increased by 24% to 29%.

Table 10.14.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Sagemoor from 2006 Hanford Site Operations

		Dose Contributions from Operating Areas, mrem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	6.6×10^{-10}	3.7×10^{-7}	3.2×10^{-4}	2.5×10^{-8}	3.2×10^{-4}
	Inhalation	5.4×10^{-5}	6.5×10^{-5}	7.7×10^{-3}	1.0×10^{-5}	7.8×10^{-3}
	Foods	1.5×10^{-6}	2.9×10^{-4}	5.5×10^{-2}	8.2×10^{-6}	5.5×10^{-2}
	Subtotal air	**5.6×10^{-5}**	**3.6×10^{-4}**	**6.3×10^{-2}**	**1.8×10^{-5}**	**6.3×10^{-2}**
Water	Recreation	5.7×10^{-8}	2.8×10^{-5}	0.0	0.0	2.8×10^{-5}
	Foods	2.9×10^{-5}	2.7×10^{-3}	0.0	0.0	2.7×10^{-3}
	Fish	2.4×10^{-5}	1.9×10^{-3}	0.0	0.0	1.9×10^{-3}
	Subtotal water	**5.3×10^{-5}**	**4.6×10^{-3}**	**0.0**	**0.0**	**4.7×10^{-3}**
Combined total		**1.1×10^{-4}**	**5.0×10^{-3}**	**6.3×10^{-2}**	**1.8×10^{-5}**	**6.8×10^{-2}**

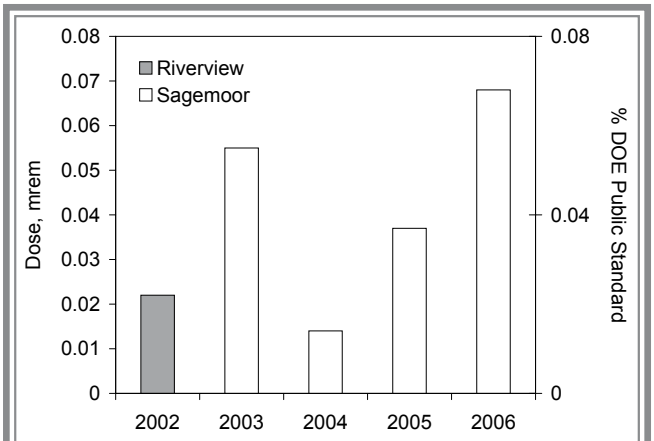

Figure 10.14.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual Near the Hanford Site, 2002 Through 2006

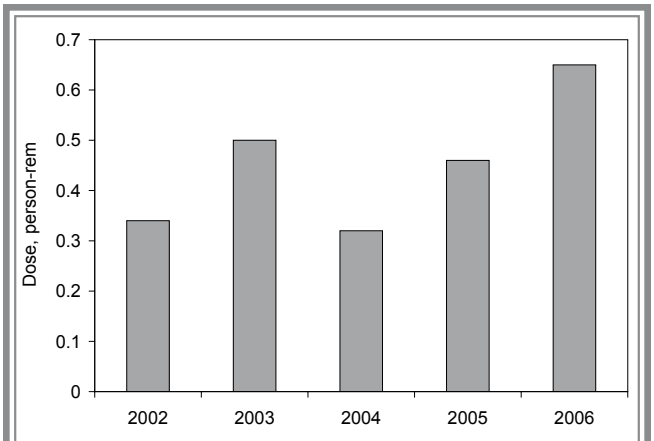

Figure 10.14.3. Collective Dose to the Population within 80 Kilometers (50 miles) of Hanford Site Operating Areas, 2002 Through 2006

The average individual dose from Hanford Site operations, based on a population of 486,000 within 80 kilometers (50 miles) of the site, was about 0.001 mrem (0.01 μSv) in 2006. 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, natural radionuclides in the body, and inhalation of naturally occurring radon (Figure 10.14.4). The estimated annual average individual dose to members of the public from Hanford Site sources in 2006 was approximately 0.0004% of the estimated annual individual dose received from natural background sources (300 mrem). The calculated radiological doses from Hanford Site operations in 2006 were a small percentage of the federal standards and of doses from natural background sources (Table 10.14.3).

10.14.3 Compliance with *Clean Air Act* Standards

In addition to complying with the all-pathways dose limits established by DOE Order 5400.5, officials managing DOE facilities are required to demonstrate their facilities comply with standards established by the EPA for airborne radionuclide emissions under the *Clean Air Act* in 40 CFR 61,

Table 10.14.2. Collective Dose to the Population from 2006 Hanford Site Operations

		Dose Contributions from Operating Areas, person-rem				
Effluent	**Pathway**	**100 Areas**	**200 Areas**	**300 Area**	**400 Area**	**Pathway Total**
Air	External	1.2×10^{-7}	3.2×10^{-5}	3.8×10^{-3}	1.1×10^{-6}	3.8×10^{-3}
	Inhalation	1.5×10^{-2}	8.3×10^{-3}	8.8×10^{-2}	7.0×10^{-4}	1.1×10^{-1}
	Foods	2.0×10^{-4}	2.6×10^{-2}	3.7×10^{-1}	3.3×10^{-4}	4.0×10^{-1}
	Subtotal air	**1.5×10^{-2}**	**3.4×10^{-2}**	**4.6×10^{-1}**	**1.0×10^{-3}**	**5.1×10^{-1}**
Water	Recreation	4.3×10^{-7}	1.6×10^{-4}	0.0	0.0	1.6×10^{-4}
	Foods	3.0×10^{-5}	2.9×10^{-3}	0.0	0.0	2.9×10^{-3}
	Fish	8.9×10^{-6}	7.2×10^{-4}	0.0	0.0	7.3×10^{-4}
	Drinking water	1.4×10^{-4}	1.3×10^{-1}	0.0	0.0	1.3×10^{-1}
	Subtotal water	**1.8×10^{-4}**	**1.3×10^{-1}**	**0.0**	**0.0**	**1.3×10^{-1}**
Combined total		**1.5×10^{-2}**	**1.7×10^{-1}**	**4.6×10^{-1}**	**1.0×10^{-3}**	**6.5×10^{-1}**

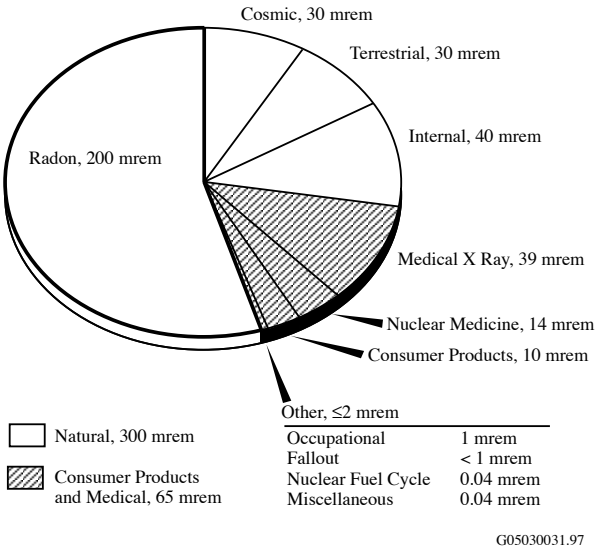

Figure 10.14.4. Annual National Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

Subpart H. This regulation specifies that no member of the public shall receive a dose greater than 10 mrem (0.1 mSv) per year from exposure to airborne radionuclide emissions (other than radon) released at DOE facilities. Whereas the DOE uses the GENII computer code at the Hanford Site to determine dose to the all-pathways maximally exposed individual, the EPA requires the use of the CAP-88 computer code (EPA 402-R-00-004) or other EPA-approved computer models to demonstrate compliance with the requirements in 40 CFR 61, Subpart H. The assumptions embodied in the CAP-88 computer code differ slightly from standard assumptions used with the GENII computer code. Therefore, air-pathway doses calculated by the two codes may differ somewhat. In addition, the maximally exposed individual for air pathways may be evaluated at a different location from the all-pathways maximally exposed individual because of the relative contributions from each exposure pathway (Section 10.14.1).

The EPA regulation also requires that an annual report for each DOE facility be submitted to the EPA that supplies information about atmospheric emissions for the preceding year and their potential contributions to offsite dose. For more detailed information about 2006 air emissions at the Hanford Site, refer to the DOE's report to the EPA, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2006* (DOE/RL-2007-01).

Table 10.14.3. Comparison of 2006 Doses to the Public from Hanford Site Effluent and Emissions to Federal Standards and Natural Background Levels

Federal Standard	Hanford Dose[a]	Percent of Standard or of Background Dose
DOE - 100 mrem/yr all pathways MEI[b]	0.068 mrem/yr	0.068
EPA - 10 mrem/yr air pathway MEI[c]	0.066 mrem/yr	0.66
Background Dose		
300 mrem/yr average U.S. individual[d]	0.004 mrem/yr	0.001
145,800 person-rem/yr to population within 80 km (50 mi)	0.65 person-rem/yr	0.0004

(a) To convert the dose values to mSv or person-Sv, divide by 100.
(b) DOE Order 5400.5.
(c) 40 CFR 61.
(d) National Council on Radiation Protection and Measurements (1987).
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
MEI = Maximally exposed individual.

10.14.3.1 Dose to an Offsite Maximally Exposed Individual

Using EPA-specified methods, the maximally exposed offsite individual for air pathways in 2006 was determined to be at a location in the Sagemoor area of Franklin County, approximately 1.4 kilometers (0.8 mile) east of the 300 Area, across the

Columbia River (Figure 10.14.1). The potential air pathway dose from stack emissions to a maximally exposed individual at that location calculated using the CAP-88 computer code was determined to be 0.066 mrem (0.00066 mSv) per year, which represented less than 0.7% of the EPA standard. This is similar to the offsite individual doses calculated for the EPA in previous years and to the air pathway doses for stack emissions in Table 10.14.1.

The dose from radon-220 and radon-222 amounted to 0.0021 mrem (0.000021 mSv) in 2006. Radon is not included in the dose calculated for compliance with the EPA standard in 40 CFR 61, but is regulated by the 10-mrem (0.1-mSv) per year standard established by Washington State in WAC 246-247.

10.14.3.2 Maximum Dose to Non-U.S. Department of Energy Workers at the Hanford Site

The DOE Richland Operations Office received guidance from the EPA's Region 10 office and the Washington State Department of Health that, in demonstrating compliance with 40 CFR 61 standards, it should evaluate potential doses to non-DOE employees who work at 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 (those requiring DOE-access authorization for entry) were evaluated for the 2006 EPA air emissions report (DOE/RL-2007-01). These locations included the Columbia Generating Station operated by Energy Northwest and the Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California (Figure 10.14.1). Of those locations, an employee at LIGO received the highest dose for non-DOE employees who worked at the Hanford Site. The dose from stack emissions calculated using the CAP-88 computer code was 0.0028 mrem (0.000028 mSv) per year, assuming full-time occupancy.

EPA guidance does not currently allow for adjustment of doses calculated using the CAP-88 computer code to account for less than full-time occupancy at locations within the Hanford Site boundary. However, if an occupancy period of 2,000 hours per year was assumed for workers at onsite non-DOE facilities, the doses to individuals at any of the locations evaluated would be lower than the dose reported for LIGO. In 2006, the estimated doses to all non-DOE onsite workers were lower than the dose to an offsite maximally exposed individual.

10.14.3.3 Dose from Diffuse and Fugitive Radionuclide Emissions

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. The DOE and EPA interpreted the regulation to include diffuse (widespread) and fugitive (unintended) emissions, as well as emissions from monitored point sources (i.e., stacks). The EPA has not specified or approved standardized methods to estimate diffuse air-emissions because of the wide variety of sources at DOE sites. The method developed at the Hanford Site to estimate potential diffuse emissions is based on environmental monitoring measurements of airborne radionuclides at the site perimeter (DOE/RL-2007-01). During 2006, the estimated dose from diffuse emissions to a maximally exposed individual at a location in the Sagemoor area was calculated using the CAP-88 computer code to be 0.038 mrem (0.00038 mSv) per year. This is consistent with results for recent years, where the dose from diffuse emissions has been similar to the dose from stack emissions because radionuclide emissions from Hanford Site facilities are currently very low. The dose to an onsite non-DOE worker from diffuse and fugitive emissions would be similar to, or lower than, the dose at the site perimeter. Therefore, the potential combined dose from stack emissions and diffuse emissions during 2006 was well below the EPA 10-mrem (0.1-mSv) per year standard for either onsite or offsite members of the public.

10.14.4 Special-Case Dose Estimates

The parameters used to calculate the dose to the maximally exposed individual were selected to provide a scenario yielding a reasonable upper (or bounding) dose estimate. 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. Three scenarios that could have potentially led to larger doses included 1) a person who consumed contaminated wildlife that migrated from the Hanford Site, 2) a person who drank water at the Fast Flux Test Facility in the 400 Area, and 3) individuals at various locations who breathed the measured radionuclide concentrations in air for an entire year. The potential doses resulting from these scenarios are examined in the following sections. A fourth scenario where an individual would spend time at the Hanford Site boundary location with the maximum external radiological dose rate was not evaluated for 2006 because external radiation surveillance by the Pacific Northwest National Laboratory, on and around the site, was discontinued in December 2005.

10.14.4.1 Outdoor Recreationalist Dose

Wildlife have access to Hanford Site areas that are contaminated with radioactive materials. Wildlife have the potential to 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 the site that were hunted or fished off the site. Because this scenario had a relatively low probability of occurrence, this pathway was not considered in the maximally exposed individual calculation.

Radionuclides detected in routinely collected wildlife samples during 2006 included potassium-40, a primordial radioisotope not of Hanford Site origin. Strontium-90 was measured only in animal bone or carcass samples, which are not routinely consumed; therefore, it was not considered further. Uranium-234 was detected in sucker muscle samples collected upstream of the Hanford Site, and uranium-234 and uranium-238 were detected in two separate suckers collected near the 300 Area. The dose from consuming the fish collected upstream of the Hanford Site was not calculated. The dose from consuming 1 kilogram (2.2 pounds) of muscle from the 300 Area fish, containing 0.006 pCi/g (0.0002 Bq/g) uranium-234 and 0.00292 pCi/g (0.0001 Bq/g) uranium-238, would be about 0.0002 mrem (0.002 µSv).

10.14.4.2 Onsite Drinking Water

During 2006, groundwater from 400 Area wells was used as drinking water by workers in the Fast Flux Test Facility. Columbia River water was used for drinking water in the 100 and 200 Areas. Drinking water was sampled and analyzed throughout the year in accordance with applicable regulations (40 CFR 141). All annual average radionuclide concentrations measured during 2006 were below applicable drinking water standards. However, tritium in the Fast Flux Test Facility groundwater wells was detected at levels greater than typical background values, and radium-228 and strontium-90 were identified in the 100-K and 100-N Areas drinking water (Section 10.6).

Based on the measured concentrations, the potential annual dose to a worker at the Fast Flux Test Facility in 2006 would be approximately 0.4 mrem (4 µSv). This dose estimate was derived by assuming a consumption rate of 1 liter (0.26 gallon) per day for 240 working days and is well below the drinking water dose limit of 4 mrem (40 µSv) per year for public drinking water supplies. Doses from the 100-K and 100-N Areas water supplies would be lower than at the Fast Flux Test Facility.

10.14.4.3 Inhalation Doses for Entire Year

A nominal inhalation rate of 23 cubic meters (812 cubic feet) per day of air and an exposure period of 8,766 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 cubic meters (1,017 cubic feet) per day to account for light-duty work.

Table 10.14.4 presents radiological inhalation doses to hypothetical offsite individuals modeled to be in the same location for the entire year and to onsite individuals located near site-wide air monitoring stations during their workday. The average radionuclide concentrations measured at the site-wide air monitoring stations were used in the calculations (Table 10.2.3) and assumed to be constant for the year-long evaluation period. Inhalation doses calculated using this method ranged from 0.0015 mrem (0.000015 µSv) in the 300 Area to 0.036 mrem (0.00036 mSv) at the site perimeter. These were comparable to doses calculated using the CAP-88 computer code and reported for various air pathways (Section 10.14.3).

Table 10.14.4. Inhalation Doses On and Around the Hanford Site Based on 2006 Average Air Surveillance Data[a]

Radionuclide	Group	Dose (mrem/yr)[b,c]
Tritium	Onsite	6.2×10^{-4}
	300 Area	1.5×10^{-3}
	Perimeter	4.2×10^{-3}
	Nearby communities	7.5×10^{-3}
	Distant community	1.5×10^{-3}
Uranium-238	Onsite	5.3×10^{-3}
	Perimeter	2.0×10^{-2}
	Nearby communities	1.8×10^{-2}
	Distant community	1.2×10^{-2}
Plutonium-239	Onsite	5.5×10^{-3}
	Perimeter	1.2×10^{-2}
Totals	Onsite	1.1×10^{-2}
	300 Area	1.5×10^{-3}
	Perimeter	3.6×10^{-2}
	Nearby communities	2.5×10^{-2}
	Distant community	1.4×10^{-2}

(a) Onsite inhalation dose calculations were based on a 2,000-hour exposure period and a 1.2 m^3/hr breathing rate; all offsite inhalation dose calculations were based on an 8,766-hour exposure period and a 0.958 m^3/hr 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.
(c) To convert to international metric system units (mSv/yr), divide reported values by 100.

10.14.5 Doses from Non-DOE Sources

DOE Order 5400.5, Chapter II, paragraph 7, has a reporting requirement for a combined dose due to DOE and other man-made sources that exceeds 100 mrem (1 mSv) per year. During 2006, 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 the Hanford Site operated by US Ecology; a nuclear power-generating station at the Hanford Site operated by Energy Northwest; a nuclear-fuel production plant operated near the site by AREVA NP; a commercial, low-level, radioactive waste treatment facility operated near the site by Pacific EcoSolutions, Inc. (now Perma-Fix Northwest, Inc.); and a commercial decontamination facility operated near the site by PN Services (Figure 10.14.1).

The 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 (0.1 mSv) per year 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 2006 individual dose from their combined activities was less than 0.02 mrem (0.0002 mSv) per year. Therefore, the combined annual dose from non-DOE and DOE sources on and near the site to a member of the public for 2006 was well below any regulatory dose limit.

10.14.6 Dose Rates to Animals

Upper estimates of the radiological dose to aquatic organisms were made in accordance with the DOE Order 5400.5 interim requirement for management and control of liquid discharges. The current dose limit for native-aquatic animal organisms is 1 rad (10 mGy) per day. The proposed dose limit for terrestrial biota is 0.1 rad (1 mGy) per day.

Concentration guides for assessing doses to biota are very different from the DOE-derived concentration guides that are used to assess radiological doses to humans. A screening method is used to estimate radiological doses to aquatic and terrestrial biota. This method uses the RESRAD-BIOTA computer code (DOE/EH-0676; DOE/STD-1153-2002) to compare radionuclide concentrations measured by routine monitoring programs to a set of conservative biota concentration guides (e.g., the water concentration of a radionuclide that would produce 1 rad [10 mGy] 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. If the initial estimated screening value (Tier 1) exceeds the guideline (sum of fractions >1.0), another screening calculation is performed (Tier 2) 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. Biota-dose screening assessments were conducted using surveillance data collected in 2006 from on and around the Hanford Site.

Maximum concentrations of radionuclides measured in sediment, onsite pond water, and Columbia River shoreline spring water were evaluated using the RESRAD-BIOTA computer code. Riverbank springs carry groundwater contaminants into the Columbia River at greater concentrations than observed in river water and provide another level of conservatism in the biota dose assessment process. The results of the screening calculations indicated that the concentrations in all Columbia River spring water and sediment samples passed the Tier 1 screen, indicating that the calculated doses were below the dose limits and guidelines (sum of fractions <1.0) (Table 10.14.5). Only the onsite location, West Lake, required a Tier 2 calculation. Tier 2 of the RESRAD BIOTA code employs mean concentrations rather than maximum concentrations. West Lake passed the Tier 2 screening with a sum of fractions of 0.47.

10.14.7 Radiological Dose in Perspective

Scientific studies (National Research Council 1980, 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) have been performed to estimate the possible risk from exposure to low levels of radiation. These studies provided information to government and scientific organizations and are used to 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 cautiously assume that the probability of these types of health effects occurring due to exposure to low doses (down to zero dose) is the same per unit dose as the health effects observed after an exposure to much higher doses (e.g., in atomic bomb survivors, individuals receiving medical exposure, 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 individual's probability or chance of developing a detrimental health effect.

Scientists do not agree on how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low radiological doses. Some scientific studies have indicated that low radiological doses result in beneficial effects (Sagan 1987). Because cancer and hereditary diseases in the general population are caused by many sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be proven conclusively. In developing *Clean Air Act* regulations, the EPA used a probability value of approximately 4 per 10 million (0.0004) 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

Table 10.14.5. Results of Using the RESRAD-BIOTA[a] Computer Code to Estimate Radiological Doses to Biota On and Around the Hanford Site, Using 2006 Onsite Pond Water, Columbia River Shoreline Spring Water, and River and Pond Sediment, as Available

Location	Tier 1 Screen Sum of Fractions[b]	Pass or Fail	Tier 2 Screen Sum of Fractions[b]	Pass or Fail
100-B Area	0.0128	Pass		
100-D Area	0.0080	Pass		
100-F Area	0.105	Pass		
100-H Area	0.0259	Pass		
100-K Area	0.00426	Pass		
100-N Area	0.0000335	Pass		
300 Area	0.549	Pass		
Hanford town site/slough	0.0430	Pass		
McNary Dam sediment	0.22	Pass		
Priest Rapids Dam sediment	0.179	Pass		
Richland	0.0783	Pass		
West Lake sediment	1.08	Fail	0.465	Pass
White Bluffs Slough	0.116	Pass		

(a) A screening method to estimate radiological doses to aquatic and terrestrial biota.
(b) A sum of fractions is calculated to account for the contribution to dose from each radionuclide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded and further screening (Tier 2) is required.

the dose is spread over an extended time. Recent guidance from the Interagency Steering Committee on Radiation Standards [ISCORS 2002] recommended a risk factor of 6 per 10 million for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv).

Government agencies are trying to determine what exposure level is safe for members of the public exposed to pollutants from industrial operations (e.g., DOE facilities, nuclear power plants, chemical plants, and hazardous waste sites). All of these industries are considered beneficial to the public 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 airplane accident. Table 10.14.6 compares the estimated risks from various radiological doses to the risks of some activities encountered in everyday life. Some activities that are estimated to be approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford Site effluents and emissions during 2006 are shown in Table 10.14.7.

Table 10.14.6. Estimated Risk from Various Activities and Exposure[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 ~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 radiological 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 4.0×10^{-5}
Dose to the hypothetical, maximally exposed individual living near the Hanford Site	4×10^{-8}

(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 radiological dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Table 10.14.7. Activities Comparable in Risk to the 0.068-mrem (0.0068-mSv) Dose Calculated for the Hanford Site Maximally Exposed Individual in 2006

Driving or riding in a car 0.1 km (0.061 mi)	Eating one 270-g (9.5-oz) charcoal-broiled steak
Smoking less than 1/1,000 of a cigarette	Drinking 100 ml (3.4 oz) of chlorinated tap water
Flying 0.25 km (0.16 mi) on a commercial airliner	Drinking 1.7 ml (0.06 oz) of wine or 5 ml (0.17 oz) of beer
Eating 0.075 Tbsp of peanut butter	

10.15 Cultural and Historic Resources Monitoring

E. P. Kennedy

Cultural and historic resources monitoring on DOE-managed portions of the Hanford Site is conducted under the auspices of the Richland Operations Office's Hanford Cultural and Historic Resources Program to assure site compliance with federal cultural resources laws and regulations (see Section 5.4.2). Program activities in 2006 included the following:

- Performing cultural resources reviews for all federal undertakings conducted at the Hanford Site in accordance with Section 106 of the *National Historic Preservation Act* and the *National Environmental Protection Act*
- Monitoring cultural resources conditions to assure that important resources were protected
- Maintaining a database of cultural resource site records, project records, and regional ethnohistory
- Maintaining archaeological and historical collections
- Identifying and evaluating new cultural resources so that they could be managed appropriately
- Consulting with Indian Tribes and stakeholders to gather input on the identification, documentation, and management of cultural resources important to them.

The DOE's Cultural and Historic Resources Program oversees all cultural resource activities at the Hanford Site. The majority of technical work is performed for the DOE by Pacific Northwest National Laboratory; Washington Closure Hanford LLC; and the Columbia River Exhibition of History, Science, and Technology (CREHST) Museum.

10.15.1 Cultural Resources Reviews

Pursuant to the *National Environmental Policy Act* and Section 106 of the *National Historic Preservation Act*, the DOE conducts cultural resources reviews of all federal activities with potential to cause effects to cultural resources at the Hanford Site. Cultural resources reviews assure that important cultural resources are identified and impacts to those resources are evaluated so that mitigation measures can be conducted.

During 2006, 165 Hanford Site cultural-resources review requests were received. The Pacific Northwest National Laboratory received 80 review requests and Washington Closure Hanford LLC received 85 review requests. Upon initial review, the DOE determined that 144 of the 165 activities were not the type with the potential to cause effects and, therefore, were exempt from full review. Examples of these activities included small excavations, such as routine maintenance activities in previously disturbed areas, especially those located within the fence lines of existing operable units. The largest number of activities determined to have no potential to cause effects were located in the 100 Areas in 2006 (Figure 10.15.1).

Six review requests were exempted from full cultural review by the *Programmatic Agreement Among the U.S. Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the*

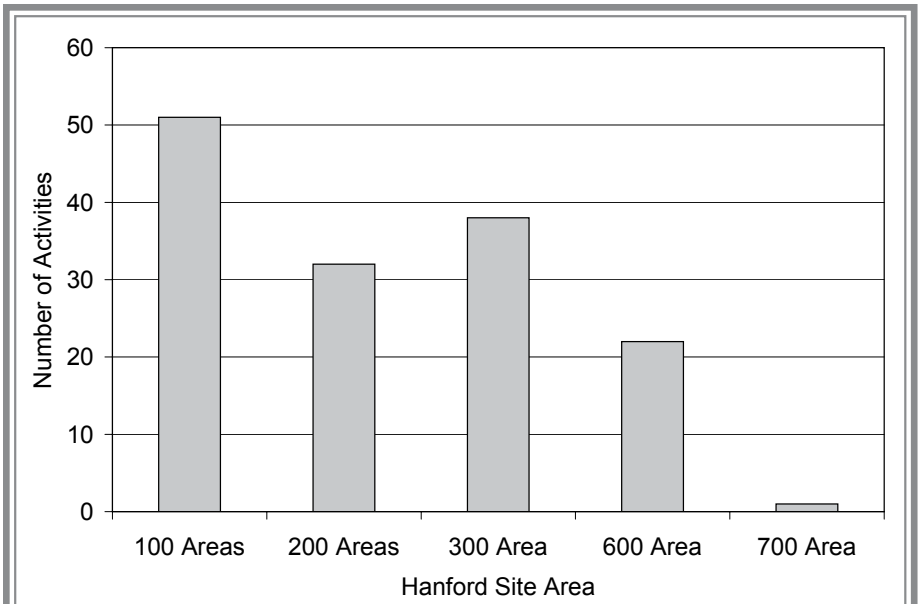

Figure 10.15.1. Number of Activities that were Reviewed in 2006 and were Determined to be Activities with No Potential To Cause Effects to Hanford Site Cultural Resources

Hanford Site, Washington (DOE/RL-96-77, Rev. 0). This programmatic agreement exempts routine modifications to Hanford Site buildings that are eligible for the National Register of Historic Places. Modifications that are exempt include routine maintenance, energy conservation measures, or materials replacements when materials are used that match the original materials used in the structure in terms of dimensions, detail, and color.

The remaining 15 activities required full reviews because they involved undisturbed ground, areas that had not been surveyed in the past, or locations in close proximity to known cultural resources. The full reviews involved efforts to identify cultural resources that might be affected by the activity, assess potential impacts, and develop mitigation measures, if necessary (Table 10.15.1). Some of the full reviews required new areas (approximately 115 hectares [285 acres]) to be surveyed for cultural resources. Others required cultural resources monitoring of project excavations.

10.15.2 Cultural Resources Protections

Activities to assure protection of Hanford Site cultural resources are conducted to comply with Section 110 of the *National Historic Preservation Act*, the *Native American Graves Protection and Repatriation Act*, and the *Archaeological Resources Protection Act*. The Hanford Site has had a monitoring program since 1987 to assess the effects of weathering and erosion or unauthorized excavation and collection upon the site's significant cultural resources. Activities include onsite inspections of important cultural resource sites to monitor site conditions, assess impacts, if any, and respond with protective measures when an impact is significant. In 2006, 17 cultural resource sites were visited.

Cultural resource site visits were conducted with the participation of tribal cultural resources personnel. Although there were no major impacts noted at the sites that were visited, minor impacts due to recreation, natural erosion, and animal activity were recorded in 2006. The DOE also continued to visit Locke Island, located in the Hanford Reach of the Columbia River, to measure river-caused erosion so protective measures can be taken if erosion rates begin to increase. In 2006, erosion was still occurring at a measurable rate on the island, and in certain areas, large blocks of bank sediment were toppling into the Columbia River. Erosion resulted in the exposure and loss of an archaeological feature consisting of fire-cracked rock (possibly a fire hearth) and revealed another fire-cracked rock feature in a separate location. One technical report regarding ways to anticipate bank loss and mitigate the loss of cultural material at Locke Island was published in 2006 (PNNL-15941).

10.15.2.1 Identification and Evaluation Activities

Identification and evaluation activities are performed to comply with Sections 106 and 110 of the *National Historic Preservation Act*. In 2006, three new archaeological sites and three new isolated finds were recorded. A collaborative effort between cultural resources personnel from The

Table 10.15.1. Full Cultural Resources Reviews Conducted on the Hanford Site in 2006

Reviewing Organization	Proposed Activity	Field Survey?	Survey Size (hectares [acres])	Review Finding
PNNL	Planting of sagebrush seedlings for habitat mitigation for the Integrated Disposal Facility	Yes	272 [672]	No historic properties located
PNNL	Sagebrush mitigation for the L-325 transmission line (north of the 200-BC Cribs Area cutoff road), 600 Area	Yes	13 [32]	No historic properties located
PNNL	Easement to city of Richland for upgrades to the Horn Rapids Road and Steven's Drive intersection, 600 Area	No	0	No adverse effect to Hanford Site plant railroad
PNNL	U.S. Navy reactor transport route improvements, 600 Area	No	0	No adverse effect to Hanford irrigation ditch
PNNL	Lightening protection upgrades to four telecommunications repeater buildings, 600 Area	No	0	Conditional adverse effect to Rattlesnake Mountain
PNNL	Upgrades to the 100-B Area export water system	No	0	No historic properties located
PNNL	100-K Area well drilling and pump-and-treat process building, west of the 100-K Area	No	0	No historic properties located
PNNL	100-KR-4 pump-and-treat expansion - construction of three 100-KR-4 pump-and-treat buildings, 100-K Area	No	0	Cultural resources mitigation plan will be followed
PNNL	Replacement of four wood poles along the Midway Benton # 1 line and the Benton B3-S4	No	0	No historic properties located
PNNL	Right-of-way access road upgrades under the Benton-451B transmission line, 600 Area	No	0	No historic properties located
PNNL	Two 200-B-1 monitoring wells to be drilled in the 600 Area	No	0	No historic properties located
WCH	105-B Reactor roof replacement	No	0	No adverse effect to B Reactor
WCH	Remedial design for solid waste site 600-202	No	0	Monitoring to be conducted
WCH	Remediation of waste sites and unplanned releases in the northwest section of the 300 Area	No	0	Monitoring to be conducted
WCH	Remedial design for solid waste site 300-275	No	0	Monitoring to be conducted

PNNL = Pacific Northwest National Laboratory.
WCH = Washington Closure Hanford LLC.

Confederated Tribes and Bands of the Yakama Indian Nation Environmental Restoration and Waste Management Program and cultural resources personnel from the Pacific Northwest National Laboratory was initiated to complete a determination of eligibility for listing in the National Register of Historic Places for Rattlesnake Mountain, a traditional cultural property sacred to area tribes.

Pacific Northwest National Laboratory personnel also pursued the use of magnetometry as a non-invasive way to characterize buried archaeological deposits. A controlled field experiment was conducted at an archaeological site to typify the magnetic signature of fire-cracked rock features. Knowledge from this experiment was applied to a large-scale magnetic investigation on another archaeological site as part of a cultural review.

10.15.2.2 Data Recovery Activities

Washington Closure Hanford LLC personnel conducted two data recovery excavations in 2006. A roasting platform (i.e., a fire-cracked rock feature) and a small shell lens were discovered during monitoring of remedial actions at a former waste-disposal site. The roasting platform was dated to 570 ± 50 radiocarbon years before the present (B. P.), while the shell lens was dated at 8,270 ± 100 B. P. The results of the data recovery are documented in *Archaeological Activity Report: Post-Review Discoveries within 45BN431 at Solid Waste Site 128-F-2* (WCH-142, Rev. 0). A second discovery was made during remediation of another former waste-disposal site. A concentration of freshwater mussel shells was observed in an undisturbed area within the waste site boundary. This feature consisted of two shell middens (i.e., shellfish processing/disposal areas) dating between 2,860 ± 70 to 2,450 ± 70 B. P. The results of this data recovery will be documented in *Archaeological Activity Report: Post-Review Discoveries within 45BN1422 at Solid Waste Site 128-B-3* (WCH-146, Rev. 0) to be issued in 2007.

10.15.2.3 Management of Artifact and Data Collections

The Pacific Northwest National Laboratory, under a DOE contract, manages Hanford Site archaeological collections, DOE cultural resources records, a reference library, an electronic database of cultural resources reviews, geographical information system data of cultural sites and surveys, and an assortment of supporting documentations required to facilitate compliance efforts for the DOE Hanford Cultural and Historic Resources Program. Files from over 1,400 cultural sites and curated archaeological collections from over 80 sites are stored in an archive room. During 2006, temperature and humidity levels within the archive room remained within limits for storage of numerous types of archived materials. During 2006, the database and geographic information system continued to be used and updated. The Pacific Northwest National Laboratory's Total Records Information Management database continues to be used for efficient retrieval of representative site photos, site monitoring photos, historic photos, and archived electronic documents produced by project activities.

The Columbia River Exhibition of History, Science and Technology (CREHST) Museum manages the Hanford Site Manhattan Project and Cold War artifact collection. Efforts to generate new collections are conducted as stipulated in the Programmatic Agreement for the Built Environment (DOE/RL-96-77, Rev. 0), which directs the DOE to assess the contents of the Hanford Site's historic buildings and structures prior to the commencement of deactivation, decontamination, or decommissioning activities. The purpose of the assessments is to identify and preserve any artifacts (e.g., control panels, signs, scale models, and machinery) that may have value as interpretive or educational exhibits within national, state, or local museums. Walk-throughs were conducted within 49 buildings under the Accelerated Building Demolition Project for buildings located in the 100-K, 100-N, 300, and 400 Areas in 2006. A total of 86 artifacts were evaluated. Twenty-eight of these items had not been previously evaluated, with two mitigated in place through photography. The remaining 58 were previously identified artifacts that were re-evaluated for retention. Among these artifacts, nine were mitigated in place, three were transferred to the CREHST Museum, and six were missing. Teams of cultural resource specialists, historians, archivists, curators, and facility experts accomplished the assessments.

In 2006, the Cultural and Historic Resources Program published a technical report that documents significant Manhattan Project and Cold War Era artifacts that cannot

be curated into the Hanford Site artifact collection because they are either too large for long-term storage and/or exhibit purposes, or are radiologically contaminated to a point where they cannot be reasonably decontaminated (PNNL-16056).

10.15.3 Cultural Resources Consultations and Public Involvement

The DOE conducts formal consultations with the Washington State Historic Preservation Office, Indian Tribes, and interested parties for cultural resources reviews to comply with Section 106 of the *National Historic Preservation Act* and the *National Environmental Policy Act* (see Section 2.0.2). In 2006, the DOE consulted with the Washington State Historic Preservation Office and Indian Tribes on 15 full cultural reviews. Interested parties were consulted on the Horn Rapids Road easement project and replacement of the B Reactor roof (Table 10.15.1).

Hanford Cultural and Historic Resources Program staff also held 10 meetings in 2006 with tribal cultural resources staff from The Confederated Tribes of the Umatilla Indian Reservation, The Confederated Tribes and Bands of the Yakama Indian Nation, the Confederated Tribes of the Colville Reservation, the Nez Perce Tribe, and the Wanapum. Discussions focused on the 15 full cultural resources reviews initiated in 2006, tribal notification and consultation processes, initiation and development of a cultural resources management plan for Gable Mountain, and approaches to protecting threatened archaeological sites and places containing human remains. There were no cultural resources meetings held with interested parties in 2006.

10.16 Climate and Meteorology

K. W. Burk

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, E.7, E.9, and E.10). Support is provided through weather forecasting and by maintaining and distributing climatological data. Forecasting is provided to help manage weather-dependent operations. Climatological data are provided to help plan weather-dependent activities and are used as a resource to assess the environmental effects of Hanford Site operations.

The Hanford Meteorology Station relies on data provided by 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 information collected at these stations includes wind speed, wind direction, temperature, precipitation, atmospheric pressure, and relative humidity; however, not all of these data are collected at all stations.

Regional temperatures, precipitation, and winds are affected by the presence of mountain barriers. The Cascade Range, beyond Yakima to the west, greatly influences the climate of the Hanford Site because of its rain shadow effect. The Rocky Mountains and ranges in southern British Columbia protect the region from severe, cold polar air masses moving southward across Canada and winter storms associated with them.

Real-time and historical data from the Hanford Meteorology Station can be obtained at http://hms.pnl.gov. 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 Hanford Meteorology Station is located on the Hanford Site's Central Plateau, where the prevailing wind direction is from the northwest all year. The secondary wind direction is from the southwest. Summaries of wind directions indicate that winds from the northwestern 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 Hanford Site. Figure 10.16.1 shows the 2006 wind roses (i.e., diagrams showing direction and frequencies of wind) measured at a height of 9 meters (30 feet) for the 30 meteorological monitoring stations at and around the Hanford 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 dispersion conditions associated with neutral and unstable stratification exist approximately 57% of the time during summer. Less favorable conditions may occur when wind speed is light and the mixing layer is shallow. These conditions are most common during winter, when moderate to extremely stable stratification exists approximately 66% of the time. Occasionally, there are extended periods of

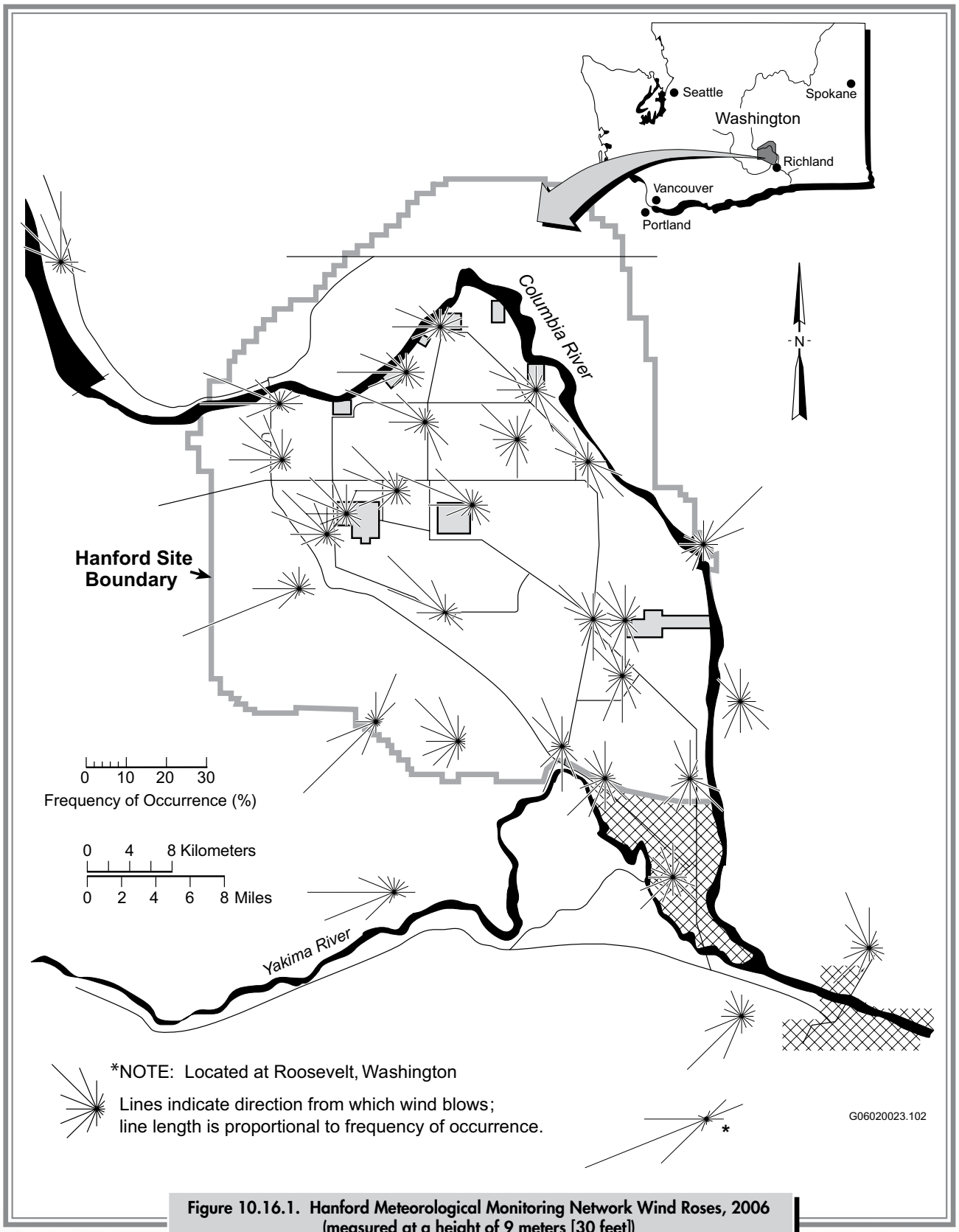

Figure 10.16.1. Hanford Meteorological Monitoring Network Wind Roses, 2006 (measured at a height of 9 meters [30 feet])

poor dispersion conditions, primarily during winter, that are associated with stagnant air in stationary, high-pressure systems.

10.16.1 Historical Climatological Information

Daily and monthly averages and extremes of temperature, dew point temperature, and relative humidity for 1945 through 2004 are reported in PNNL-15160. From 1945 through 2006, the record maximum temperature was 45°C (113.0°F) recorded in July 2006, July 2002, and August 1961. The record minimum temperature was -30.6°C (-23.1°F) in February 1950. Normal monthly average temperatures ranged from a low of -0.2°C (31.7°F) in December to a high of 24.6°C (76.3°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 normal annual relative humidity at the Hanford Meteorology Station is 54%. Humidity is highest during winter, averaging approximately 76%, and lowest during summer, averaging approximately 36%. Normal annual precipitation at the Hanford Meteorology Station is 17.7 centimeters (6.98 inches). The wettest year on record, 1995, received 31 centimeters (12.31 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.

10.16.2 Results of 2006 Monitoring

The calendar year 2006 average temperature was slightly above normal and precipitation was above normal.

The average temperature for 2006 was 12.3°C (54.1°F), which was 0.3°C (0.5°F) above normal (12.0°C [53.6°F]). Five months during 2006 were warmer than normal; seven months were cooler than normal. January had the greatest positive departure, 3.7°C (6.6°F); and December, at 1.5°C (2.7°F) below normal, had the greatest negative departure.

Precipitation during 2006 totaled 21.5 centimeters (8.46 inches), which is 121% of normal (17.7 centimeters [6.98 inches]). Snowfall for 2006 totaled 11.2 centimeters (4.4 inches), compared to normal snowfall of 39.1 centimeters (15.4 inches).

The average wind speed during 2006 was 3.5 meters per second (7.8 miles per hour), which was 0.1 meter per second (0.2 mile per hour) above normal. The peak gust for the year was 33.1 meters per second (74 miles per hour) on December 15.

One dust storm was recorded at the Hanford Meteorology Station in 2006. There has been an average of five dust storms per year at the Hanford Meteorology Station during the entire period of record (1945-2006).

Table 10.16.1 provides monthly and annual climatological data collected at the Hanford Meteorology Station during 2006.

Table 10.16.1. Monthly and Annual Climatological Data for 2006 from the Hanford Meteorology Station

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				Average Speed, m/sec	Departure[b]	Peak Gusts		
	Daily Maximum	Daily Minimum	Monthly	Departure[b]	Highest	Date	Lowest	Date	Total	Departure[b]	Total	Departure[b]	Average	Departure[b]			Speed, m/sec	Direction	Date
J	7.2	-0.1	3.6	+3.7	14.4	30[c]	-5.6	25	3.0	+0.8	1.3	-9.4	81.2	+3.6	3.4	+0.6	24.1	SSW	30
F	8.4	-3.8	2.3	-1.0	15.6	23	-15.0	19	1.0	-0.7	T[d]	-6.6	57.0	-13.7	3.8	+0.7	24.1	SW	23
M	13.5	0.8	7.2	-0.6	19.4	29	-7.2	13	0.6	-0.9	0	-1.0	57.5	+0.9	3.6	+0.1	20.1	SW	8
A	18.2	4.2	11.2	-0.7	30.0	29	-0.6	18	3.3	+2.2	0	-T[d]	54.7	+7.2	3.7	-0.2	20.6	WNW	29
M	24.9	9.0	17.0	+0.4	37.8	18[c]	1.1	2	1.4	0	0	0	43.8	+0.8	3.8	-0.2	25.5	SSW	18
J	29.1	13.6	21.3	+0.6	42.2	27	9.4	22	3.4	+2.4	0	0	45.6	+6.0	3.8	-0.3	20.1	SW	16
J	36.2	17.3	26.7	+2.1	45.0	23	8.9	30	T[d]	-0.7	0	0	29.3	-4.0	3.8	0	19.7	WNW	6
A	33.4	14.2	23.8	-0.3	40.0	7	7.2	31	T[d]	-0.7	0	0	32.6	-3.1	3.4	-0.1	17.9	NW	10
S	28.6	10.1	19.3	+0.5	37.8	6[c]	3.3	17	0.5	-0.3	0	0	44.8	+2.7	3.0	-0.3	16.5	NW	13
O	18.9	3.7	11.3	-0.4	23.3	14[c]	-6.1	31	1.9	+0.7	0	-0.3	60.2	-4.1	2.8	-0.1	17.9	NW	29
N	9.5	-0.8	4.4	-0.1	23.3	6	-11.7	30	1.8	-0.7	4.8	-1.0	71.3	-2.3	3.8	+0.9	27.3	SW	13
D	2.0	-5.4	-1.7	-1.5	13.3	13	-13.3	3[c]	4.4	+1.6	5.1	-9.6	85.6	+5.2	2.7	0	33.1	SW	15
Y[e]	19.2	5.3	12.3	+0.3	45.0	Jul 23	-15.0	Feb 19	21.5	+3.8	11.2	-27.9	55.3	+0.7	3.5	+0.1	33.1	SW	Dec 15

NOTE: See Table A.2, Conversion Table in the section, Helpful Information, 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 (1971-2000) climatological normals.
(c) Latest of several occurrences.
(d) Trace.
(e) Yearly averages, extremes, and totals.

10.17 Quality Assurance

Quality assurance and quality control practices encompass all aspects of Hanford Site environmental monitoring and surveillance programs. This section provides information on specific measures taken in 2006 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 Hanford Site environmental monitoring and surveillance programs also include procedures and protocols to perform the following:

- 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.

10.17.1 Hanford Site-Wide and Offsite Environmental Surveillance and Groundwater Monitoring

E. A. Lepel

During 2006, comprehensive quality assurance programs, including various quality control practices, were maintained to assure the quality of data collected through the Pacific Northwest National Laboratory's Surface Environmental Surveillance Project and Soil and Groundwater Remediation Project. Quality assurance plans were maintained for all project activities and defined the appropriate controls and documentation required by the EPA and DOE.

10.17.1.1 Project Management Quality Assurance

Site environmental monitoring, groundwater monitoring, and related activities (such as performing dose calculations) were subject to an overall quality assurance program. This program implements the requirements of DOE Order 414.1B, "Quality Assurance." Quality assurance plans are maintained by each monitoring project; these plans describe the specific quality assurance elements that apply to each project. These plans were approved by a quality assurance organization that monitored compliance with the plans. Work performed through contracts, such as sample analyses, must meet the same quality assurance requirements. Potential equipment and service suppliers are audited before service contracts are approved and awarded or materials are purchased that could have a significant impact on quality within the projects.

10.17.1.2 Sample Collection Quality Assurance and Quality Control

Surface Environmental Surveillance Project samples were collected by personnel 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 duplicate samples were collected for air, water, and biota (Table 10.17.1). The water duplicates consisted of

Table 10.17.1. Summary of Field Duplicate Sample Results for Samples Submitted to Severn Trent Laboratories, Inc., Richland, Washington (currently known as TestAmerica Richland), for the Surface Environmental Surveillance Project, 2006

Media (Number of Samples)	Radionuclides	Number of Results Reported for Each Radionuclide[a]	Number Within Control Limits for Each Radionuclide[b]
Air (13)	^{3}H	13	6
Water (4)	^{3}H	4	4
	^{234}U, ^{238}U	3	3
	Gross beta	1	1
	^{90}Sr	2	1
Biota[c] (2)	^{3}H	2	2
	^{40}K	2	2

(a) Number of reported results are those results greater than the minimum detectable activity.
(b) Number of reported results within control limits are those results with the relative percent difference value less than 30%, and the result is greater than the minimum detectable activity.
(c) Cow's milk.

three Columbia River water samples and one onsite pond water sample. The biota duplicates were samples of cow's milk. There were 13 duplicate air samples collected for tritium analyses. A field duplicate is used to assess sampling and measurement precision. The analytical results were reviewed against the criterion that the result must be greater than the minimum detectable activity value to be evaluated. To be an acceptable result, the relative percent difference of the two duplicates must be less than 30%. Of the evaluated results, 71% of the 2006 field duplicates were acceptable, but 46% of the air-tritium results were unacceptable.

Samples for the Soil and Groundwater Remediation Project were collected by trained personnel according to approved and documented procedures. Chain-of-custody procedures in *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846, Third Edition* (EPA 1986) were followed. Samples representing field blanks and field duplicates were obtained during field operations. Summaries of the 2006 groundwater field quality control sample results are provided in Appendix C of PNNL-16346. In fiscal year 2006, the percentage of acceptable field blank results was 96% and the percentage of acceptable field duplicate results was 98%. For field blanks, a result was acceptable if it was less than two times the method detection limit for non-radiological data or less than two times the total propagated analytical uncertainty for radiological data. An acceptable result indicates that there was not a contamination problem found with the sample. For a field duplicate, the result was acceptable if the measured precision was within 20%, as measured by the relative percent difference, and the result was greater than five times the minimum detectable activity or method detection limit.

Relative percent difference (RPD) – A measure of the precision of the measurement of a sample (S) and its duplicate (D). The formula is

$$RPD = \left(\frac{|S - D|}{\frac{(S + D)}{2}} \right) \times 100$$

10.17.1.3 Analytical Results Quality Assurance and Quality Control

Routine chemical analyses of water samples were performed under contract primarily by Severn Trent Laboratories (STL) St. Louis in St. Louis, Missouri,[a] for the environmental surveillance and groundwater monitoring projects. During the fourth quarter of 2006 (October through December), some groundwater samples were analyzed onsite by the Waste Sampling and Characterization Facility. Chemical analysis of split samples and blind standards for the *Comprehensive Environmental Response, Compensation, and Liability Act* groundwater program were performed under contract by Lionville Laboratory, Inc. in Lionville, Pennsylvania. Each laboratory participated in the EPA-sanctioned Water Pollution and Water Supply Performance Evaluation Studies conducted by Environmental Resource

(a) Currently known as TestAmerica St. Louis.

Double-blind spiked sample – A sample of known activity and/or concentration prepared to look like a typical sample submitted to the analytical service laboratory.

Associates in Arvada, Colorado. Each laboratory maintained an internal quality control program that met the requirements in EPA (1986); each program was audited and reviewed internally by Pacific Northwest National Laboratory personnel, who submitted additional quality control double-blind spiked samples to these laboratories for analysis.

Routine metals analyses were also performed by Battelle's Marine Sciences Laboratory, located at the Pacific Northwest National Laboratory's Sequim Marine Research Operations in Washington State. The Marine Sciences Laboratory participated in the NSI Solutions, Inc. Proficiency Testing Program. NSI Solutions, Inc. in Raleigh, North Carolina, supplied spiked soil and water samples for analyses. Analytical results were provided to NSI Solutions, Inc. and compared to the known concentrations of the spikes. Water sample results from three studies in 2006 were reported. The criteria of being acceptable were met by 96% of the results from the water samples. There were also results reported from two soil studies in 2006; 100% of these results were acceptable. The results are summarized in Table 10.17.2.

Routine radiochemical analyses of samples for the environmental surveillance and groundwater monitoring projects were performed primarily by STL Richland in Richland, Washington.[(b)] STL Richland participated in the DOE's Mixed Analyte Performance Evaluation Program and the InterLab RadChem Proficiency Testing Program conducted by Environmental Resource Associates. Environmental Resource Associates prepared and distributed proficiency standard samples according to EPA requirements. A quality control blind-spiked sample program also was conducted for each project by the Pacific Northwest National Laboratory. The laboratory maintains an internal quality control program, which was audited and internally reviewed. Additional information on these quality control efforts is provided in the following sections.

10.17.1.4 DOE and EPA Comparison Studies

Blind-spiked water samples were distributed to participating laboratories as part of the EPA performance evaluation program. These blind-spiked samples contained specific

Table 10.17.2. Summary of Battelle's Marine Sciences Laboratory Performance on NSI Solutions, Inc. Proficiency Testing Program Samples (five studies), 2006

Media	Analytes	Number of Results Reported for Each Analyte	Number Within Control Limits for Each Analyte
Soil	Al, Sb, As, Ba, Be, B, Ca, Cd, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Na, Ni, K, Se, Ag, Sr, Sn, Tl, Ti, V, Zn	2	2
Water	Hg	2	2
	Mo, Se	2	2
	Total alkalinity ($CaCO_3$)	5	3
	Al, Sb, As, Ba, Be, Cd, Cr, Cu, Pb, Mg, Mn, Ni, K, Ag, Na, Tl, V	2	2
	Ca, Fe	2	2
	Co, Sr	2	2

(b) Currently known as TestAmerica Richland.

Blind spiked sample – A sample of known activity and/or concentration submitted to the analytical laboratory but not necessarily in the same physical geometry as the typical samples submitted.

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 2006 groundwater samples are provided in PNNL-16346, Appendix C, for the primary laboratory, STL St. Louis.

The DOE Mixed Analyte Performance Evaluation Program conducted by the Radiological and Environmental Sciences Laboratory in Idaho Falls, Idaho, and the Environmental Resource Associates Proficiency Testing Program provided standard samples of environmental media (e.g., water, air filters, soil, and vegetation) that contained specific amounts of one or more radionuclides that were unknown by the participating laboratory. After analysis, the results were forwarded to the Radiological and Environmental Sciences Laboratory (two studies) or Environmental Resource Associates (three studies) for comparison with known values and results from other laboratories. Both the Radiological and Environmental Sciences Laboratory and Environmental Resource Associates had established criteria for evaluating the accuracy of results (NERL-Ci-0045). The Radiological and Environmental Sciences Laboratory evaluates the DOE Mixed Analyte Performance Evaluation Program radiological and inorganic samples results for accuracy by determining if each result falls within ±30% of a reference value. Summaries of the 2006 results are provided in Tables 10.17.3 and 10.17.4. The DOE Mixed Analyte Performance Evaluation Program provided two sets of performance evaluation samples consisting of soil, water,

Table 10.17.3. Summary of Severn Trent Laboratories, Inc., Richland, Washington (currently known as TestAmerica Richland), Performance on Twelve Performance Evaluation Program Samples Provided by the DOE Mixed Analyte Performance Evaluation Program, 2006

Media	Radionuclides	Number of Results Reported for Each Radionuclide	Number of Results Within Control Limits for Each Radionuclide[a]
Air filters	Gross alpha, gross beta, ^{54}Mn, $^{239/240}$Pu	2	2
	^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{234}U, ^{238}Pu, ^{238}U	2	1
Soil	^{40}K, ^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{99}Tc, ^{137}Cs, ^{234}U, ^{238}Pu, ^{238}U, ^{241}Am	2	2
	^{55}Fe, ^{63}Ni, ^{134}Cs	2	1
	$^{239/240}$Pu	1	1
Vegetation	^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu	2	2
	^{234}U, ^{238}U, ^{241}Am	2	1
	$^{239/240}$Pu	1	1
Water	Gross alpha, gross beta, ^{3}H, ^{54}Mn, ^{55}Fe, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{99}Tc, ^{134}Cs, ^{137}Cs, ^{234}U, ^{238}Pu, ^{238}U, ^{241}Am	2	2
	^{63}Ni	2	1
	$^{239/240}$Pu	1	1

(a) Control limits are from EML-621.

Table 10.17.4. Summary of Severn Trent Laboratories, Inc., Richland, Washington (currently known as Test America Richland), Performance on Five Performance Evaluation Program Water Samples Provided by the Environmental Resource Associates Proficiency Testing Program, 2006

Media	Radionuclides	Number of Results Reported for Each Radionuclide	Number of Results Within Control Limits for Each Radionuclide[a]
Water	Gross alpha	6	5
	^{60}Co, ^{65}Zn, ^{89}Sr, ^{90}Sr, ^{133}Ba, ^{134}Cs, ^{226}Ra	5	5
	Gross beta, ^{137}Cs	5	4
	^{228}Ra, U (natural)	4	4
	^{3}H, ^{131}I	3	1

(a) Control limits are from NERL-Ci-0045.

vegetation, and air filters that were analyzed by STL Richland. Acceptable control limits, as defined by the DOE Mixed Analyte Performance Evaluation Program, were met by 86% of the DOE performance assessment sample results. The acceptable control limit range as defined by the *National Standards for Water Proficiency Testing Studies, Criteria Document* (NERL-Ci-0045) was met by 95% of the Environmental Resource Associates samples.

10.17.1.5 Pacific Northwest National Laboratory Evaluations

In addition to the DOE and EPA interlaboratory quality control programs, the 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 both radiological and non-radiological blind-spiked samples. Blind-spiked quality control samples and blanks were prepared and submitted to check the accuracy and precision of analyses at STL Richland. In fiscal year 2006, 85% of blind-spiked groundwater samples were acceptable (PNNL-16346, Appendix C).

Eight blind-spiked samples were submitted for analyses for the Surface Environmental Surveillance Project. The samples included air filters, soil, water, and vegetation (Table 10.17.5). For all media, 73% of STL Richland, radiochemistry blind-spiked determinations were within the control limit (±30% of the known value). Last year, 88% of the results were acceptable. In 2006, 8 of 15 air filter blind-spiked analysis results were outside the control limit. Seven of the results were from the first blind-spiked air filter submitted. The unacceptable results were for cobalt-60, cesium-134, and cesium-137 by gamma; strontium-90, uranium-234, and uranium-238 by uranium isotopic; and plutonium-238 and plutonium-239/240 by plutonium isotopic. It appears a fundamental error was carried through to the final calculation for these analyses. There were five analyses that failed due to chemistry problems (blank failure): strontium-90 in vegetation, and plutonium-238 and plutonium-239/240 in vegetation and in soil. Three gamma results were outside the control limits – cobalt-60 in an air filter, and cobalt-60 and cesium-137 in vegetation.

10.17.1.6 Laboratory Internal Quality Assurance Programs

Analytical laboratories were required to maintain an internal quality assurance and control program. The laboratories are audited at least annually for compliance to the quality assurance and control programs. At STL St. Louis, the quality control program met the quality assurance and control criteria in EPA (1986). The laboratories also were 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. Detection levels for each analytical method were determined at least annually.

Table 10.17.5. Summary of Severn Trent Laboratories, Inc., Richland, Washington (currently known as TestAmerica Richland), Performance on Blind-Spiked Samples Submitted by Pacific Northwest National Laboratory for the Surface Environmental Surveillance Project, 2006

Media	Radionuclides	Number of Results Reported for Each Radionuclide	Number of Results Within the Control Limit for Each Radionuclide[a]
Air Filters	^{137}Cs	2	2
	^{90}Sr, ^{134}Cs, ^{234}U, ^{238}Pu, ^{238}U, $^{239/240}$Pu	2	1
	^{60}Co	2	0
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U	2	2
	^{238}Pu, $^{239/240}$Pu	2	1
Vegetation	^{40}K	2	2
	^{60}Co, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239/240}$Pu	2	1
Surface Water	^{3}H, ^{60}Co, ^{137}Cs, ^{234}U, ^{238}Pu, ^{238}U, $^{239/240}$Pu	2	2
	^{134}Cs	1	1

(a) Control limit of ±30%.

The internal quality control program at STL Richland involved routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation-check sources and background counts, replicate and spiked sample analyses, the use of 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 counts 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).

The internal quality control program at the Marine Sciences Laboratory involved routine daily calibrations of analytical instruments, analysis of certified reference materials, replicate and spiked sample analyses, and the use of matrix and reagent blanks. Acceptable results were achieved for over 95% of quality control analyses. Most failures were attributed to the results for certified reference materials that were certified at or near the achieved detection limit for that analyte. Available calibration standards traceable to the National Institute of Standards and Technology were used for calibrating instruments used in metal analyses. Calculations of method detection limits are performed annually according to 40 CFR 136, Appendix B. The Marine Sciences Laboratory maintained strict adherence to in-house sample handling and chain-of-custody procedures, and all data were fully validated prior to release.

Periodically, inspections of services were performed and conformance of the analytical facility with its contractual requirements was documented. These inspections provided the framework to identify and resolve potential performance problems. Responses to inspection findings were documented by written communication, and corrective actions were verified by follow-up audits and inspections. In 2006, five audits of the commercial laboratories supporting the Soil and Groundwater Remediation Project were performed. These five audits were performed by the DOE Consolidated Assessment Program. The DOE Consolidated Assessment Program audit evaluated 1) STL Knoxville[c] in Knoxville, Tennessee, in December 2005; 2) STL St. Louis in St. Louis,

(c) Currently known as TestAmerica Knoxville.

Missouri, in April 2006; 3) Eberline Services in Richmond, California, in February 2006; 4) Lionville Laboratory in Lionville, Pennsylvania, in May 2006; and 5) STL Richland in Richland, Washington, in May 2006. The scope of the DOE Consolidated Assessment Program audits included the following specific functional areas: 1) quality assurance management systems and general laboratory practices, 2) data quality for organic analyses, 3) data quality for inorganic and wet chemistry analyses, 4) data quality for radiochemistry analyses, 5) hazardous and radioactive materials management, and 6) verification of corrective-action implementation from previous audit findings.

A total of 34 findings (requiring some corrective action by the laboratory) and 45 observations were noted for the 5 DOE Consolidated Assessment Program audits. Results of these audits are summarized in Appendix C of PNNL-16346. Corrective actions for all the audit findings were accepted and verification of the corrective actions will be performed in future audits. All laboratories have been qualified by the DOE Consolidated Assessment Program to continue to provide analytical services for samples generated at DOE sites.

Internal laboratory quality control program data were reported with the analytical results. Pacific Northwest National Laboratory scientists summarized the results quarterly. The Surface Environmental Surveillance Project and the Soil and Groundwater Remediation Project indicated that each laboratory met the contract-specified requirements for each quarter of calendar year 2006 (for the Surface Environmental Surveillance Project) and fiscal year 2006 (for the Soil and Groundwater Remediation Project).

10.17.1.7 Media Audits and Comparisons

Additional audits and comparisons were conducted on several specific types of samples. The Washington State Department of Health routinely analyzed co-samples of various environmental media during 2006 as part of its oversight monitoring program (see Section 3.0.4). Media that were analyzed for radionuclides included irrigation water from 2 locations, water from 16 locations along and across the Columbia River, water from 4 Columbia River shoreline springs, water from 1 onsite drinking water location, and sediment from 8 Columbia River sites from Priest Rapids Dam (upriver from the Hanford Site) to McNary Dam (downriver from the Hanford Site). Also analyzed for radionuclides were samples of carp and quail (muscle and bone), as well as downwind samples of potato tubers, asparagus, leafy vegetables, apples, and red and white wines.

The U.S. Food and Drug Administration also received co-samples from downwind sampling locations and analyzed potato tubers and apples provided by the Pacific Northwest National Laboratory for radionuclides (Table 10.17.6). Potassium-40 concentrations measured by the U.S. Food and Drug Administration and STL Richland in apples and potatoe tubers were in agreement. Potassium-40 is taken up by the plant from the soil. The abundance of potassium-40 in the Earth's crust is about 14 pCi/g soil (Mason and Berry 1968, p. 126). Except for one apple sample that the U.S. Food and Drug Administration analyzed, all other results were less than the minimum detectable activity level. Three apple samples were collected at Riverview and two of the results reported (one from the U.S. Food and Drug Administration and the other from STL Richland) had strontium-90 values below the minimum detectable activity level. The third value determined by the U.S. Food and Drug Administration was above the minimum detectable activity level. A review of strontium-90 results for apples back to 1990 did not identify any other detectable strontium-90 concentrations.

10.17.2 Effluent Monitoring and Environmental Monitoring Near Facilities and Operations

D. L. Dyekman

The Effluent Monitoring and Near-Facility Environmental Monitoring Programs were subject to the quality assurance requirements specified in DOE/RL-96-68, Rev. 2. These quality assurance programs complied with DOE Order 414.1B, using standards from the American Society of Mechanical Engineers (ASME NQA-1 1997 Edition) as their basis. The program also adhered to the guidelines and objectives in *Requirements for Quality Assurance Project Plans for Environmental Data Operations* (EPA QA/R-5).

Table 10.17.6. Comparison of U.S. Food and Drug Administration and Pacific Northwest National Laboratory[a] Results for Food and Farm Product Samples Collected Near the Hanford Site, 2006[b]

Media	Sampling Area[c]	Organization	Potassium-40 pCi/g[d,e]	Strontium-90, pCi/g[d,e]	Ruthenium-106, pCi/g[d,e]	Cesium-137 pCi/g[d,e]
Apples	Riverview	FDA	1.23 ± 0.63	0.0031 ± 0.0011	<0.24	<0.028
		FDA	1.43 ± 0.63	<0.0012	<0.20	<0.030
		STL	0.98 ± 0.22	0.00082 ± 0.0017	0.022 ± 0.039	0.00022 ± 0.0048
Apples	Sagemoor	FDA	0.77 ± 0.62	<0.0012	<0.22	<0.026
		FDA	0.97 ± 0.62	<0.0014	<0.23	<0.028
		STL	0.57 ± 0.22	-0.0027 ± 0.0041	0.0031 ± 0.056	0.0028 ± 0.0064
Potato tuber	Sunnyside	FDA	3.4 ± 0.7	<0.0037	<0.27	<0.029
		FDA	3.3 ± 0.8	<0.0018	<0.28	<0.031
		STL	4.4 ± 0.7	0.0011 ± 0.0051	0.024 ± 0.038	-0.0043 ± 0.0048
Potato tuber	Sagemoor	FDA	3.8 ± 0.8	<0.0012	<0.24	<0.030
		FDA	4.0 ± 0.8	<0.0012	<0.25	<0.029
		STL	3.9 ± 0.5	-0.0015 ± 0.0049	-0.018 ± 0.038	0.00030 ± 0.0045

(a) Samples analyzed by Severn Trent Laboratories, Inc., Richland, Washington.
(b) Sample results are wet weight.
(c) Sampling areas are illustrated in Figure 10.8.1.
(d) To convert pCi/g to Bq/g, multiply by 0.037.
(e) Errors reported are 2 standard deviations. Less than (<) values are minimum detectable activities at 3 standard deviations.
FDA = U.S. Food and Drug Administration.
STL = Severn Trent Laboratories, Inc., Richland.

The monitoring programs each have a quality assurance project plan describing applicable quality assurance elements. These plans were approved by contractor quality assurance groups, who monitored compliance with the plans. Work, such as sample analyses 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 project quality.

10.17.2.1 Sample Collection Quality Assurance

Samples for the Effluent Monitoring and Near-Facility Environmental Monitoring Programs were collected by personnel trained in accordance with the approved procedures. Established sampling locations were accurately identified and documented to ensure continuity of data for those sites and are described in PNNL-16623, APP. 2.

10.17.2.2 Analytical Results Quality Assurance

H. K. Meznarich and E. J. Wyse

Samples for the Effluent Monitoring and Near-Facility Environmental Monitoring Programs were analyzed by up to three different analytical laboratories. Use of these laboratories was dependent on the Hanford Site contractor collecting the samples. Table 10.17.7 provides a summary of the Hanford Site's analytical laboratories used for effluent monitoring and near-facility monitoring samples in 2006.

Analytical data quality was ensured by several means. For instance, counting room instruments were verified to perform 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 laboratories are qualified to perform analyses through formal classroom and on-the-job training.

Table 10.17.7. A Summary of Hanford Site Laboratories Used by Site Contractors and Types of Effluent Monitoring and Near-Facility Monitoring Samples Analyzed, 2006

	Effluent Monitoring Samples					Near-Facility Environmental Monitoring Samples		
	Fluor Hanford, Inc.		Pacific Northwest National Laboratory	Bechtel Hanford, Inc. and Washington Closure Hanford LLC		Fluor Hanford, Inc.		
Analytical Laboratory	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[b]								X
Severn Trent Laboratories, Inc., Richland[c]	X	X	X	X	X			
Radiochemical Processing Laboratory[d]	X	X	X					

(a) Operated by Fluor Hanford, Inc.
(b) Operated by Advanced Technologies and Laboratories International, Inc.
(c) Currently known as TestAmerica Richland.
(d) Operated by Pacific Northwest National Laboratory.

The participation of the Hanford Site analytical laboratories in EPA and DOE laboratory performance evaluation programs also served to ensure the quality of data produced. Samples formerly provided by the EPA are now available only from National Institute of Standards and Technology-approved private contractors.

Performance of the Waste Sampling and Characterization Facility was evaluated by its participation in the following laboratory performance intercomparison studies in 2006: the EPA Water Pollution and Soil studies, the DOE Mixed Analyte Performance Evaluation Program studies, and the National Institute of Standards and Technology Radiochemistry Intercomparison Program study. The Waste Sampling and Characterization Facility Laboratory received and analyzed samples containing 443 different analytes and compounds during participation in the EPA Water Pollution Studies Nos. 132 and 138, and EPA Soil Studies Nos. 53 and 55. Of the 443 reported analytes, 436 results were acceptable while 7 were unacceptable for a total acceptable rate of 98%. In the DOE Mixed Analyte Performance Evaluation Program studies (MAPEP-06-Study 15 and MAPEP-06-Study 16), samples containing 418 different radionuclides and analytes were submitted to the Waste Sampling and Characterization Facility for analysis. Of the 418 reported radionuclide analytes, 392 results were acceptable while 26 were unacceptable for a total acceptable rate of 94%. In the National Institute of Standards and Technology Radiochemistry Intercomparison Program study, samples containing strontium-90, plutonium-238, uranium-238, and americium-241 in filters and soils were submitted to the Waste Sampling and Characterization Facility for 40 different analyses (i.e., five samples of each radionuclide for each medium). All radionuclide results for both filters and soils were acceptable except for strontium-90 results in soil that were affected by a very high barium-133 concentration (200 times higher than strontium-90). This type of interference (i.e., very high barium-133 to strontium-90 ratio) is not typically present in Hanford samples. A second set of National Institute of Standards and Technology Radiochemistry Intercomparison Program soil samples for strontium-90 was analyzed and was acceptable (report issued in 2007). Performance evaluation results for the Waste Sampling and Characterization Facility are presented in Table 10.17.8.

Table 10.17.8. The Hanford Site's Waste Sampling and Characterization Facility[a] Performance on DOE Mixed Analyte Performance Evaluation Program Samples and National Institute of Standards and Technology Radiochemistry Intercomparison Program Samples, 2006

Media	Program	Radionuclide	Number of Results Reported	Number of Results Within Control Limits
Air filters	MAPEP	^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{134}Cs, ^{137}Cs, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am, gross alpha, gross beta	26	20 (Failed ^{90}Sr, $^{233/234}$U, ^{238}Pu, ^{238}U, and ^{241}Am due to a preparation error; re-analyses were all acceptable)
	NRIP	$^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am	5	5
Soil	MAPEP	^{40}K, ^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{99}Tc, ^{134}Cs, ^{137}Cs, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am	25	21 (Failed $^{233/234}$U, ^{238}Pu, ^{238}U, and $^{239/240}$Pu due to different digestion method; spiked refractory Pu required total dissolution)
	NRIP	^{90}Sr, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am	6	6
Vegetation	MAPEP	^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{134}Cs, ^{137}Cs, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am	22	14 (Failed ^{54}Mn, ^{57}Co, ^{65}Zn, ^{137}Cs, ^{238}Pu, and ^{241}Am due to density difference for GEA)
Water	MAPEP	^{3}H, ^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{99}Tc, ^{134}Cs, ^{137}Cs, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am, gross alpha, gross beta	30	29 (Failed ^{99}Tc once)

(a) Onsite laboratory operated by Fluor Hanford, Inc.
GEA = Gamma energy analysis.
MAPEP = Mixed Analyte Performance Evaluation Program.
NRIP = National Institute of Standards and Technology Radiochemistry Intercomparison Program.

Performance of the 222-S Analytical Laboratory (located at the Hanford Site) was evaluated by its participation in three different laboratory intercomparison studies in 2006: the EPA Water Pollution Studies, the DOE Mixed Analyte Performance Evaluation Program studies, and the International Atomic Energy Agency worldwide open proficiency test (IAEA-CU-2006-03). The 222-S Analytical Laboratory received and analyzed samples containing 334 different analytes and compounds during participation in the EPA Water Pollution Studies. Of the 334 reported analytes, 327 results were acceptable while 7 were unacceptable for a total acceptable rate of 98%. The 222-S Analytical Laboratory also participated in the DOE's Mixed Analyte Performance Evaluation Program (MAPEP). For the MAPEP-15 study, 41 out of 41 results were acceptable, for an acceptable rate of 100%. For the MAPEP-16 study, 38 out of 40 results were acceptable, for an acceptable rate of 95%. The International Atomic Energy Agency worldwide open proficiency test on the determination of gamma-emitting radionuclides resulted in 12 out of 12 acceptable results for an acceptable rate of 100%. Performance evaluation results for the 222-S Analytical Laboratory are presented in Tables 10.17.9 through 10.17.11.

Table 10.17.9. The Hanford Site's 222-S Laboratory[a] Performance on DOE Mixed Analyte Performance Evaluation Program Samples, 2006[b]

Media	Radionuclide	Number of Results Reported	Number of Results Within Control Limits
Air filters	^{57}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{134}Cs, ^{137}Cs, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am, gross alpha, gross beta	22	21[c]
Soil	^{40}K, ^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{134}Cs, ^{137}Cs, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am	15	15
Vegetation	^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{134}Cs, ^{137}Cs, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am	13	12[c]
Water	^{3}H, ^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{99}Tc, ^{134}Cs, ^{137}Cs, $^{233/234}$U, ^{238}Pu, ^{238}U, $^{239/240}$Pu, ^{241}Am, gross alpha, gross beta	31	31

(a) Onsite laboratory operated by Advanced Technologies and Laboratories International, Inc.
(b) The data represent combined values from the MAPEP-15 and MAPEP-16 studies. Results were received for the MAPEP-15 study in May 2006, and results for the MAPEP-16 study were received in November 2006.
(c) Incorrect value for ^{90}Sr.
MAPEP = Mixed Analyte Performance Evaluation Program.

Table 10.17.10. The Hanford Site's 222-S Laboratory[a] Performance on EPA Laboratory Water Pollution Inorganic and Organic Studies, 2006

Laboratory	Water Pollution Study (WP-135) June 2006 % Acceptable	Water Pollution Study (WP-141) December 2006 % Acceptable
222-S Laboratory	96.9[b]	98.6[c]

(a) Onsite laboratory operated by Advanced Technologies and Laboratories International, Inc.
(b) 156 of 161 analytes were evaluated as acceptable.
(c) 171 of 173 analytes were evaluated as acceptable; one of two missed analytes was a reporting error; a "less-than" result was reported without the "<," but the measured result was correct.

Table 10.17.11. The Hanford Site's 222-S Laboratory[a] Performance on International Atomic Energy Agency Worldwide Open Proficiency Test on the Determination of Gamma-Emitting Radionuclides

Media	Radionuclide	Number of Results Reported	Number of Results Within Control Limits
Soil	^{54}Mn, ^{60}Co, ^{65}Zn, ^{134}Cs, ^{137}Cs, ^{241}Am	6	6
Water	^{54}Mn, ^{60}Co, ^{65}Zn, ^{109}Cd, ^{134}Cs, ^{137}Cs	6	6

(a) Onsite laboratory operated by Advanced Technologies and Laboratories International, Inc.

10.18 References

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40 CFR 61. "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

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40 CFR 122. "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

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Appendix A
Helpful Information

R. W. Hanf

The following information is provided to assist the reader in understanding this report. Included here is information on scientific notation, units of measure, radioactivity units, radiological dose units, chemical and elemental nomenclature, understanding data tables and data uncertainty, understanding graphs, and greater than or less than symbols. Definitions of technical terms can be found in Appendix B.

Scientific Notation

Scientific notation is used 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 follow the International System of Units (SI) and 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
hr	hour
min	minute
ses	second
yr	year
Rate	
cfs (or ft^3/sec)	cubic feet per second
cpm	counts per minute
gpm	gallon per minute
mph	mile per hour
mR/hr	milliroentgen per hour
mrem/yr	millirem per year
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

Symbol	Name
Concentration	
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
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)
lb	pound

Table A.2. Conversion Table

Multiply	By	To Obtain	Multiply	By	To Obtain
cm	0.394	in.	in.	2.54	cm
m	3.28	ft	ft	0.305	m
km	0.621	mi	mi	1.61	km
kg	2.205	lb	lb	0.454	kg
L	0.2642	gal	gal	3.785	L
m^2	10.76	ft^2	ft^2	0.093	m^2
ha	2.47	acres	acre	0.405	ha
km^2	0.386	mi^2	mi^2	2.59	km^2
m^3	35.31	ft^3	ft^3	0.0283	m^3
m^3	1.308	yd^3	yd^3	0.7646	m^3
pCi	1,000	nCi	nCi	0.001	pCi
µCi/mL	10^9	pCi/L	pCi/L	10^{-9}	µCi/mL
Ci/m^3	10^{12}	pCi/m^3	pCi/m^3	10^{-12}	Ci/m^3
mCi/cm^3	10^{15}	pCi/m^3	pCi/m^3	10^{-15}	mCi/cm^3
nCi/m^2	1.0	mCi/km^2	mCi/km^2	1.0	nCi/m^2
Ci	3.7×10^{10}	Bq	Bq	2.7×10^{-11}	Ci
pCi	0.037	Bq	Bq	27	pCi
rad	0.01	Gy	Gy	100	rad
rem	0.01	Sv	Sv	100	rem
ppm	1,000	ppb	ppb	0.001	ppm
°C	(°C x 9/5) + 32	°F	°F	(°F -32) ÷ 9/5	°C
oz	28.349	g	g	0.035	oz
ton	0.9078	tonne	tonne	1.1	ton

Radioactivity Units

Much of this report deals with levels of activity (also known as radioactivity) in various environmental media. Activity in this report is usually discussed in units of **curies** (**Ci**), with conversions to **becquerels** (**Bq**), the SI unit, provided (Table A.3). The curie is the basic unit used to describe the amount of activity present, and activities are generally expressed in terms of curies per 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. One becquerel is equivalent to one disintegration per second. Nuclear disintegrations produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these. Table A.4 includes selected conversions from curies to becquerels.

Radiological Dose Units

Radiological dose in this report is usually written in terms of effective dose equivalent and reported numerically in units of millirems (mrem), with the metric units millisieverts (mSv) following in parenthesis or footnoted.

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

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel (2.7×10^{-11} Ci)
mCi	millicurie (1×10^{-3} Ci)	kBq	kilobecquerel (1×10^{3} Bq)
µCi	microcurie (1×10^{-6} Ci)	MBq	megabecquerel (1×10^{6} Bq)
nCi	nanocurie (1×10^{-9} Ci)	mBq	millibecquerel (1×10^{-3} Bq)
pCi	picocurie (1×10^{-12} Ci)	GBq	gigabecquerel (1×10^{9} Bq)
fCi	femtocurie (1×10^{-15} Ci)	TBq	terabecquerel (1×10^{12} Bq)
aCi	attocurie (1×10^{-18} Ci)		

Table A.4. Conversions for Radioactivity Units

aCi	fCi	fCi	pCi	pCi	nCi	nCi	µCi	µCi	mCi	mCi	Ci	Ci	kCi
27	1	27	1	27	1	27	1	27	1	27	1	27	1
1	37	1	37	1	37	1	37	1	37	1	37	1	37
µBq	µBq	mBq	mBq	Bq	Bq	kBq	kBq	MBq	MBq	GBq	GBq	TBq	TBq

New unit of quantity = Becquerel (Bq) (formerly curie [Ci]) (1 Ci = 3.7×10^{10} dps).
1 Becquerel = 1 disintegration/sec (dps).

Millirem (millisievert) is a term that relates a given amount of absorbed radiation energy to its biological effectiveness or risk (to humans). For perspective, a dose of 0.01 millirem (1 millisievert) would have a biological effect roughly the same as received from 1 day's exposure to natural background radiation. An acute (short-term) dose to the whole body of 100 rem (1 sievert) would likely cause temporary radiation sickness in some exposed individuals. An acute dose of over 500 rem (5 sieverts) would soon result in death in approximately 50% of those exposed. Exposure to lower amounts of radiation (10 mrem [100 µSv] 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 mrem (3 mSv). Medical and dental x-rays and air travel add to this total. Table A.5 includes selected conversions from rems to sieverts.

Table A.5. Conversions for Radiological Dose Units

µSv	µSv	µSv	µSv	µSv	mSv	mSv	mSv	Sv
0.01	0.1	1	10	100	1	10	100	1
1	10	100	1	10	100	1	10	100
µrem	µrem	µrem	mrem	mrem	mrem	rem	rem	rem

Unit of absorbed dose – Gray (Gy) (formerly rad).
Unit of dose equivalent – Sievert (Sv) (formerly rem).
Table also converts Gy to rad.

Also used in this report is the **rad**, with the corresponding unit **gray** (**Gy**) in parenthesis or footnoted. The rad (gray) 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. The gray can be converted to rad by multiplying by 100. The conversions in Table A.5 can also be used to convert grays to rads.

A **roentgen (R)** is a measure of exposure to electromagnetic radiation (i.e., gamma and x-radiation) with no SI equivalent. One roentgen is equivalent to a charge release of 258 microcoulombs per kilogram of air.

The names and symbols for units of radiation dose used in this report are listed in Table A.6

Additional information on radiation and dose terminology can be found in Appendix B. A list of the radionuclides discussed in this report, their symbols, and their half-lives are included in Table A.7.

Table A.6. Names and Symbols for Units of Radiation Dose or Exposure

Symbol	Name
mrad	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
µrem	microrem (1×10^{-6} rem)
Sv	sievert (100 rem)
mSv	millisievert (1×10^{-3} Sv)
µSv	microsievert (1×10^{-6} Sv)
R	roentgen
mR	milliroentgen (1×10^{-3} R)
µR	microroentgen (1×10^{-6} R)
Gy	gray (100 rad)
mGy	milligray (1×10^{-3} rad)

Table A.7. 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	natural uranium	~4.5×10^{9}[b]
^{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) Natural uranium is a mixture dominated by ^{238}U, thus the half-life is ~4.5×10^{9} years.

Chemical and Elemental Nomenclature

Many of the chemical contaminants discussed in this report are listed in Table A.8 along with their chemical (or elemental) names and their corresponding symbols.

Understanding the Data Tables

Some degree of variability, or uncertainty, is associated with all analytical measurements. This uncertainty is the consequence of random or systematic inaccuracies related to collecting, preparing, 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. In this report, the uncertainties used include standard deviation, total propagated analytical uncertainty, and standard error of the mean.

Standard Deviation

The standard deviation (SD) of sample data relates to the variation around the mean of a set of individual sample results. If differences in analytical results occur among samples, then two times the standard deviation (or ±2 SD) implies that 95% of the time, a re-count or re-analysis of the same sample would give a value somewhere between the mean result minus two times the standard deviation and the mean result plus two times the standard deviation.

Table A.8. Elemental and Chemical Constituent Nomenclature

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

Total Propagated Analytical Uncertainty

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 (e.g., ashed, dried, or chemically treated) in the laboratory before counting, the total propagated analytical uncertainty only accounts for the uncertainty associated with counting the sample. The uncertainty associated with samples that are analyzed but not counted (e.g., chemical or water quality measurements) includes only the analytical process uncertainty. 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, the mean of mean values (averages) is accompanied by ±2 times the standard error of the calculated mean (or ±2 SEM). Two times the standard error of the mean implies that approximately 95% of the time the next calculated mean will fall somewhere between the reported value minus two times the standard error and the reported value plus two times 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 of an odd numbered set and the average of the two central values in an even numbered set. For example, the

median value in the odd numbered 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 average with a ± statistical uncertainty or when the data do not follow a bell-shape (i.e., normal) distribution. Figure A.1 provides a graphical representation of median, maximum, and minimum values. The upper line is the maximum value, the center dot is the median value, and the lower line is the minimum value.

Negative Concentrations

Instruments used in the laboratory to measure radioactivity in Hanford Site environmental samples are sensitive enough to measure 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 background radiation level must be subtracted from the total amount of radioactivity measured by an instrument. Because of the randomness of radioactive emissions, the very low activities of some contaminants, or the presence of undesirable materials, 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 Graphs

Graphs are useful when comparing numbers collected at several locations or at one location over time. Graphs often make it easy to visualize differences in data where they exist. However, careful consideration should be given to the scale (linear or logarithmic) and units.

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 or are very close together. 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.2). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure A.3).

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 value, these lines (called error bars) indicate the amount of uncertainty (standard deviation, total propagated analytical uncertainty, or two standard error of the mean) in the reported value.

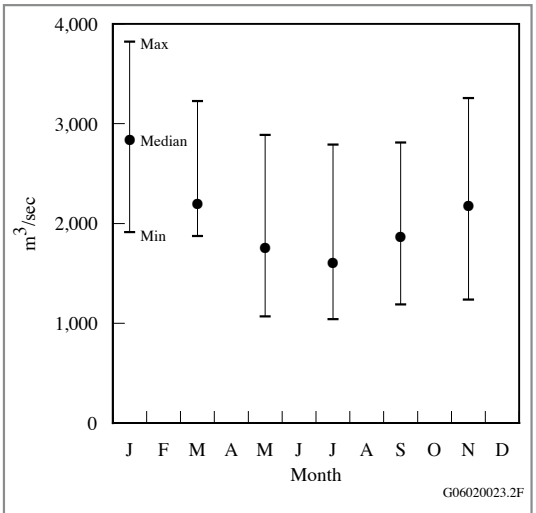

Figure A.1. A Graphical Representation of Maximum, Median (or sometimes average), and Minimum Values

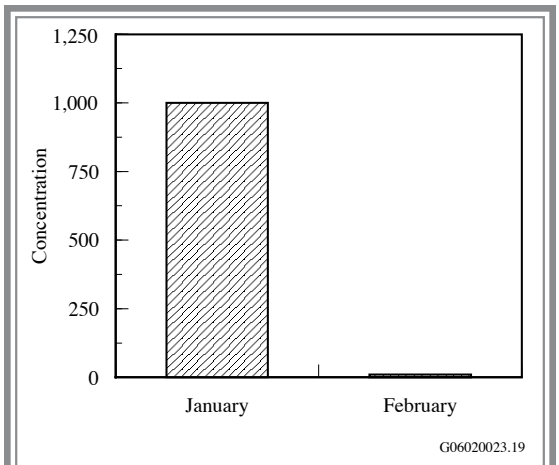

Figure A.2. Data Plotted Using a Linear Scale

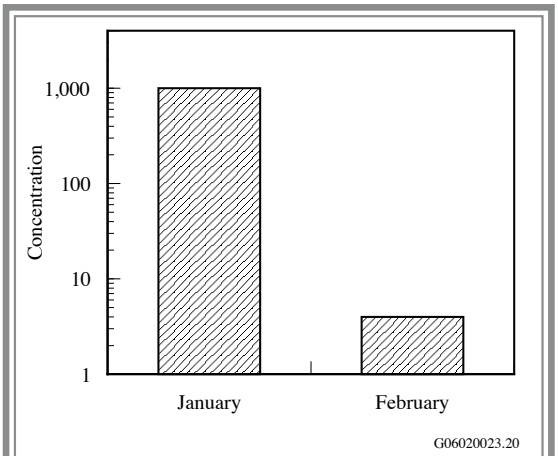

Figure A.3. Data Plotted Using a Logarithmic Scale

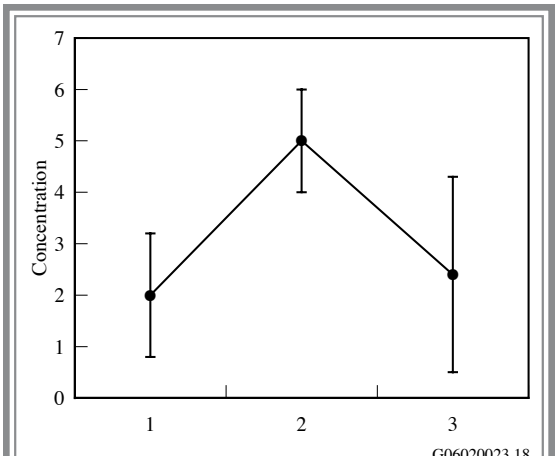

Figure A.4. Data with Error Bars Plotted Using a Linear Scale

The error bars in this report represent a 95% chance that the value is between the upper and lower ends of the error bar and a 5% chance that the true value is either lower or higher than the error bar.[(a)] For example, in Figure A.4, the first plotted value is 2.0 ± 1.1, so there is a 95% chance that the true value 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 value. These bars provide a quick, visual indication that one value may be statistically similar to or different from another value. If the error bars of two or more values overlap, as is the case with values 1 and 3 and values 2 and 3, the values may be statistically similar. If the error bars do not overlap (values 1 and 2), the values may be statistically different. Values that appear to be very different visually (values 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.1).

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. A symbol pointed in the opposite direction (<0.09) would indicate that the number is less than the value presented. A symbol used with an underscore ($\underline{\leq}$ or $\underline{\geq}$) indicates that the actual value is less than or equal to or greater than or equal to the number given, respectively.

Reference

Shleien B. 1992. *The Health Physics and Radiological Health Handbook, Revised Edition*. Scinta, Inc., Silver Spring, Maryland.

(a) Assuming the data are normally distributed.

Appendix B
Glossary

This glossary contains selected words and phrases used in this report that may not be familiar to the reader. Words appearing in *italic* within a definition are also defined in this glossary.

absorbed dose - Energy absorbed per unit mass from any kind of ionizing *radiation* in any kind of matter. Units: *rad*, which is equal to the absorption of 100 ergs per gram of material irradiated, or *gray*, which is the International System of Units (SI) equivalent.

activation product - Material made radioactive by *exposure* to *radiation*, principally by neutron radiation as in metals in a nuclear reactor, e.g., cobalt-60 from cobalt-59 in stainless steel.

adsorption - The accumulation of gases, liquids, or solutes on the surface of a solid or liquid.

alpha particle - A positively charged particle composed of two protons and two neutrons ejected spontaneously from the nuclei of some *radionuclides*. It has low penetrating power and short range. The most energetic alpha will generally fail to penetrate the skin. Alpha particles are hazardous when an alpha-emitting *isotope* is introduced into the body.

anion - A negatively charged ion.

aquifer - Underground sediment or rock that stores and/or transmits 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. It also includes *radiation* from global *fallout* from historical atmospheric nuclear weapons testing. In the United States, the average person receives approximately 300 *millirem* of background radiation per year.

bank storage - Hydrologic term that describes river water that flows into and is retained in permeable stream banks during periods of high river stage. Flow is reversed during periods of low river stage.

becquerel (Bq) - Unit of activity or amount of a radioactive substance (also *radioactivity*) equal to one nuclear transformation per second (1 Bq = 1 disintegration per second). Another unit of *radioactivity*, the *curie*, is related to the becquerel: 1 Ci = 3.7×10^{10} Bq.

beta particle - A negatively charged particle (essentially an electron) 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.

cation - A positively charged ion.

clean closed - A facility is classified as "clean closed" under Resource Conservation and Recovery Act 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-rem* or *person-sievert*.

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* to various tissues in the body, each multiplied by the appropriate weighting factor.

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. G*roundwater* 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 sampling period.

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. These structures are no longer used at Hanford.

curie (Ci) - A unit of *radioactivity* equal to 37 billion (3.7×10^{10}) nuclear transformations per second (*becquerels*).

decay - The decrease in the amount of any radioactive material (disintegration) 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). Informally referred to as daughter products. See *radioactivity*.

deep-dose equivalent - The *dose equivalent* at a tissue depth of 1 centimeter from *radiation* 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 *millirem* per year.

detection level (or limit) - Minimum amount of a substance that can be measured with a specified or implied confidence that the analytical result is greater than a specific value (e.g., zero).

dispersion - Process whereby *effluent* or *emissions* are spread or mixed when they are transported by *groundwater*, surface water, or air.

dose equivalent - Product of the *absorbed dose*, a 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*.

dose rate - The rate at which a dose is delivered over time, e.g., *dose equivalent* rate in *millirem* per hour (mrem/hr).

dosimeter - Portable device for measuring the accumulated *exposure* or *absorbed dose* from specific types or energies of ionizing *radiation* fields.

effective dose - See *effective dose equivalent*.

effective dose equivalent - The sum of products of *dose equivalent* to selected tissues of the body and appropriate tissue weighting factors. The tissue weighting factors put doses to various tissues and organs on an equal basis in terms of health *risk*.

effluent - Liquid material released from a facility.

effluent monitoring - Sampling or measuring specific liquid *effluent* streams for the presence of pollutants.

emission - Gaseous stream released from a facility.

exposure - The interaction of an organism with a physical agent (e.g., *radiation*) or a chemical agent (e.g., arsenic) of interest. Also used as a term for quantifying x- and *gamma radiation* fields. See *roentgen*.

external radiation - *Radiation* originating from a source outside the body.

fallout - Typically refers to 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.

fission products - Nuclides formed from fissioning. Many fission products are radioactive.

fully institutionalized - To incorporate into a formalized, structured system and be implemented and fully functional.

gamma radiation - High-energy electromagnetic *radiation* (*photons*) originating in the nucleus of decaying *radionuclides*. Gamma radiation is substantially more penetrating than *alpha* or *beta particles*.

grab sample - A short duration sample (e.g., air, water, and soil) that is grabbed from the collection site.

groundwater - Subsurface water that is in the pores of sand and gravel or in the cracks of fractured rock.

gray (Gy) - Unit of *absorbed dose* in the International System of Units (SI) equal to the absorption of 1 joule per kilogram. The common unit of *absorbed dose*, the *rad*, is equal to 0.01 Gy.

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-activity waste - See *high-level waste*.

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.

institutional controls - Long-term actions or restrictions including *monitoring*, periodic sampling, access controls, and land use restrictions designed to mitigate any *risks* posed by contamination following *remediation*. Institutional controls alone may be sufficient to reduce *risks* posed by low levels of contamination.

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 the same number of protons but a differing number of neutrons.

isotopic plutonium - Any of two or more atoms of the chemical element *plutonium* with the same atomic number and position in the periodic table and nearly identical chemical behavior but with differing atomic mass number and different physical properties. Plutonium-239 is produced by neutron *irradiation* of uranium-238.

isotopic uranium - Any of two or more atoms of the chemical element uranium with the same atomic number and position in the periodic table and nearly identical chemical behavior but with differing atomic mass number and different physical properties. Uranium exists naturally as a mixture of three *isotopes* of mass 234, 235, and 238 in the proportions of 0.006%, 0.71%, and 99.27%, respectively.

legacy waste - Waste that was generated prior to termination of Hanford's nuclear materials production mission.

low-activity waste - See *low-level waste*.

low-level waste - Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, *transuranic waste*, byproduct material, or naturally occurring radioactive material.

maximally exposed individual - A hypothetical member of the public residing near the Hanford Site who, by virtue of location and living habits, would reasonably receive the highest possible *radiation* dose from materials originating from Hanford.

mean (or average) - Average value of a series of measurements. The mean is computed as:

$$\text{mean} = \frac{\Sigma_x}{n}$$

where n is the number of measurements and Σ_x is the sum of all measurements.

median - Middle value in an odd numbered set of results when the data are ranked in increasing or decreasing order or the average of two central values in an even number set of results.

millirem - A unit of *radiation dose equivalent* that is equal to one one-thousandth (1/1000) of a *rem*.

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 U.S. Environmental Protection Agency or state designated dangerous, extremely hazardous, or acutely hazardous waste that contains both a non-radioactive hazardous component and a radioactive component.

monitoring - As defined in DOE Order 5400.5, the collection and analysis of samples or measurements of liquid *effluent* and gaseous *emissions* for purposes of characterizing and quantifying contaminants, assessing *radiation exposure* to the public, and demonstrating compliance with regulatory standards.

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* pathway for radioactive noble gases is direct external dose from the surrounding air.

nuclide - A particular combination of neutrons and protons. A *radionuclide* is a radioactive nuclide.

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 *effluent* 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-rem.

photon - A quantum of radiant energy. *Gamma radiation* and x-radiation (x-rays) are both composed of photons of varying energy.

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, 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.

primordial radionuclide - A radioactive material in the earth's crust that has a very long *half-life* and has existed since the beginning of the planet.

quality assurance - Actions that provide confidence that an item or process meets or exceeds a 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 (e.g., *alpha* and *beta particles*) such as that from transforming *radionuclides*. For this report, radiation refers to ionizing types of radiation; not radiowaves, microwaves, radiant light, or other types of non-ionizing radiation.

radioactivity - Property possessed by *radioisotopes* emitting *radiation* (such as *alpha* or *beta particles*, or high-energy *photons*) spontaneously in their *decay* process also, the *radiation* emitted.

radioisotope - An unstable *isotope* of an element that *decays* or disintegrates spontaneously, emitting *radiation* (Shleien 1992).

radiologically controlled area - An area to which access is controlled to protect individuals from *exposure* to *radiation* or radioactive materials.

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 but carbon-12, which is not radioactive, is referred to simply as a *nuclide*.

recruitment - Survival from one life form or stage to the next or from one age class to the next.

redox - A chemical reaction involving oxidation and reduction.

rem - A unit of *dose equivalent* and *effective dose equivalent*.

remediation - Reduction (or cleanup) of known *risks* to the public and environment to an agreed-upon level.

risk - The probability that a detrimental health effect will occur.

risk-based disposal approval - A written application to the U.S. Environmental Protection Agency intended for the management and disposal of Toxic Substances Control Act-regulated polychlorinated biphenyl waste not addressed suitably within the regulations. The risk-based disposal approval process is applicable to any person wishing to sample, clean up, or dispose of waste in a manner other than as prescribed in 40 CFR 761. For polychlorinated biphenyl *remediation* waste, the requirements for a risk-based disposal approval are specified in 40 CFR 761.61(c). A written approval from the U.S. Environmental Protection Agency is required before waste management activities are performed.

roentgen (R) - The unit of x-ray or gamma *photon exposure* as 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) - The unit of *dose equivalent* and its variants in the International System of Units (SI). The common unit for *dose equivalent* and its variants, the *rem*, is equal to 0.01 Sv.

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*.

spent fuel - Uranium metal or oxide and its metal container that have been used to power a nuclear reactor and for one reason or another has reached the end of its useful life. 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*.

surveillance - As defined in DOE Order 5400.5, the collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media, and the measurement of *external radiation* for purposes of demonstrating compliance with applicable standards, assessing *exposures* to the public, and assessing effects, if any, on the local environment.

tank farm - A group of underground waste storage tanks.

transuranic element - 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*) per gram of alpha-emitting transuranic isotopes (*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 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 the intake of radioactive material and *dose equivalent* from exposure to *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 ground 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.

water table - The top of the *unconfined aquifer*.

wind rose - A diagram showing how often winds of various speeds blow from different directions, usually based on yearly averages.

References

40 CFR 761. "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

40 CFR 761.61(c). "PCB Remediation Waste." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

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Shleien B. (ed.). 1992. *The Health Physics and Radiological Health Handbook, Revised Edition*. Scinta, Inc., Silver Spring, Maryland.

Resource Conservation and Recovery Act. 1976. Public Law 94-580, as amended, 90 Stat. 2795, 42 USC 6901 et seq. Accessed on May 1, 2007, at http://www.epa.gov/region5/defs/html/rcra.htm.

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Appendix C
Additional Monitoring Results for 2006

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This appendix contains additional information on 2006 monitoring results, supplementing data summarized in the main body of the report. More detailed information is available in *Hanford Site Environmental Surveillance Data Report for Calendar Year 2006* (PNNL-16623, APP. 1) and *Hanford Site Near-Facility Monitoring Data Report for Calendar Year 2006* (PNNL-16623, APP. 2).

Table C.1. Concentrations of Selected Radionuclides (pCi/m³)[a] in Near-Facility Air Samples, 2006 Compared to Previous Years

Radionuclide	Areas	2006 Number of Samples	2006 Number of Detections[b]	2006 Average[c]	2006 Maximum[d]	Sampler Number	2001-2005 Number of Samples	2001-2005 Number of Detections[b]	2001-2005 Average[c]	2001-2005 Maximum[d]	EPA Table 2[e,f]
Gross alpha	100-B/C FR	135	123	1.1E-03 ± 1.0E-03	3.2E-03 ± 8.2E-04	N496	511	450	1.2E-03 ± 1.4E-03	4.1E-03 ± 1.0E-03	2.0E-02
	100-F FR	189	159	1.0E-03 ± 1.2E-03	3.3E-03 ± 9.0E-04	N552	427	342	1.0E-03 ± 1.5E-03	4.4E-03 ± 1.1E-03	
	105-H ISS	34	29	8.4E-04 ± 8.0E-04	1.8E-03 ± 6.2E-04	N525	260	219	1.3E-03 ± 1.9E-03	6.9E-03 ± 2.6E-03	
	100-K ISS	81	65	1.1E-03 ± 1.2E-03	2.7E-03 ± 7.8E-04	N477	312	271	1.2E-03 ± 1.5E-03	5.8E-03 ± 1.2E-03	
	118-K-1 FR	81	70	1.0E-03 ± 1.0E-03	2.2E-03 ± 7.2E-04	N535	141	125	1.3E-03 ± 2.1E-03	7.5E-03 ± 1.6E-03	
	100-K SNF	214	185	1.1E-03 ± 1.1E-03	3.0E-03 ± 9.8E-04	N404	1,041	919	1.3E-03 ± 1.8E-03	1.4E-02 ± 1.6E-02	
	100-N	81	78	1.2E-03 ± 1.1E-03	3.0E-03 ± 1.0E-03	N102	397	361	1.3E-03 ± 1.5E-03	5.7E-03 ± 1.5E-03	
	200-East	537	495	1.2E-03 ± 1.2E-03	3.5E-03 ± 9.2E-04	N969	2,496	2,267	1.2E-03 ± 1.5E-03	6.7E-03 ± 1.6E-03	
	200-West	675	610	1.2E-03 ± 1.2E-03	3.4E-03 ± 9.0E-04	N457	2,926	2,644	1.3E-03 ± 1.5E-03	1.1E-02 ± 1.6E-02	
	300 Area D&D	27	26	1.2E-03 ± 1.1E-03	2.2E-03 ± 7.6E-04	N557	23	20	1.4E-03 ± 2.8E-03	7.3E-03 ± 1.7E-03	
	300-FF-2 FR	54	54	1.2E-03 ± 9.8E-04	2.5E-03 ± 7.5E-04	N527	361	318	1.3E-03 ± 1.6E-03	6.3E-03 ± 7.8E-03	
	ERDF	108	97	1.2E-03 ± 1.2E-03	3.7E-03 ± 1.0E-03	N482	523	447	1.1E-03 ± 1.3E-03	5.4E-03 ± 1.5E-03	
Gross beta	100-B/C FR	135	135	1.5E-02 ± 1.2E-02	2.9E-02 ± 3.0E-03	N497	511	511	1.7E-02 ± 2.3E-02	6.7E-02 ± 5.8E-03	9.0E+00
	100-F FR	189	189	1.6E-02 ± 1.4E-02	4.1E-02 ± 4.4E-03	N552	429	429	1.7E-02 ± 2.4E-02	7.1E-02 ± 7.6E-03	
	105-H ISS	34	34	1.3E-02 ± 8.4E-03	2.2E-02 ± 2.4E-03	N524	260	260	1.9E-02 ± 2.6E-02	8.7E-02 ± 7.4E-03	
	100-K ISS	81	81	1.7E-02 ± 1.7E-02	3.6E-02 ± 3.5E-03	N477	312	312	1.8E-02 ± 2.4E-02	7.1E-02 ± 6.5E-03	
	118-K-1 FR	81	81	1.5E-02 ± 1.4E-02	3.6E-02 ± 3.6E-03	N403	141	141	1.9E-02 ± 2.8E-02	7.8E-02 ± 7.9E-03	
	100-K SNF	214	214	1.6E-02 ± 1.5E-02	3.7E-02 ± 3.7E-03	N479	1,041	1,041	1.9E-02 ± 2.6E-02	1.2E-01 ± 1.1E-02	
	100-N	81	81	1.6E-02 ± 1.4E-02	3.6E-02 ± 4.0E-03	N102	397	397	1.8E-02 ± 2.5E-02	8.2E-02 ± 7.0E-03	
	200-East	537	537	1.5E-02 ± 1.6E-02	9.6E-02 ± 7.8E-03	N019	2,496	2,496	1.7E-02 ± 2.2E-02	7.9E-02 ± 7.7E-03	
	200-West	675	675	1.6E-02 ± 1.4E-02	5.0E-02 ± 4.6E-03	N456	2,926	2,925	1.7E-02 ± 2.2E-02	7.1E-02 ± 6.8E-03	
	300 Area D&D	27	27	1.7E-02 ± 1.9E-02	5.2E-02 ± 5.5E-03	N557	23	23	1.7E-02 ± 2.7E-02	6.4E-02 ± 6.8E-03	
	300-FF-2 FR	54	54	1.5E-02 ± 1.4E-02	3.1E-02 ± 3.2E-03	N527	361	360	1.8E-02 ± 2.6E-02	8.1E-02 ± 1.0E-02	
	ERDF	108	108	1.5E-02 ± 1.4E-02	4.1E-02 ± 3.8E-03	N963	523	522	1.6E-02 ± 2.2E-02	7.1E-02 ± 6.8E-03	
Cobalt-60	100-B/C FR	10	0	-1.8E-05 ± 7.4E-05	4.3E-05 ± 7.6E-05	N465	42	0	2.1E-06 ± 8.5E-05	8.1E-05 ± 9.0E-05	1.7E-02
	100-F FR	20	0	8.5E-05 ± 2.7E-04	2.8E-05 ± 1.0E-04	N519	41	0	1.0E-04 ± 3.3E-04	6.5E-04 ± 7.5E-04	
	105-H ISS	6	0	-6.0E-05 ± 1.9E-04	6.2E-05 ± 8.8E-05	N524	38	1	2.1E-05 ± 1.5E-04	2.1E-04 ± 1.2E-04	
	100-K ISS	4	0	-8.1E-06 ± 7.5E-05	3.6E-05 ± 7.5E-05	N476	20	0	7.2E-06 ± 6.6E-05	5.9E-05 ± 9.4E-05	
	118-K-1 FR	6	0	-1.4E-05 ± 7.2E-05	3.9E-05 ± 7.3E-05	N534	14	0	6.2E-05 ± 3.4E-04	5.5E-04 ± 5.7E-04	
	100-K SNF	16	0	1.6E-05 ± 6.9E-05	7.9E-05 ± 8.9E-05	N401	80	0	6.7E-06 ± 9.1E-05	1.2E-04 ± 8.5E-05	
	100-N	6	0	4.5E-06 ± 5.5E-05	4.2E-05 ± 7.7E-05	N102	30	9	1.1E-04 ± 1.9E-04	2.9E-04 ± 1.4E-04	
	200-East	40	0	1.6E-05 ± 8.4E-05	1.1E-04 ± 1.1E-04	N158	192	2	5.4E-06 ± 8.8E-05	1.4E-04 ± 6.7E-05	
	200-West	50	1	4.3 E-06 ± 9.9E-05	1.5E-04 ± 1.5E-04	N433	229	0	4.5E-06 ± 8.7E-05	1.6E-04 ± 9.0E-05	
	300 Area D&D	4	0	-1.3E-05 ± 4.2E-05	1.1E-05 ± 1.1E-04	N557	4	0	-4.6E-05 ± 3.8E-04	8.2E-05 ± 1.6E-04	
	300-FF-2 FR	4	0	-3.5E-05 ± 8.8E-05	2.7-E05 ± 7.2E-05	N130	40	0	-4.1E-05 ± 5.1E-04	1.1E-03 ± 1.3E-03	
	ERDF	8	0	-2.6E-06 ± 9.9E-05	8.5E-05 ± 8.1E-05	N518	40	3	3.6E-05 ± 1.8E-04	3.0E-04 ± 1.4E-04	

Table C.1. (contd)

Radionuclide	Site	2006 Number of Samples	2006 Number of Detections[b]	2006 Average[c]	2006 Maximum[d]	Sampler Number	2001-2005 Number of Samples	2001-2005 Number of Detections[b]	2001-2005 Average[c]	2001-2005 Maximum[d]	EPA Table 2[e,f]
Strontium-90	100-B/C FR	10	1	8.7E-06 ± 1.3E-04	1.4E-04 ± 1.2E-04	N497	42	7	2.1E-06 ± 2.5E-04	2.7E-04 ± 1.1E-04	1.9E-02
	100-F FR	20	1	3.5E-06 ± 1.4E-04	2.7E-04 ± 1.3E-04	N520	40	8	3.5E-05 ± 2.0E-04	2.5E-04 ± 1.3E-04	
	105-H ISS	6	0	-1.5E-04 ± 3.7E-04	1.6E-04 ± 1.7E-04	N524	38	14	5.2E-05 ± 5.4E-04	6.7E-04 ± 2.6E-04	
	100-K ISS	4	0	3.7E-05 ± 1.3E-04	1.2E-04 ± 1.3E-04	N476	20	7	3.9E-05 ± 2.3E-04	2.2E-04 ± 1.6E-04	
	118-K-1 FR	6	0	4.2E-06 ± 1.5E-04	1.3E-04 ± 1.2E-04	N534	14	7	1.1E-04 ± 7.7E-04	9.5E-04 ± 4.3E-04	
	100-K SNF	16	0	-2.0E-05 ± 1.5E-04	1.2E-04 ± 1.3E-04	N476	80	25	4.9E-05 ± 2.2E-04	2.7E-04 ± 1.2E-04	
	100-N	6	1	3.5E-05 ± 1.6E-04	1.6E-04 ± 1.1E-04	N102	30	7	4.0E-05 ± 2.8E-04	4.5E-04 ± 1.8E-04	
	200-East	40	1	2.5E-06 ± 1.6E-04	3.0E-04 ± 1.6E-04	N984	192	58	5.8E-05 ± 3.0E-04	1.0E-03 ± 3.3E-04	
	200-West	50	3	8.5E-06 ± 2.7E-04	6.2E-04 ± 2.2E-04	N161	229	47	2.0E-05 ± 2.2E-04	6.6E-04 ± 2.6E-04	
	300 Area D&D	4	0	-1.6E-05 ± 2.8E-04	1.9E-04 ± 2.1E-04	N557	4	0	-5.6E-06 ± 4.5E-04	3.8E-04 ± 4.7E-04	
	300-FF-2 FR	2	0	2.9E-05 ± 1.6E-05	3.7E-05 ± 9.0E-05	N130	10	2	-2.4E-08 ± 2.2E-04	1.4E-04 ± 8.7E-05	
	ERDF	8	0	-2.4E-05 ± 1.4E-04	8.3E-05 ± 1.3E-04	N517	40	6	3.5E-05 ± 2.0E-04	2.8E-04 ± 1.2E-04	
Cesium-137	100-B/C FR	10	0	1.9E-05 ± 8.8E-05	1.0E-04 ± 7.2E-05	N464	42	0	1.8E-05 ± 8.9E-05	1.5E-04 ± 2.0E-04	1.9E-02
	100-F FR	20	0	1.1E-04 ± 3.1E-04	3.7E-05 ± 1.0E-04	N553	41	1	1.4E-04 ± 5.3E-04	1.6E-03 ± 6.8E-04	
	105-H ISS	6	0	-9.8E-06 ± 1.4E-04	8.8E-05 ± 3.2E-04	N524	38	4	7.3E-05 ± 4.6E-04	1.1E-03 ± 4.0E-04	
	100-K ISS	4	0	2.4E-05 ± 3.8E-05	5.2E-05 ± 9.9E-05	N477	20	1	2.7E-05 ± 8.8E-05	1.6E-04 ± 1.5E-04	
	118-K-1 FR	6	1	3.7E-05 ± 7.6E-05	1.1E-04 ± 9.0E-05	N535	14	2	4.7E-05 ± 1.6E-04	1.4E-04 ± 1.3E-04	
	100-K SNF	16	0	2.1E-05 ± 8.0E-05	8.9E-05 ± 1.2E-04	N402	80	4	3.5E-05 ± 1.0E-04	1.6E-04 ± 1.5E-04	
	100-N	6	0	3.1E-05 ± 7.2E-05	7.5E-05 ± 1.0E-04	N106	30	4	5.0E-05 ± 1.2E-04	1.9E-04 ± 1.1E-04	
	200-East	40	4	8.3E-05 ± 3.6E-04	8.9E-04 ± 3.6E-04	N984	192	30	7.8E-05 ± 4.1E-04	2.3E-03 ± 7.6E-04	
	200-West	50	5	4.3E-05 ± 1.4E-04	3.2E-04 ± 1.8E-04	N550	229	26	7.1E-05 ± 2.7E-04	1.3E-03 ± 5.1E-04	
	300 Area D&D	4	0	4.0E-06 ± 1.3E-04	7.6E-05 ± 1.2E-04	N557	4	0	8.5E-06 ± 1.4E-04	1.2E-04 ± 3.1E-04	
	300-FF-2 FR	4	0	1.7E-05 ± 3.4E-05	3.1E-05 ± 9.9E-05	N130	40	0	2.1E-05 ± 2.8E-04	4.6E-04 ± 7.8E-04	
	ERDF	8	1	6.1E-05 ± 1.8E-04	2.8E-04 ± 1.7E-04	N517	40	5	7.1E-05 ± 1.2E-04	2.6E-04 ± 1.5E-04	
Uranium-234	100-B/C FR	10	8	9.5E-06 ± 7.0E-06	1.7E-05 ± 9.6E-06	N464	42	39	1.2E-05 ± 1.6E-05	5.1E-05 ± 2.1E-05	7.7E-03
	100-F FR	15	9	1.5E-05 ± 1.8E-05	1.8E-05 ± 9.7E-06	N552	30	20	2.3E-05 ± 7.8E-05	2.3E-04 ± 2.0E-03	
	105-H ISS	6	5	2.0E-05 ± 2.3E-05	3.7E-05 ± 2.4E-05	N524	38	31	1.9E-05 ± 1.6E-05	4.6E-05 ± 2.4E-05	
	100-K ISS	4	4	1.2E-05 ± 6.8E-06	1.7E-05 ± 9.8E-06	N476	20	20	1.1E-05 ± 6.3E-06	1.7E-05 ± 9.9E-06	
	118-K-1 FR	6	5	1.2E-05 ± 8.6E-06	1.8E-05 ± 1.0E-05	N535	14	12	2.2E-05 ± 4.0E-05	8.4E-05 ± 4.3E-05	
	100-K SNF	16	14	1.0E-05 ± 7.3E-06	1.8E-05 ± 1.0E-05	N401	80	71	1.1E-05 ± 8.8E-06	2.6E-05 ± 1.2E-05	
	100-N	6	6	1.4E-05 ± 8.8E-06	2.2E-05 ± 1.1E-05	N102	30	29	1.2E-05 ± 6.8E-06	1.9E-05 ± 9.9E-06	
	200-East	40	38	1.1E-05 ± 8.2E-06	2.4E-05 ± 1.1E-05	N984	192	172	1.3E-05 ± 1.2E-05	3.9E-05 ± 1.8E-05	
	200-West	50	43	1.1E-05 ± 1.0E-05	2.8E-05 ± 1.4E-05	N550	229	208	1.4E-05 ± 1.4E-05	6.3E-05 ± 2.8E-05	
	300 Area D&D	4	4	2.7E-05 ± 1.3E-05	3.3E-05 ± 1.6E-05	N557	4	4	5.1E-05 ± 7.0E-05	1.1E-04 ± 5.3E-05	
	300-FF-2 FR	4	4	1.4E-05 ± 4.3E-06	1.8E-05 ± 1.0E-05	N527	40	36	5.2E-05 ± 1.0E-04	1.9E-04 ± 9.7E-05	
	ERDF	8	8	1.4E-05 ± 9.2E-06	1.9E-05 ± 1.0E-05	N518	40	38	1.7E-05 ± 1.5E-05	4.8E-05 ± 2.2E-05	

Table C.1. (contd)

Radionuclide	Site	2006 Number of Samples	2006 Number of Detections[b]	2006 Average[c]	2006 Maximum[d]	Sampler Number	2001-2005 Number of Samples	2001-2005 Number of Detections[b]	2001-2005 Average[c]	2001-2005 Maximum[d]	EPA Table 2[e,f]
Uranium-235	100-B/C FR	10	2	2.9E-06 ± 2.0E-06	5.4E-06 ± 4.5E-06	N497	42	12	4.0E-06 ± 7.4E-06	2.1E-05 ± 1.6E-05	7.1E-03
	100-F FR	15	0	1.7E-06 ± 3.0E-06	3.1E-06 ± 3.9E-06	N552	30	9	4.5E-06 ± 8.8E-06	2.4E-05 ± 1.2E-04	
	105-H ISS	6	1	8.1E-06 ± 1.1E-05	1.9E-05 ± 1.7E-05	N524	38	7	5.2E-06 ± 7.4E-06	1.7E-05 ± 1.3E-05	
	100-K ISS	4	3	3.6E-06 ± 3.5E-06	5.5E-06 ± 4.6E-06	N476	20	2	2.2E-06 ± 2.5E-06	5.3E-06 ± 5.4E-06	
	118-K-1 FR	6	1	3.3E-06 ± 1.5E-06	4.4E-06 ± 4.0E-06	N535	14	3	5.9E-06 ± 1.2E-05	2.3E-05 ± 2.3E-05	
	100-K SNF	16	5	2.9E-06 ± 3.5E-06	5.7E-06 ± 5.1E-06	N478	80	10	2.4E-06 ± 3.7E-06	1.2E-05 ± 7.9E-06	
	100-N	6	2	3.0E-06 ± 5.1E-06	8.2E-06 ± 6.9E-06	N103	30	8	2.4E-06 ± 3.8E-06	6.4E-06 ± 5.3E-06	
	200-East	40	9	2.8E-06 ± 3.9E-06	8.7E-06 ± 6.1E-06	N967	192	44	2.9E-06 ± 4.0E-06	1.0E-05 ± 6.8E-06	
	200-West	50	13	2.8E-06 ± 3.9E-06	7.8E-06 ± 5.7E-06	N168	229	66	3.1E-06 ± 5.3E-06	1.9E-05 ± 1.2E-05	
	300 Area D&D	4	0	5.1E-06 ± 1.0E-06	5.5E-06 ± 5.8E-06	N557	4	0	3.2E-06 ± 5.9E-06	6.0E-06 ± 7.2E-06	
	300-FF-2 FR	4	0	1.1E-06 ± 7.7E-07	1.5E-06 ± 2.2E-06	N130	40	12	1.3E-05 ± 4.5E-05	1.3E-04 ± 8.9E-05	
	ERDF	8	3	2.5E-06 ± 4.2E-06	7.1E-06 ± 5.4E-06	N482	40	5	2.6E-06 ± 3.6E-06	7.8E-06 ± 5.7E-06	
Plutonium-238	100-B/C FR	10	0	-1.0E-07 ± 5.8E-06	3.7E-06 ± 4.1E-06	N465	42	2	3.1E-06 ± 1.9E-05	2.9E-05 ± 2.1E-05	2.1E-03
	100-F FR	20	0	6.6E+00 ± 4.8E+01	1.4E-05 ± 1.3E-05	N553	39	0	1.9E-01 ± 1.4E+00	3.6E+00 ± 3.6E-01	
	105-H ISS	6	0	-1.3E-05 ± 3.2E-05	6.8E-06 ± 2.6E-05	N525	38	1	3.0E-07 ± 2.9E-05	2.7E-05 ± 3.5E-05	
	100-K ISS	4	0	-4.1E-06 ± 2.4E-05	9.6E-06 ± 2.8E-05	N476	20	0	4.2E-07 ± 1.4E-05	1.7E-05 ± 2.9E-05	
	118-K-1 FR	6	0	4.6E-07 ± 8.3E-06	7.8E-06 ± 2.2E-05	N403	14	0	5.3E-06 ± 3.3E-05	3.3E-05 ± 6.0E-05	
	100-K SNF	16	0	-7.7E-07 ± 2.1E-05	1.2E-05 ± 2.0E-05	N402	80	0	1.3E-06 ± 2.2E-05	3.0E-05 ± 3.7E-05	
	100-N	6	0	1.3E-06 ± 2.2E-06	2.7E-06 ± 3.0E-06	N103	30	0	-6.7E-07 ± 1.6E-05	2.2E-05 ± 1.5E-05	
	200-East	40	0	1.1E-06 ± 1.0E-05	1.5E-05 ± 2.6E-05	N480	192	1	6.2E-07 ± 1.4E-05	3.7E-05 ± 2.8E-05	
	200-West	50	0	1.9E-06 ± 8.9E-06	1.5E-05 ± 1.7E-05	N165	229	3	1.9E-06 ± 1.5E-05	4.0E-05 ± 2.5E-05	
	300 Area D&D	4	1	1.7E-05 ± 4.4E-05	5.5E-05 ± 4.4E-05	N557	4	0	-3.0E-07 ± 4.1E-05	1.5E-05 ± 3.4E-05	
	300-FF-2 FR	4	2	2.2E-06 ± 4.9E-06	6.0E-06 ± 4.8E-06	N527	19	0	8.8E-06 ± 8.2E-05	1.4E-04 ± 1.6E-04	
	ERDF	8	0	2.5E-06 ± 1.1E-05	1.4E-05 ± 1.4E-05	N963	40	2	1.8E-06 ± 1.1E-05	1.3E-05 ± 1.6E-05	
Uranium-238	100-B/C FR	10	10	8.2E-06 ± 3.0E-06	1.1E-05 ± 6.9E-06	N466	42	34	9.6E-06 ± 8.8E-06	2.8E-05 ± 1.3E-05	8.3E-03
	100-F FR	15	13	9.9E-06 ± 8.5E-06	1.7E-05 ± 9.6E-06	N552	30	22	1.4E-05 ± 3.7E-05	1.1E-04 ± 8.2E-05	
	105-H ISS	6	4	1.5E-05 ± 1.6E-05	2.7E-05 ± 1.9E-05	N524	38	25	1.3E-05 ± 1.2E-05	3.2E-05 ± 1.9E-05	
	100-K ISS	4	4	7.6E-06 ± 2.3E-06	8.7E-06 ± 6.3E-06	N476	20	18	9.0E-06 ± 6.2E-06	1.4E-05 ± 8.1E-06	
	118-K-1 FR	6	6	1.3E-05 ± 5.1E-06	1.7E-05 ± 9.8E-06	N534	14	12	1.7E-05 ± 2.0E-05	3.9E-05 ± 2.6E-05	
	100-K SNF	16	15	8.5E-06 ± 4.8E-06	1.5E-05 ± 9.5E-06	N403	80	71	9.0E-06 ± 8.3E-06	2.6E-05 ± 1.2E-05	
	100-N	6	4	6.4E-06 ± 3.7E-06	8.6E-06 ± 5.8E-06	N103	30	25	8.7E-06 ± 6.8E-06	1.5E-05 ± 9.5E-06	
	200-East	40	35	7.7E-06 ± 5.1E-06	1.4E-05 ± 8.4E-06	N976	192	172	1.1E-05 ± 1.1E-05	4.0E-05 ± 1.9E-05	
	200-West	50	42	8.9E-06 ± 9.5E-06	2.9E-05 ± 1.4E-05	N550	229	207	1.1E-05 ± 1.2E-05	4.6E-05 ± 2.2E-05	
	300 Area D&D	4	3	2.2E-05 ± 2.6E-05	3.6E-05 ± 2.0E-05	N557	4	2	1.5E-05 ± 1.9E-05	2.7E-05 ± 1.5E-05	
	300-FF-2 FR	4	4	9.4E-06 ± 3.9E-06	1.2E-05 ± 7.9E-06	N527	40	36	4.0E-05 ± 7.9E-05	1.5E-04 ± 1.0E-04	
	ERDF	8	6	1.3E-05 ± 9.8E-06	1.8E-05 ± 9.7E-06	N518	40	38	1.4E-05 ± 1.7E-05	4.9E-05 ± 2.2E-05	

Table C.1. (contd)

Radionuclide	Site	2006 Number of Samples	2006 Number of Detections[b]	2006 Average[c]	2006 Maximum[d]	Sampler Number	2001-2005 Number of Samples	2001-2005 Number of Detections[b]	2001-2005 Average[c]	2001-2005 Maximum[d]	EPA Table 2[e,f]
Plutonium-239/240	100-B/C FR	10	0	2.2E-06 ± 2.1E-06	4.5E-06 ± 4.2E-06	N465	42	6	2.8E-06 ± 1.0E-05	2.6E-05 ± 1.2E-05	2.0E-03
	100-F FR	20	1	9.4E-02 ± 8.2E-01	5.2E-06 ± 5.2E-06	N519	37	3	4.9E-01 ± 4.1E+00	9.0E+00 ± 9.0E-01	
	105-H ISS	6	0	2.1E-06 ± 3.5E-06	3.9E-06 ± 7.9E-06	N524	38	13	1.5E-05 ± 5.7E-05	1.6E-04 ± 6.4E-05	
	100-K ISS	4	1	6.7E-06 ± 4.8E-06	9.4E-06 ± 8.5E-06	N477	20	4	4.6E-06 ± 1.0E-05	2.0E-05 ± 1.4E-05	
	118-K-1 FR	6	2	6.7E-06 ± 8.1E-06	1.2E-05 ± 1.1E-05	N403	14	6	1.2E-05 ± 3.7E-05	5.4E-05 ± 3.3E-05	
	100-K SNF	16	4	6.2E-06 ± 1.1E-05	1.3E-05 ± 9.7E-06	N479	80	18	7.2E-06 ± 1.7E-05	4.8E-05 ± 2.4E-05	
	100-N	6	3	4.0E-06 ± 5.2E-06	9.0E-06 ± 6.1E-06	N102	30	11	5.4E-06 ± 6.8E-06	1.3E-05 ± 8.3E-06	
	200-East	40	4	1.7E-06 ± 4.5E-06	6.7E-06 ± 5.3E-06	N972	192	39	4.2E-06 ± 1.7E-05	7.2E-05 ± 3.2E-05	
	200-West	50	18	1.5E-05 ± 1.1E-04	3.6E-04 ± 1.4E-04	N165	229	118	2.8E-05 ± 1.6E-04	5.4E-04 ± 2.1E-04	
	300 Area D&D	4	0	3.4E-06 ± 3.9E-06	6.5E-06 ± 1.2E-05	N557	4	1	1.1E-05 ± 3.2E-05	3.9E-05 ± 2.8E-05	
	300-FF-2 FR	4	0	7.4E-07 ± 3.1E-07	9.6E-07 ± 1.4E-06	N130	19	3	3.7E-05 ± 2.7E-04	6.2E-04 ± 2.5E-04	
	ERDF	8	5	8.9E-06 ± 1.6E-05	2.8E-05 ± 1.3E-05	N517	40	18	2.1E-05 ± 1.4E-04	4.3E-04 ± 1.3E-04	
Americium-241	100-K ISS	4	1	9.4E-06 ± 7.0E-06	1.3E-05 ± 7.3E-06	N477	20	4	7.0E-06 ± 9.6E-06	1.5E-05 ± 1.0E-05	1.9E-03
	118-K-1 FR	2	2	2.3E-04 ± 4.3E-04	4.4E-04 ± 1.7E-04	N403	10	2	1.2E-05 ± 2.3E-05	3.8E-05 ± 2.3E-05	
	100-K SNF	16	8	3.5E-05 ± 2.1E-04	4.4E-04 ± 1.7E-04	N403	80	11	7.6E-06 ± 1.5E-05	3.8E-05 ± 2.3E-05	
	200-East	4	0	4.4E-06 ± 8.5E-06	8.6E-06 ± 1.3E-05	N480	20	1	4.3E-06 ± 7.2E-06	1.3E-05 ± 1.6E-05	
Plutonium-241	100-K ISS	4	1	7.5E-04 ± 9.8E-04	1.5E-03 ± 7.8E-04	N476	20	2	1.2E-04 ± 1.2E-03	1.3E-03 ± 7.4E-04	1.0E-01
	118-K-1 FR	2	0	6.7E-04 ± 6.5E-04	1.0E-03 ± 8.4E-04	N403	10	0	2.4E-04 ± 9.8E-04	1.1E-03 ± 1.0E-03	
	100-K SNF	16	3	7.0E-04 ± 1.0E-03	1.8E-03 ± 8.8E-04	N479	80	9	1.7E-04 ± 1.2E-03	1.7E-03 ± 8.3E-04	
	200-East	4	1	4.4E-04 ± 7.4E-04	1.0E-03 ± 6.3E-04	N481	20	2	1.8E-05 ± 1.5E-03	1.7E-03 ± 8.7E-04	

(a) 1 pCi = 0.037 Bq.
(b) Number of samples with measurable concentrations of contaminant.
(c) Average ± two standard deviations of all samples analyzed.
(d) Maximum ± analytical uncertainty.
(e) DOE-derived concentration guides are shown for gross alpha and gross beta.
(f) EPA values are based on an effective dose equivalent of 10 mrem/yr (40 CFR 61, Appendix E, Table 2).

D&D = Decontamination and decommissioning.
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
ERDF = Environmental Restoration Disposal Facility.
FR = Field Remediation project.
ISS = Interim Safe Storage projects at 105-H and 100-K Areas.
SNF = Spent nuclear fuel.

Table C.2. Selected U.S. Geological Survey Columbia River Water Quality Data for Vernita Bridge and Richland, Washington,[a] 2006

		Vernita Bridge (upstream)				Richland (downstream)				Washington Ambient Surface Water Quality Standard[b]
Analysis	Units	No. of Samples	Median	Maximum	Minimum	No. of Samples	Median	Maximum	Minimum	
Temperature	°C	3	11	21	8.3	3	10	21	8.1	20 (maximum)
Dissolved oxygen	mg/L	3	12.2	12.6	9.0	3	11.1	12.8	8.9	8 (minimum)
Turbidity	NTU	3	<2	2.9	<2	3	<2	2.0	<2	5 + background
pH	pH units	3	7.9	8.0	7.6	3	7.8	7.8	7.3	6.5 - 8.5
Sulfate, dissolved	mg/L	3	8.4	9.0	8.0	3	8.8	9.3	8.2	--[c]
Dissolved solids, 180°C (356°F)	mg/L	3	76	83	72	3	82	91	77	--
Specific conductance	µS/cm	3	132	138	131	3	138	140	132	--
Total hardness, as $CaCO_3$	mg/L	3	64	67	62	3	66	66	59	--
Alkalinity	mg/L	3	57	60	51	3	57	60	53	
Phosphorus, total	mg/L	3	<0.04	<0.04	<0.04	3	<0.04	<0.04	<0.04	--
Chromium, dissolved	µg/L	3	0.09	0.11[d]	0.04	3	0.08	0.09[d]	0.02[d]	10
Dissolved organic carbon	mg/L	3	1.6	1.9	1.5	3	2.1	2.0	1.5	--
Iron, dissolved	µg/L	3	6	7	4[d]	3	<6	7	<6	--
Ammonia, dissolved, as nitrogen	mg/L	3	<0.02	<0.04	<0.01	3	<0.02	<0.04	<0.01	--
Nitrite + nitrate, dissolved, as nitrogen	mg/L	3	0.12	0.15	0.07	3	0.13	0.17	0.08	--

(a) Provisional data from U.S. Geological Survey National Stream Quality Accounting Network (NASQAN), subject to revision.
(b) From WAC 173-201A.
(c) Dashes indicate no standard available.
(d) Estimated value.
NTU = Nephelometric turbidity units.

Table C.3. Radionuclide Concentrations in Columbia River Water Samples Collected at Priest Rapids Dam, Washington, 2006 Compared to Previous 5 Years

Radionuclide[a]		2006 No. of Samples	2006 Concentration,[b] pCi/L Maximum	2006 Concentration,[b] pCi/L Average	2001-2005 No. of Samples	2001-2005 Concentration,[b] pCi/L Maximum	2001-2005 Concentration,[b] pCi/L Average	Ambient Surface Water Quality Standard, pCi/L
Composite System								
Tritium		12	34 ± 10	25 ± 6.8	60	80 ± 9.0	32 ± 28	20,000[c]
Alpha (gross)		12	1.0 ± 0.83[d]	0.44 ± 1.0[d]	60	1.7 ± 1.1	0.47 ± 0.71	15[e,f]
Beta (gross)		12	2.2 ± 2.0[d]	1.0 ± 1.5[d]	60	3.2 ± 1.8	0.69 ± 1.7	50[e,f]
Strontium-90		12	0.069 ± 0.037	0.047 ± 0.024	60	0.24 ± 0.085	0.072 ± 0.066	8[e,f]
Technetium-99		12	0.36 ± 0.40[d]	0.084 ± 0.39[d]	60	0.53 ± 0.55[d]	0.069 ± 0.43	900[c]
Iodine-129		0			20	0.000021 ± 0.0000028	0.0000072 ± 0.000012	1[c]
Uranium-234		12	0.28 ± 0.11	0.24 ± 0.065	60	0.28 ± 0.064	0.22 ± 0.052	--[g]
Uranium-235		12	0.013 ± 0.018[d]	0.0056 ± 0.013[d]	60	0.014 ± 0.014[d]	0.0058 ± 0.0088	--
Uranium-238		12	0.22 ± 0.10	0.18 ± 0.048	60	0.25 ± 0.058	0.18 ± 0.058	--
Uranium (total)		12	0.50 ± 0.15	0.42 ± 0.11	60	0.54 ± 0.087	0.40 ± 0.095	--
Continuous System								
Cesium-137	P	12	0.0019 ± 0.0012[d]	0.00075 ± 0.0015[d]	60	0.0032 ± 0.0013	0.00040 ± 0.0012	200[c]
	D	12	0.0047 ± 0.0031[d]	0.00099 ± 0.0029[d]	60	0.0034 ± 0.0021[d]	0.00092 ± 0.0020[d]	
Europium-155	P	12	0.0050 ± 0.0065[d]	0.00047 ± 0.0061[d]	60	0.0040 ± 0.0051[d]	0.00036 ± 0.0023[d]	600[c]
	D	12	0.0059 ± 0.0063[d]	0.0014 ± 0.0048[d]	60	0.0091 ± 0.0046[d]	0.0023 ± 0.0047	
Plutonium-239/240	P	4	0.000041 ± 0.000055[d]	0.000016 ± 0.000035[d]	19	0.00018 ± 0.000069	0.000035 ± 0.000088	--
	D	4	0.000055 ± 0.000057[d]	0.000028 ± 0.000036[d]	20	0.000055 ± 0.000072[d]	0.000026 ± 0.000030	

(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 10.4).
(b) Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard deviations of the mean. To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.
(c) WAC 173-201A-250 and EPA-570/9-76-003.
(d) Less than the laboratory-reported detection limit.
(e) WAC 246-290.
(f) 40 CFR 141.
(g) Dashes indicate no concentration guides available.

Table C.4. Radionuclide Concentrations in Columbia River Water Samples Collected at Richland, Washington, 2006 Compared to Previous 5 Years

Radionuclide[a]		2006 No. of Samples	2006 Concentration,[b] pCi/L Maximum	2006 Concentration,[b] pCi/L Average	2001-2005 No. of Samples	2001-2005 Concentration,[b] pCi/L Maximum	2001-2005 Concentration,[b] pCi/L Average	Ambient Surface Water Quality Standard, pCi/L
Composite System								
Tritium		12	88 ± 19	51 ± 32	60	140 ± 14	61 ± 54	20,000[c]
Alpha (gross)		12	0.57 ± 0.75[d]	0.34 ± 0.43[d]	60	1.6 ± 1.1	0.50 ± 0.79	15[e,f]
Beta (gross)		12	2.2 ± 2.1[d]	1.3 ± 0.97	60	2.8 ± 2.1[d]	0.77 ± 1.4	50[e,f]
Strontium-90		12	0.058 ± 0.035	0.039 ± 0.028	60	0.26 ± 0.059	0.070 ± 0.070	8[e,f]
Technetium-99		12	0.48 ± 0.41[d]	0.14 ± 0.37[d]	60	1.2 ± 0.57	0.13 ± 0.52	900[c]
Iodine-129		0			20	0.00019 ± 0.000021	0.000076 ± 0.000072	1[c]
Uranium-234		12	0.31 ± 0.11	0.25 ± 0.063	60	0.32 ± 0.11	0.26 ± 0.067	--[g]
Uranium-235		12	0.017 ± 0.016	0.0071 ± 0.013	60	0.018 ± 0.018[d]	0.0072 ± 0.0083	--
Uranium-238		12	0.24 ± 0.10	0.20 ± 0.046	60	0.30 ± 0.066	0.21 ± 0.069	--
Uranium (total)		12	0.56 ± 0.15	0.46 ± 0.10	60	0.63 ± 0.095	0.48 ± 0.13	--
Continuous System								
Cesium-137	P	11	0.00088 ± 0.00088[d]	0.00029 ± 0.0012[d]	60	0.0016 ± 0.0010[d]	0.00042 ± 0.00099[d]	200[f]
	D	11	0.0026 ± 0.0029[d]	0.00040 ± 0.0021[d]	60	0.0026 ± 0.0016[d]	0.00072 ± 0.0019[d]	
Europium-155	P	11	0.0023 ± 0.0034[d]	0.0011 ± 0.0022[d]	60	0.0032 ± 0.0087[d]	0.00031 ± 0.0020[d]	600[f]
	D	11	0.0049 ± 0.0056[d]	0.0016 ± 0.0059[d]	60	0.0074 ± 0.0077[d]	0.0016 ± 0.0055[d]	
Plutonium-239/240	P	4	0.000060 ± 0.000068[d]	0.000027 ± 0.000055	19	0.000089 ± 0.000046	0.000025 ± 0.000046	--
	D	4	0.000048 ± 0.00012[d]	0.000018 ± 0.000041[d]	20	0.00015 ± 0.000070	0.000021 ± 0.000086	

(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 10.4).
(b) Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard deviations of the mean. To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.
(c) WAC 173-201A-250 and EPA-570/9-76-003.
(d) Less than the laboratory-reported detection limit.
(e) WAC 246-290.
(f) 40 CFR 141.
(g) Dashes indicate no concentration guides available.

Table C.5. Radionuclide Concentrations Measured in Columbia River Water Samples Collected Along Transects of the Hanford Reach, 2006

Transect/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Minimum
Vernita Bridge (HRM 0.3)			
Tritium	16	32 ± 11	19 ± 7.7
Strontium-90	16	0.070 ± 0.045	0.012 ± 0.038[b]
Uranium (total)	16	0.51 ± 0.15	0.34 ± 0.14
100-N Area (HRM 9.5)			
Tritium	7	62 ± 14	25 ± 7.9
Strontium-90	7	0.11 ± 0.046	0.022 ± 0.043[b]
Uranium (total)	7	0.62 ± 0.16	0.38 ± 0.14
Hanford Town Site (HRM 28.7)			
Tritium	6	2,600 ± 450	30 ± 8.4
Strontium-90	6	0.085 ± 0.041	0.042 ± 0.040
Uranium (total)	6	0.59 ± 0.14	0.34 ± 0.13
300 Area (HRM 43.1)			
Tritium	6	72 ± 15	24 ± 7.8
Strontium-90	6	0.046 ± 0.039	0.025 ± 0.039[b]
Uranium (total)	6	0.88 ± 0.16	0.36 ± 0.14
Richland (HRM 46.4)			
Tritium	26	65 ± 15	18 ± 7.3
Strontium-90	26	0.22 ± 0.054	0.015 ± 0.032[b]
Uranium (total)	26	1.1 ± 0.21	0.36 ± 0.14

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2 sigma). To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.
(b) Less than the laboratory-reported detection limit.
HRM = Hanford river marker.

Table C.6. Radionuclide Concentrations Measured in Columbia River Water Samples Collected at Near-Shore Locations in the Hanford Reach, 2006

Near-Shore/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Concentration,[a] pCi/L Minimum
Vernita Bridge (HRM 0.3)			
Tritium	4	29 ± 9.0	23 ± 8.8
Strontium-90	4	0.065 ± 0.043	0.026 ± 0.038[b]
Uranium (total)	4	0.46 ± 0.14	0.34 ± 0.14
100-N Area (HRM 8.4 to 9.8)			
Tritium	6	62 ± 14	42 ± 10
Strontium-90	6	1.3 ± 0.21	0.050 ± 0.042
Uranium (total)	6	0.46 ± 0.14	0.40 ± 0.14
Hanford town site (HRM 26 to 30)			
Tritium	5	5,700 ± 980	30 ± 8.4
Strontium-90	5	0.073 ± 0.041	0.042 ± 0.040
Uranium (total)	5	0.79 ± 0.16	0.37 ± 0.14
300 Area (HRM 41.5 to 43.1)			
Tritium	5	120 ± 23	57 ± 13
Strontium-90	5	0.048 ± 0.061[b]	0.029 ± 0.041[b]
Uranium (total)	5	0.49 ± 0.14	0.37 ± 0.13
Richland (HRM 43.5 to 46.4)			
Tritium	22	86 ± 18	28 ± 8.2
Strontium-90	22	0.22 ± 0.054	0.018 ± 0.042[b]
Uranium (total)	22	0.55 ± 0.16	0.37 ± 0.14

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2 sigma). To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.
(b) Less than the laboratory-reported detection limit.
HRM = Hanford river marker.

Table C.7. Concentrations (µg/L) of Dissolved Metals in Columbia River Transect and Near-Shore Water Samples Collected Near the Hanford Site, September 2006

Location	Metal	No. of Samples	Maximum	Minimum	Average	±2SD
Vernita Bridge	Antimony	4	0.18	0.15	0.16	0.20
	Arsenic	4	0.68	0.63	0.65	0.051
	Beryllium	4	0.015	0.0075	0.012	0.0069
	Cadmium	4	0.088	0.0064	0.0079	0.0021
	Chromium	4	0.13	0.060	0.087	0.060
	Copper	4	0.70	0.62	0.65	0.074
	Lead	4	0.059	0.031	0.042	0.027
	Nickel	4	0.67	0.58	0.64	0.083
	Selenium	4	0.39	0.10	0.24	0.23
	Silver[a]	4	0.004	0.004	0.004	0.0
	Thallium	4	0.016	0.015	0.016	0.0011
	Zinc	4	1.5	0.92	1.2	0.48
100-N Area[b]	Antimony	10	0.16	0.14	0.15	0.0063
	Arsenic	10	0.78	0.62	0.67	0.096
	Beryllium	10	0.011	0.0044	0.0072	0.0050
	Cadmium	10	0.016	0.0082	0.012	0.0046
	Chromium	10	0.89	0.066	0.23	0.50
	Copper	10	0.85	0.66	0.74	0.12
	Lead	10	0.15	0.066	0.088	0.053
	Nickel	10	0.99	0.56	0.72	0.30
	Selenium	10	0.40	0.16	0.28	0.14
	Silver	10	0.011	0.004	0.0048	0.0046
	Thallium	10	0.017	0.014	0.015	0.0018
	Zinc	10	1.8	1.1	1.3	0.47
Hanford town site	Antimony	10	0.16	0.15	0.15	0.0036
	Arsenic	10	1.0	0.59	0.70	0.29
	Beryllium[a]	10	0.004	0.004	0.004	0.0
	Cadmium	10	0.014	0.0072	0.0092	0.0045
	Chromium	10	0.51	0.074	0.20	0.27
	Copper	10	0.70	0.57	0.63	0.073
	Lead	10	0.052	0.027	0.040	0.13
	Nickel	10	0.77	0.59	0.65	0.11
	Selenium	10	0.46	0.10	0.20	0.25
	Silver[a]	10	0.004	0.004	0.004	0.0
	Thallium	10	0.017	0.016	0.016	0.00080
	Zinc	10	1.4	0.86	1.1	0.29
300 Area	Antimony	10	0.16	0.15	0.51	0.0061
	Arsenic	10	0.78	0.62	0.68	0.11
	Beryllium	10	0.022	0.004	0.0062	0.011
	Cadmium	10	0.012	0.0064	0.0089	0.0033
	Chromium	10	0.52	0.090	0.19	0.26
	Copper	10	0.67	0.60	0.64	0.043
	Lead	10	0.15	0.079	0.12	0.046
	Nickel	10	1.2	0.66	0.84	0.32
	Selenium	10	0.45	0.21	0.29	0.15
	Silver[a]	10	0.004	0.004	0.004	0.0
	Thallium	10	0.018	0.014	0.015	0.0020
	Zinc	10	0.95	0.65	0.83	0.17

Table C.7. (contd)

Location	Metal	No. of Samples	Maximum	Minimum	Average	±2SD
Richland	Antimony	10	0.16	0.15	0.16	0.0052
	Arsenic	10	0.92	0.62	0.68	0.18
	Beryllium	10	0.0075	0.004	0.0046	0.0024
	Cadmium	10	0.012	0.0069	0.0095	0.0033
	Chromium	10	0.19	0.077	0.13	0.058
	Copper	10	0.69	0.58	0.63	0.073
	Lead	10	0.086	0.046	0.066	0.032
	Nickel	10	1.1	0.70	0.80	0.25
	Selenium	10	0.40	0.17	0.28	0.14
	Silver[a]	10	0.004	0.004	0.004	0.0
	Thallium	10	0.016	0.013	0.015	0.0018
	Zinc	10	0.92	0.50	0.72	0.23

(a) All values were below the limit of detection (shown).
(b) 100-N Area values are for unfiltered (total) water samples. The filtered results for chromium, copper, nickel, and zinc were highly elevated compared to the unfiltered sample and blank contamination of the filtered sample is suspected.
SD = Standard deviation.

Table C.8. Radionuclide and Total Organic Carbon Concentrations in Sediment from the Columbia River Near the Hanford Site, 2006 Compared to Previous 5 Years

Location and TOC Concentrations (2006 TOC Value)	Radionuclide	2006 No. of Samples	2006 Concentration, pCi/g[a] Average[b]	2006 Concentration, pCi/g[a] Maximum[c]	2001-2005 No. of Samples	2001-2005 Concentration, pCi/g[a] Average[b]	2001-2005 Concentration, pCi/g[a] Maximum[c]
Priest Rapids Dam (5,100 - 5,710 mg/kg)	Cobalt-60	2	0.0025 ± 0.0025[d]	0.0034 ± 0.015[d]	11	-0.000024 ± 0.010[d]	0.0068 ± 0.015[d]
	Cesium-137	2	0.30 ± 0.021	0.31 ± 0.055	11	0.38 ± 0.24	0.65 ± 0.086
	Europium-155	2	0.065 ± 0.081[d]	0.093 ± 0.045[d]	11	0.049 ± 0.047[d]	0.089 ± 0.043[d]
	Plutonium-239/240	2	0.0091 ± 0.0018	0.0098 ± 0.0016	13	0.0099 ± 0.0036	0.015 ± 0.0024
	Strontium-90	2	-0.014 ± 0.00099[d]	-0.014 ± 0.045[d]	11	0.0062 ± 0.027[d]	0.031 ± 0.029[d]
	Uranium-234	2	0.85 ± 0.17	0.92 ± 0.15	11	0.70 ± 0.30	0.95 ± 0.16
	Uranium-235	2	0.027 ± 0.019	0.034 ± 0.012	11	0.024 ± 0.015	0.038 ± 0.017
	Uranium-238	2	0.73 ± 0.14	0.78 ± 0.15	11	0.59 ± 0.20	0.74 ± 0.13
White Bluffs Slough (3,330 mg/kg)	Cobalt-60	1		0.0096 ± 0.012[d]	5	0.038 ± 0.038	0.060 ± 0.025[d]
	Cesium-137	1		0.72 ± 0.091	5	1.2 ± 1.9	2.8 ± 0.33
	Europium-155	1		0.072 ± 0.037[d]	5	0.046 ± 0.025[d]	0.056 ± 0.031[d]
	Plutonium-239/240	1		0.0058 ± 0.00095	5	0.0069 ± 0.0044	0.010 ± 0.0019
	Strontium-90	1		-0.028 ± 0.046[d]	5	0.0012 ± 0.021[d]	0.016 ± 0.015[d]
	Uranium-234	1		0.43 ± 0.093	5	0.66 ± 1.1	1.6 ± 0.30
	Uranium-235	1		0.010 ± 0.0078	5	0.026 ± 0.032	0.053 ± 0.016
	Uranium-238	1		0.41 ± 0.11	5	0.57 ± 0.85	1.3 ± 0.24
100-F Slough (740 mg/kg)	Cobalt-60	1		0.0054 ± 0.010[d]	5	0.0072 ± 0.0067[d]	0.012 ± 0.010[d]
	Cesium-137	1		0.24 ± 0.037	5	0.26 ± 0.18	0.39 ± 0.055
	Europium-155	1		0.021 ± 0.029[d]	5	0.047 ± 0.039[d]	0.069 ± 0.062[d]
	Plutonium-239/240	1		0.0014 ± 0.00060	4	0.0015 ± 0.0014	0.0020 ± 0.0012
	Strontium-90	1		-0.019 ± 0.044[d]	5	-0.00046 ± 0.015[d]	0.0079 ± 0.017[d]
	Uranium-234	1		0.60 ± 0.11	5	0.15 ± 0.042	0.18 ± 0.037
	Uranium-235	1		0.015 ± 0.0090	5	0.0044 ± 0.011	0.011 ± 0.0058
	Uranium-238	1		0.60 ± 0.13	5	0.16 ± 0.059	0.19 ± 0.044
Hanford Slough (1,940 mg/kg)	Cobalt-60	1		0.0058 ± 0.013[d]	5	0.017 ± 0.048	0.055 ± 0.020
	Cesium-137	1		0.0070 ± 0.012[d]	5	0.082 ± 0.26	0.32 ± 0.046
	Europium-155	1		0.058 ± 0.038[d]	5	0.044 ± 0.039[d]	0.059 ± 0.064[d]
	Plutonium-239/240	1		0.00029 ± 0.00035[d]	5	0.0023 ± 0.0047	0.0053 ± 0.0026
	Strontium-90	1		-0.023 ± 0.045[d]	5	0.0019 ± 0.011[d]	0.0059 ± 0.019[d]
	Uranium-234	1		0.56 ± 0.11	5	0.32 ± 0.30	0.53 ± 0.10
	Uranium-235	1		0.019 ± 0.0095	5	0.012 ± 0.014	0.021 ± 0.016
	Uranium-238	1		0.53 ± 0.13	5	0.30 ± 0.24	0.47 ± 0.092

Table C.8. (contd)

Location	Radionuclide	2006 No. of Samples	2006 Concentration, pCi/g[a] Average[b]	2006 Concentration, pCi/g[a] Maximum[c]	2001-2005 No. of Samples	2001-2005 Concentration, pCi/g[a] Average[b]	2001-2005 Concentration, pCi/g[a] Maximum[c]
Richland (792 mg/kg)	Cobalt-60	1		0.0024 ± 0.014[d]	5	0.0091 ± 0.027[d]	0.032 ± 0.023[d]
	Cesium-137	1		0.16 ± 0.030	5	0.17 ± 0.11	0.24 ± 0.049
	Europium-155	1		0.044 ± 0.037[d]	5	0.073 ± 0.061[d]	0.10 ± 0.053[d]
	Plutonium-239/240	1		0.0016 ± 0.00046	4	0.0015 ± 0.00024	0.0016 ± 0.00049
	Strontium-90	1		-0.017 ± 0.043[d]	5	-0.0060 ± 0.028[d]	0.015 ± 0.020[d]
	Uranium-234	1		0.36 ± 0.089	5	0.20 ± 0.13	0.29 ± 0.054
	Uranium-235	1		0.014 ± 0.0091	5	0.0070 ± 0.0060	0.011 ± 0.0094[d]
	Uranium-238	1		0.38 ± 0.11	5	0.19 ± 0.13	0.26 ± 0.051
McNary Dam (3,780 - 4,890 mg/kg)	Cobalt-60	2	0.016 ± 0.00016[d]	0.016 ± 0.014[d]	17	0.031 ± 0.061[d]	0.12 ± 0.042[d]
	Cesium-137	2	0.30 ± 0.086	0.33 ± 0.054	17	0.35 ± 0.43	1.1 ± 0.15
	Europium-155	2	0.022 ± 0.024[d]	0.031 ± 0.034[d]	17	0.074 ± 0.056[d]	0.13 ± 0.066[d]
	Plutonium-239/240	2	0.0082 ± 0.00045	0.0083 ± 0.0014	20	0.0094 ± 0.011	0.032 ± 0.0048
	Strontium-90	2	-0.0041 ± 0.0012[d]	0.00023 ± 0.046[d]	20	0.012 ± 0.031	0.043 ± 0.028
	Uranium-234	2	1.1 ± 0.37	1.2 ± 0.19	17	0.86 ± 0.36	1.4 ± 0.24
	Uranium-235	2	0.045 ± 0.0031	0.046 ± 0.014	17	0.027 ± 0.016	0.052 ± 0.015
	Uranium-238	2	0.83 ± 0.054	0.85 ± 0.16	17	0.68 ± 0.13	1.0 ± 0.19

(a) To convert to the International System of Units, multiply pCi/g by 0.037 to obtain Bq/g. All values are dry weight.
(b) Average values are not provided when only one sample was analyzed.
(c) Values are ± total propagated analytical uncertainty (2 sigma).
(d) Below detection limit.
TOC = Total organic content.

Table C.9. Range of Metal Concentrations (mg/kg dry wt.) in Sediment Samples Collected from the Columbia River Near the Hanford Site, 2006

Metal	(n=2) Priest Rapids Dam	(n=4) Hanford Reach[a]	(n=2) McNary Dam	(n=7) Shoreline Springs[b]
Antimony	0.93 - 0.95	0.54 - 1.9	0.82 - 0.85	0.50 - 0.93
Arsenic	8.2 - 9.1	4.0 - 18	8.0 - 9.0	3.1 - 8.7
Beryllium	1.3 - 1.4	1.4 - 1.8	1.5 - 1.7	1.5 - 1.8
Cadmium	5.1 - 7.8	0.23 - 1.2	1.6 - 2.2	0.38 - 0.97
Chromium	76 - 78	45 - 62	59 - 60	48 - 110
Copper	47 - 55	21 - 42	35 - 39	15 - 29
Lead	50 - 54	17 - 170	28 - 32	16 - 61
Mercury	0.16 - 0.18	0.013 - 0.054	0.11 - 0.12	0.010 - 0.032
Nickel	43 - 45	16 - 27	29 - 30	16 - 28
Selenium	0.43 - 0.51	0.18 - 0.18	0.20 - 0.40	0.14 - 0.39
Silver	0.28 - 0.29	0.054 - 0.30	0.183 - 0.184	0.037 - 0.082
Thallium	0.81 - 1.3	0.44 - 0.57	0.57 - 0.75	0.48 - 0.58
Zinc	430 - 550	79 - 420	240 - 280	96 - 300

(a) White Bluffs Slough, 100-F Slough, Hanford Slough, and Richland.
(b) 100-B Area (n=1), 100-F Area (n=1), 100-H Area (n=1), Hanford town site (n=2), and 300 Area (n=2).
n = Number of samples.

Table C.10. Radionuclide Concentrations Measured in Columbia River Water Samples Collected from Shoreline Springs Along the Hanford Site, 2006 Compared to Previous 5 Years

Location/Radionuclide	2006 No. of Samples	2006 Concentration,[a] pCi/L Maximum	2006 Concentration,[a] pCi/L Average	2001-2005 No. of Samples	2001-2005 Concentration,[a] pCi/L Maximum	2001-2005 Concentration,[a] pCi/L Average	Washington State Ambient Surface Water Quality Standard,[b] pCi/L
100-B Area							
Alpha (gross)	2	1.4 ± 1.2	1.2 ± 0.84	7	9.4 ± 3.8	2.8 ± 6.2	15
Beta (gross)	2	10 ± 2.7	8.0 ± 5.6	7	24 ± 4.5	10 ± 14	50
Strontium-90	2	2.8 ± 0.42	1.4 ± 4.0	7	4.0 ± 0.59	1.0 ± 3.5	8
Technetium-99	2	5.8 ± 0.68	4.0 ± 5.2	7	12 ± 0.95	6.1 ± 8.1	900[c]
Tritium	2	2,800 ± 180	2,800 ± 0.0	7	6,400 ± 380	5,500 ± 1,400	20,000
100-K Area							
Alpha (gross)	1	2.7 ± 1.1		9	3.2 ± 1.9	1.0 ± 2.1	15
Beta (gross)	1	4.3 ± 2.2		9	7.2 ± 2.3	5.0 ± 2.4	50
Strontium-90	1	1.2 ± 0.18		9	3.2 ± 0.72	1.5 ± 2.8	8
Technetium-99	0			5	2.3 ± 0.28	0.69 ± 2.1	900[c]
Tritium	1	6.6 ± 81[d]		9	6,100 ± 530	1,100 ± 4,000	20,000
100-N Area							
Alpha (gross)	1	1.2 ± 1.0[d]		6	4.9 ± 2.7	2.1 ± 3.2	15
Beta (gross)	1	3.2 ± 2.2		6	9.3 ± 2.4	4.6 ± 5.4	50
Strontium-90	1	0.017 ± 0.019[d]		11	0.043 ± 0.020	0.021 ± 0.036	8
Technetium-99	0			5	0.67 ± 0.40	0.51 ± 0.35	900[c]
Tritium	1	8,900 ± 390		10	17,000 ± 800	10,000 ± 6,600	20,000
100-D Area							
Alpha (gross)	2	7.6 ± 2.9	6.2 ± 4.0	8	14 ± 4.9	3.6 ± 9.3	15
Beta (gross)	2	10 ± 2.8	7.6 ± 3.8	8	41 ± 7.9	9.1 ± 27	50
Strontium-90	2	0.12 ± 0.032	0.084 ± 0.12	7	0.55 ± 0.17	0.23 ± 0.39	8
Tritium	2	4,800 ± 250	2,400 ± 3,400	8	5,200 ± 450	1,000 ± 3,600	20,000
Uranium (total)	2	1.6 ± 0.23	1.2 ± 1.2	6	3.2 ± 0.43	1.1 ± 2.2	--[e]
100-H Area							
Alpha (gross)	2	3.8 ± 1.3	1.7 ± 2.9	10	3.9 ± 2.2	1.8 ± 2.3	15
Beta (gross)	2	6.0 ± 2.4	5.8 ± 0.64	10	27 ± 4.7	11 ± 17	50
Strontium-90	2	3.6 ± 0.52	1.8 ± 5.0	9	14 ± 3.2	4.6 ± 11	8
Technetium-99	2	0.52 ± 0.42[d]	0.39 ± 0.37	10	8.0 ± 0.97	1.4 ± 5.4	900[c]
Tritium	2	1,300 ± 180	720 ± 790	10	5,500 ± 470	1,800 ± 3,600	20,000
Uranium (total)	2	1.2 ± 0.21	0.71 ± 1.3	10	4.1 ± 0.60	1.7 ± 2.3	--[e]

Table C.10. (contd)

Location/Radionuclide	2006 No. of Samples	2006 Concentration,[a] pCi/L Maximum	2006 Concentration,[a] pCi/L Average	2001-2005 No. of Samples	2001-2005 Concentration,[a] pCi/L Maximum	2001-2005 Concentration,[a] pCi/L Average	Washington State Ambient Surface Water Quality Standard,[b] pCi/L
100-F Area							
Alpha (gross)	1	28 ± 8.8		6	14 ± 6.1	6.8 ± 8.6	15
Beta (gross)	1	43 ± 9.6		6	15 ± 4.3	10 ± 6.8	50
Strontium-90	1	0.019 ± 0.032[d]		6	0.058 ± 0.023	0.0076 ± 0.068	8
Tritium	1	1,300 ± 130		6	1,400 ± 120	930 ± 940	20,000
Uranium (total)	1	20 ± 4.3		6	5.4 ± 0.67	3.8 ± 3.3	--[e]
Hanford Town Site							
Alpha (gross)	3	14 ± 5.6	5.3 ± 15	12	5.0 ± 2.5	2.0 ± 2.6	15
Beta (gross)	3	47 ± 12	20 ± 46	12	36 ± 5.8	19 ± 20	50
Iodine-129	0			9[f]	0.25 ± 0.022	0.17 ± 0.11	1
Technetium-99	3	25 ± 1.7	18 ± 17	12	110 ± 7.5	48 ± 70	900[c]
Tritium	3	19,000 ± 1,300	13,000 ± 12,000	12	110,000 ± 4,100	46,000 ± 67,000	20,000
Uranium (total)	3	5.6 ± 0.69	2.5 ± 5.4	12	3.9 ± 0.52	1.9 ± 2.3	--[e]
300 Area							
Alpha (gross)	4	97 ± 20	46 ± 74	14	140 ± 36	63 ± 77	15
Beta (gross)	4	35 ± 7.3	24 ± 16	14	55 ± 10	23 ± 26	50
Iodine-129[f]	2			10	0.0068 ± 0.00084	0.0044 ± 0.0027	1
Technetium-99	0			2	11 ± 0.96	10 ± 0.71	900[c]
Tritium	4	8,900 ± 660	6,400 ± 7,200	17	12,000 ± 580	7,900 ± 5,800	20,000
Uranium (total)	4	120 ± 13	67 ± 97	19	140 ± 15	60 ± 75	--[e]

(a) Maximum values are ± total propagated analytical uncertainty. Averages are ±2 standard deviations of the mean. To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.
(b) WAC 246-290, 40 CFR 141, and Appendix D, Table D.4.
(c) WAC 173-201A-250 and EPA-570/9-76-003.
(d) Value below the laboratory-reported detection limit.
(e) Dashes indicate no concentration guides available.
(f) 2001 - 2004 results; no results were available for 2005.

Table C.11. Radionuclide Concentrations in Columbia River Shoreline Sediment for 2006 Compared to Previous 5 Years

Location	Radionuclide	2006 No. of Samples	2006 Concentration, pCi/g[a] Average[b]	2006 Concentration, pCi/g[a] Maximum[c]	2001-2005 No. of Samples	2001-2005 Concentration, pCi/g[a] Average[b]	2001-2005 Concentration, pCi/g[a] Maximum[c]
100-B Spring	Cobalt-60	1		-0.0084 ± 0.010[d]	4	0.0094 ± 0.018[d]	0.022 ± 0.013[d]
	Cesium-137	1		0.052 ± 0.016	4	0.058 ± 0.040	0.075 ± 0.019
	Europium-152	1		-0.034 ± 0.026[d]	2	0.0046 ± 0.014[d]	0.0097 ± 0.045[d]
	Strontium-90	1		0.0034 ± 0.0055[d]	4	-0.0051 ± 0.030[d]	0.0068 ± 0.016[d]
	Uranium-234	1		0.18 ± 0.063	4	0.31 ± 0.30	0.48 ± 0.097
	Uranium-235	1		0.0053 ± 0.0060[d]	4	0.011 ± 0.0074	0.014 ± 0.0080
	Uranium-238	1		0.12 ± 0.077	4	0.28 ± 0.24	0.41 ± 0.085
100-K Spring	Cobalt-60	0			2	0.0049 ± 0.0012[d]	0.0053 ± 0.013[d]
	Cesium-137	0			2	0.11 ± 0.019	0.11 ± 0.024
	Europium-152	0			1		-0.0059 ± 0.023[d]
	Strontium-90	0			2	0.016 ± 0.0031[d]	0.017 ± 0.019[d]
	Uranium-234	0			2	0.28 ± 0.059	0.30 ± 0.065
	Uranium-235	0			2	0.088 ± 0.00079	0.0091 ± 0.0064
	Uranium-238	0			2	0.26 ± 0.057	0.28 ± 0.060
100-H Spring	Cobalt-60	1		0.0065 ± 0.014[d]	3	0.010 ± 0.0056[d]	0.012 ± 0.012[d]
	Cesium-137	1		0.15 ± 0.029	3	0.16 ± 0.067	0.20 ± 0.029
	Europium-152	1		0.028 ± 0.033[d]	3	0.041 ± 0.041[d]	0.061 ± 0.047[d]
	Strontium-90	1		0.10 ± 0.017	3	-0.00065 ± 0.029[d]	0.016 ± 0.021[d]
	Uranium-234	1		0.31 ± 0.96	3	0.38 ± 0.095	0.43 ± 0.10
	Uranium-235	1		0.013 ± 0.012	3	0.010 ± 0.0042	0.012 ± 0.0085
	Uranium-238	1		0.27 ± 0.11	3	0.33 ± 0.12	0.39 ± 0.12
100-F Spring	Cobalt-60	1		-0.0019 ± 0.013[d]	5	0.0076 ± 0.012[d]	0.016 ± 0.011[d]
	Cesium-137	1		0.094 ± 0.023	5	0.13 ± 0.15	0.26 ± 0.051
	Europium-152	1		0.025 ± 0.030[d]	3	0.055 ± 0.12[d]	0.13 ± 0.060[d]
	Strontium-90	1		-0.0010 ± 0.0046[d]	5	-0.0058 ± 0.017[d]	0.0018 ± 0.025[d]
	Uranium-234	1		0.60 ± 0.13	5	0.52 ± 0.32	0.70 ± 0.14
	Uranium-235	1		0.018 ± 0.0098	5	0.028 ± 0.037	0.060 ± 0.019
	Uranium-238	1		0.50 ± 0.13	5	0.45 ± 0.30	0.65 ± 0.13

Table C.11. (contd)

Location	Radionuclide	2006 No. of Samples	2006 Concentration, pCi/g[a] Average[b]	2006 Concentration, pCi/g[a] Maximum[c]	2001-2005 No. of Samples	2001-2005 Concentration, pCi/g[a] Average[b]	2001-2005 Concentration, pCi/g[a] Maximum[c]
Hanford Spring	Cobalt-60	2	0.010 ± 0.016[d]	0.016 ± 0.013[d]	4	0.021[d] ± 0.022[d]	0.032 ± 0.012[d]
	Cesium-137	2	0.11 ± 0.11	0.15 ± 0.028	4	0.17 ± 0.15	0.26 ± 0.041
	Europium-152	2	0.049 ± 0.0054[d]	0.051 ± 0.030[d]	3	0.10 ± 0.11[d]	0.15 ± 0.058[d]
	Strontium-90	2	0.037 ± 0.10	0.074 ± 0.013	4	-0.0024 ± 0.037[d]	0.022 ± 0.035[d]
	Uranium-234	2	0.50 ± 0.12	0.54 ± 0.12	4	0.54 ± 0.12	0.61 ± 0.13
	Uranium-235	2	0.013 ± 0.0072	0.016 ± 0.011	4	0.014 ± 0.0035	0.015 ± 0.014
	Uranium-238	2	0.37 ± 0.15	0.42 ± 0.13	4	0.42 ± 0.072	0.45 ± 0.089
300 Area Spring	Cobalt-60	3	0.0037 ± 0.0097[d]	0.0092 ± 0.012[d]	12	0.0048 ± 0.012[d]	0.014 ± 0.011[d]
	Cesium-137	3	0.12 ± 0.18	0.23 ± 0.037	12	0.095 ± 0.15	0.25 ± 0.038
	Europium-152	3	0.034 ± 0.084[d]	0.082 ± 0.049[d]	9	0.018 ± 0.060[d]	0.064 ± 0.035[d]
	Strontium-90	3	0.0077 ± 0.0070	0.010 ± 0.0058	9	0.0052 ± 0.033[d]	0.027 ± 0.021[d]
	Uranium-234	3	0.60 ± 0.88	1.1 ± 0.20	12	2.7 ± 5.8	11 ± 2.0
	Uranium-235	3	0.026 ± 0.042	0.046 ± 0.015	12	0.11 ± 0.21	0.38 ± 0.075
	Uranium-238	3	0.53 ± 0.80	0.98 ± 0.20	12	2.5 ± 5.1	10 ± 1.8

(a) To convert to the International System of Units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) Averages are ±2 standard deviations of the mean. Average values are not provided when only one sample was analyzed.
(c) Values are ± total propagated analytical uncertainty (2 sigma).
(d) Below detection limit.

Table C.12. Concentrations (µg/g dry wt.) of Metals in Livers from Carp and Suckers Collected from the Hanford Reach of the Columbia River and from a Columbia River Background Location Near Desert Aire, Washington, in 2006[a]

	100-N to 100-D Areas (n=5)			300 Area (n=5)			Background Location Near Desert Aire, Washington (n=5)		
Metal	**Maximum**	**Minimum**	**Median**	**Maximum**	**Minimum**	**Median**	**Maximum**	**Minimum**	**Median**
Aluminum	61	1.9[b]	8.2	21	4.1[b]	6.8	27	0.55[b]	9.9
Antimony	0.21[c]	0.031[c]	0.090[c]	0.081[c]	0.041[c]	0.054[c]	0.11[c]	0.022[c]	0.064[c]
Arsenic	1.7	0.16	0.67	1.0	0.1[d]	0.25	0.6[d]	0.20	0.44
Beryllium	0.02[d]	0.02[d]	0.02[d]	0.02[d]	0.02[d]	0.02[d]	0.005[d]	0.005[d]	0.005[d]
Cadmium	33	2.0	6.2	2.3	0.23	0.83	9.3	0.17	7.0
Chromium	0.78	0.36	0.51	0.61	0.42	0.50	0.62	0.29[c]	0.48
Copper	110	18	36	54	7.0	11	120	15	53
Lead	0.43	0.065	0.33	0.21	0.12	0.17	0.33	0.046	0.16
Manganese	69	5.6	8.8	73	14	33	29	5.3	12
Mercury	0.43	0.069	0.098	0.12	0.031[b]	0.050	0.12	0.029	0.074
Nickel	1.3	0.14	0.29	1.7	0.49	0.56	0.45	0.12[c]	0.23
Selenium	6.2	3.5	4.8	4.5	3.0	3.5	5.1	2.5	4.8
Silver	1.2	0.028	0.14	0.38	0.014	0.018	0.25	0.041	0.15
Thallium	0.037	0.014	0.027	0.038	0.015	0.025	0.036	0.021	0.031
Thorium	0.094[c]	0.01[d]	0.01[d]	0.019[c]	0.01[d]	0.01[d]	0.03[d]	0.03[d]	0.03[d]
Uranium	0.27	0.037	0.12	0.37	0.027	0.10	0.14	0.0093[b]	0.085
Zinc	650	74	130	270	58	140	190	59	120

(a) Data are not blank corrected; values rounded to two significant figures.
(b) Value less than required detection limit and greater than method detection limit.
(c) Analyte detected in both the sample and associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration.
(d) Analyte not detected above the method detection limit.
n = Number of samples.

Table C.13. Concentrations (µg/g dry wt.) of Metals in Livers from Quail Collected Along the Hanford Reach of the Columbia River in 2006 and at a Background Location Near Grandview, Washington, in 2004[a]

	Background Location Near Grandview, Washington, 2004 (n=5)			100-D to 100-H Areas, 2006 (n=4)			100-H to 100-F Areas, 2006 (n=1)
Metal	**Maximum**	**Minimum**	**Median**	**Maximum**	**Minimum**	**Median[b]**	**Maximum**
Aluminum	1.5[c]	1.00[c]	1.3[c]	19.0	2.6[c]	2.7	0.81[c]
Antimony	0.017[d]	0.01[e]	0.011[d]	0.02	0.02	0.02	0.02[e]
Arsenic	0.77[d]	0.46[d]	0.61[d]	0.44	0.1[e]	0.19	0.32
Beryllium	0.02[e]	0.02[e]	0.02[e]	0.02[e]	0.02[e]	0.02	0.02[e]
Cadmium	1.0	0.28	0.39	3.0	0.67	2.1	0.43
Chromium	0.66	0.36	0.40	0.48	0.37[d]	0.44	0.42
Copper	17.0	14.0	14.0	22.0	20.0	21.0	21.0
Lead	1.1	0.030	0.10	0.94	0.13	0.44	0.48
Manganese	12.0	8.8	11.0	19.0	17.0	18.0	19.0
Mercury	NA	NA	NA	NA	NA	NA	NA
Nickel	0.05[e]	0.05[e]	0.05[e]	0.090	0.02[e]	0.047	0.037[c]
Selenium	2.3	1.4	1.6	6.4	3.7	5.1	4.2
Silver	0.01[e]	0.01[e]	0.01[e]	0.01[e]	0.01[e]	0.01	0.01[e]
Thallium	0.01[c]	0.0022[c]	0.0043[c]	0.0055[c]	0.003[e]	0.0031	0.0032[c]
Thorium	0.02[e]	0.02[e]	0.02[e]	0.0046[c]	0.003[e]	0.003	0.003[e]
Uranium	0.01[e]	0.01[e]	0.01[e]	0.002[e]	0.002[e]	0.002	0.002[e]
Zinc	110	85.0	92.0	130	100	110	130

(a) Data are not blank corrected; values rounded to two significant figures.
(b) Calculated median with no qualifiers.
(c) Value less than required detection limit and greater than method detection limit.
(d) Analyte detected in both the sample and associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration.
(e) Analyte not detected above the method detection limit.
n = Number of samples.
NA = Not analyzed.

Table C.14. Concentrations (µg/g dry wt.) of Metals in Livers from Deer Collected from the Hanford Site in 2006 and at a Background Location Near Olympia, Washington, in 2002 and 2004[a]

	Background Location Near Olympia, Washington, 2002 (n=1)	Background Location Near Olympia, Washington, 2004 (n=1)	North Population, 2006 (n=1)	South Population, 2006 (n=1)
Metal	**Maximum**	**Maximum**	**Maximum**	**Maximum**
Aluminum	0.72[b]	1.2	0.5[c]	0.5[c]
Antimony	0.01[c]	0.01[c]	0.02[c]	0.02[c]
Arsenic	0.15[b]	0.1[c]	0.6[c]	0.6[c]
Beryllium	0.004[c]	0.004[c]	0.005[c]	0.005[c]
Cadmium	0.31	0.12	0.53	0.73
Chromium	0.50[d]	0.52[d]	0.35	0.35
Copper	100[d]	22.0[d]	35.0	65.0
Lead	0.03[c]	0.03[c]	0.037	0.031
Manganese	17.0	20.0	13.0	9.5
Mercury	0.004[c]	0.004[c]	NA	NA
Nickel	0.02[c]	0.02[c]	0.026[b]	0.025[b]
Selenium	0.2[c]	0.2[c]	1.1	1.5
Silver	0.022[b]	0.022[b]	0.045	0.044
Thallium	0.0082[b]	0.004[c]	0.003[c]	0.003[c]
Thorium	0.0096[b]	0.005[c]	0.043	0.013[b]
Uranium	0.003[c]	0.003[c]	0.002[c]	0.002[c]
Zinc	150	150	140	1,300

(a) Data are not blank corrected; values rounded to two significant figures.
(b) Value less than required detection limit and greater than method detection limit.
(c) Analyte not detected above the method detection limit (2002 background = below analytical detection limits).
(d) Analyte detected in both the sample and associated quality control blank, and the sample concentration was less than or equal to five times the blank concentration.
n = Number of samples.
NA = Not analyzed.

References

40 CFR 61, Appendix E, Table 2. "Compliance Procedures Methods for Determining Compliance with Subpart I; Concentration Levels for Environmental Compliance." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

40 CFR 141. "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule." U.S. Environmental Protection Agency, *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-16623, APP. 1. 2007. *Hanford Site Environmental Surveillance Data Report for Calendar Year 2006*. LE Bisping, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16623, APP. 2. 2007. *Hanford Site Near-Facility Monitoring Data Report for Calendar Year 2006*. CJ Perkins, MC Dorsey, SM McKinney, and RC Roos, Energy*Solutions*, LLC for 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 173-201A-250. "Radioactive Substances." *Washington Administrative Code*, Olympia, Washington.

WAC 246-290. "Public Water Supplies." *Washington Administrative Code*, Olympia, Washington.

Appendix D
Standards and Permits

R. W. Hanf and G. W. Patton

Permits required for regulated releases to water and air have been issued by the U.S. Environmental Agency (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 Department of Fish and Wildlife and the U.S. Fish and Wildlife Service. Current permits are discussed in Table D.1.

U.S. Department of Energy (DOE) Order 5400.5 established 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 mrem (1 mSv) 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.2 lists selected DOE-derived concentration guides for radionuclides of particular interest at the Hanford Site. These guides are useful reference values but do not generally represent concentrations in the environment that assure compliance with DOE, *Clean Air Act*, or drinking-water dose standards.

Hanford Site operations must conform to a variety of government standards and permits. The primary environmental quality standards and permits applicable to Hanford Site operations in 2006 are listed in the following tables. Washington State has water quality standards for the Columbia River, as defined in WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington." 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. In 2003, the Washington State Department of Ecology revised the surface-water quality standards and submitted them to the EPA for approval. As the new standards are approved, the Class A (Excellent) designation uses are being replaced by other-use designations. Four use-designations have been identified for water bodies in Washington State: 1) Aquatic Life Uses, 2) Recreational Uses, 3) Water Supply Uses, and 4) Miscellaneous Uses. Within each designation are categories that apply to specific bodies of water. For the Hanford Reach of the Columbia River, the category for Aquatic Life Uses is noncore salmon and trout; for the protection of spawning, noncore rearing and migration of salmon and trout, and other associated aquatic life. The category for Recreational Uses is primary contact, which refers to the amount of fecal-coliform bacteria allowed in the water. Designated water-supply uses and miscellaneous uses include domestic water, industrial water, agricultural water, stock water, wildlife habitat, harvesting, commerce and navigation, boating, and aesthetics. Some of the new-use designations and associated criteria have been approved and some have not. For those not yet approved, the old criteria are still in effect. A summary of currently applicable Hanford Reach water criteria is provided in Table D.3. Table D.4 summarizes federal and state drinking water standards (40 CFR 141), "National Primary Drinking Water Regulations" and WAC 246-290, "Public Water Systems." Select surface freshwater quality criteria for toxic pollutants are included in Table D.5.

Table D.1. Environmental Permits

***Clean Air Act* Permits**

Prevention of Significant Deterioration Permit No. PSD-X80-14, issued to the U.S. Department of Energy Richland Operations Office by the U.S. Environmental Protection Agency Region 10, covers emission of NO_x to the atmosphere from the Plutonium-Uranium Extraction Plant and the Uranium-Trioxide Plant. No expiration date.

Hanford Site Air Operating Permit 00-05-006, Renewal 1, covers operations on the Hanford Site having a potential to emit airborne emissions. This permit was effective on January 1, 2007, and expires January 1, 2012. The permit is intended to provide a compilation of applicable *Clean Air Act* requirements both for radioactive and non-radioactive emissions at the Hanford Site. It will be implemented through federal and state programs.

State License FF-01 was incorporated into the Hanford Site Air Operating Permit.

***Clean Water Act* – National Pollutant Discharge Elimination System Permits**

Permit WA-002591-7 (governing effluent discharges to the Columbia River) includes the outfall for the 300 Area Treated Effluent Disposal Facility and two outfalls in the 100-K Area.

Permit WAR05A57F governs storm water discharges. This permit expired October 30, 2005, and a new permit has not yet been issued. However, facilities covered by this permit are automatically granted an administrative continuance of permit coverage until a new permit is issued.

Permit CR-IU005 allows wastewater from the Environmental Molecular Sciences Laboratory to be discharged to the city of Richland's wastewater treatment facility.

Washington State Department of Ecology – State Wastewater Permits

Permit ST 4500 allows treated wastewater from the Effluent Treatment Facility to be discharged to the State-Approved Land Disposal Site. This permit expired August 1, 2005, and is scheduled to be reissued in 2007. The old permit will remain in effect until the new permit is issued.

Permit ST 4501 allows for the discharge of cooling water and other primarily uncontaminated wastewater from 400 Area facilities to two ponds located north-northeast of the 400 Area perimeter fence. This permit was effective October 1, 2003.

Permit ST 4502 allows treated effluent from the 200-East and 200-West Areas to be discharged to the 200 Area Treated Effluent Disposal Facility. This permit expired in May 2005 and is scheduled to be reissued in 2007. The old permit will remain in effect until the new permit is issued.

Permit ST 4507 allows domestic wastewater to be discharged to the 100-N Area sewage lagoon. This permit expired in May 2002. A renewal application has been submitted. Still operating on an extension of the old permit, which will be in effect until a new permit is issued.

Permit ST 4511 is a consolidation of permits: ST 4508, ST 4509, and ST 4510. This Categorical State Waste Discharge Permit authorizes the discharge of wastewater from maintenance, construction, and hydrotesting activities and allows for cooling water, condensate, and industrial storm water discharges at the Hanford Site. This permit was issued February 16, 2005, and expires February 16, 2010.

Permit WAG-50-5180 (General Sand and Gravel) for the Concrete Batch Plant in the 200-East Area. Reissued in May 2006.

Permit WAG-50-5181 for Gravel Pit 30 in the 200-East Area. Reissued in May 2006.

Wildlife Sampling Permits

Scientific Collection Permit 05-628, issued by the Washington Department of Fish and Wildlife to Pacific Northwest National Laboratory for 2006; covered the collection of food fish, shellfish, game fish, and wildlife for research purposes. This permit is 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 March 31, 2009.

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 98504-7600

U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, WA 98101

U.S. Department of Energy
Richland Operations Office
825 Jadwin Avenue
Richland, WA 99352

Table D.2. Selected DOE-Derived Concentration Guides[a,b,c]

Radionuclide	Consumed Water, pCi/L (Bq/L)		Inhaled Air, pCi/m³ (Bq/m³)	
Tritium	2,000,000	(74,000)	100,000	(3,700)
Carbon-14	70,000	(2,590)	500,000	(18,500)
Chromium-51	1,000,000	(37,000)	60,000	(2,220)
Cobalt-60	5,000	(185)	80	(2.96)
Strontium-90	1,000	(37)	9	(0.333)
Technetium-99	100,000	(3,700)	2,000	(74)
Ruthenium-103	50,000	(1,850)	2,000	(74)
Ruthenium-106	6,000	(222)	30	(1.11)
Iodine-129	500	(18.5)	70	(2.59)
Iodine-131	3,000	(111)	400	(14.8)
Cesium-137	3,000	(111)	400	(14.8)
Uranium-234	500	(18.5)	0.09	(0.00333)
Uranium-235	600	(22.2)	0.1	(0.0037)
Uranium-238	600	(22.2)	0.1	(0.0037)
Plutonium-238	40	(1.48)	0.03	(0.00111)
Plutonium-239	30	(1.11)	0.02	(0.00074)
Plutonium-240	30	(1.11)	0.02	(0.00074)
Americium-241	30	(1.11)	0.02	(0.00074)

(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 (1 mSv) per year.
(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.

Table D.3. Washington State Water Quality Criteria 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 (0.026 gallons) (2) Not more than or equal to 10% of samples may exceed the geometric mean value of 200 colonies/100 milliliters (0.026 gallons)
Dissolved oxygen	Greater than 8 mg/L (8 ppm)
Temperature	(1) Less than or equal to 18°C (64°F) as a result of human activities (2) When natural conditions exceed 18°C (64°F), no temperature increases will be allowed that will raise the temperature of the receiving water by more than 0.3°C (0.54°F) (3) Incremental temperature increases resulting from point sources shall not at any time exceed t = 28/(T + 7), where t = maximum permissible temperature increase measured at a mixing zone boundary and T = background temperature. Incremental temperature increases resulting from non-point sources shall not exceed 2.8°C (5.04°F)
pH	(1) 6.5 to 8.5 range (2) Less than 0.5-unit induced variation
Turbidity	Turbidity shall be less than or equal to 5 nephelometric turbidity units over background turbidity when the background turbidity is 50 nephelometric units or less, and shall not increase more than 10% when the background turbidity is >50 nephelometric units
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 1/12.5 of the values listed in WAC 246-221-290 or 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 in 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.5)

(a) WAC 173-201A.
EPA = U.S. Environmental Protection Agency.
WAC = *Washington Administrative Code*.

Table D.4. Selected Drinking Water Standards

Constituent	DWS		Agency[a]
Antimony	6 µg/L	(0.006 ppm)	EPA, DOH
Arsenic	10 µg/L	(0.01 ppm)	EPA, DOH
Barium	2,000 µg/L	(2 ppm)	EPA, DOH
Cadmium	5 µg/L	(0.005 ppm)	EPA
Carbon tetrachloride	5 µg/L	(0.005 ppm)	EPA, DOH
Chloroform (THM)[b]	80 µg/L	(0.08 ppm)	EPA
Chromium	100 µg/L	(0.1 ppm)	EPA, DOH
cis-1,2-Dichloroethene	70 µg/L	(0.07 ppm)	EPA, DOH
Copper	1,300 µg/L	(1.3 ppm)	EPA
Cyanide	200 µg/L	(0.2 ppm)	EPA, DOH
Fluoride	4 mg/L	(4 ppm)	EPA, DOH
Lead	15 µg/L	(0.015 ppm)	EPA
Mercury (inorganic)	2 µg/L	(0.002 ppm)	EPA, DOH
Methylene chloride	5 µg/L	(0.005 ppm)	EPA, DOH
Nitrate, as NO_3^-	45 mg/L	(45 ppm)	EPA, DOH
Nitrite, as NO_2^-	3.3 mg/L	(3.3 ppm)	EPA, DOH
Selenium	50 µg/L	(0.05 ppm)	EPA, DOH
Tetrachloroethene	5 µg/L	(0.005 ppm)	EPA, DOH
Thallium	2 µg/L	(0.002 ppm)	EPA, DOH
Trichloroethene	5 µg/L	(0.005 ppm)	EPA, DOH
Antimony-125	300 pi/L[c]	(11.1 Bq/L)	EPA
Beta particle and photon activity	4 mrem/yr[d]	(40 µSv/yr)	EPA, DOH
Carbon-14	2,000 pCi/L[c]	(74.1 Bq/L)	EPA
Cesium-137	200 pCi/L[c]	(7.4 Bq/L)	EPA
Cobalt-60	100 pCi/L[c]	(3.7 Bq/L)	EPA
Iodine-129	1 pCi/L[c]	(0.037 Bq/L)	EPA
Ruthenium-106	30 pCi/L[c]	(1.11 Bq/L)	EPA
Strontium-90	8 pCi/L[c]	(0.296 Bq/L)	EPA, DOH
Technetium-99	900 pCi/L[c]	(33.3 Bq/L)	EPA
Total alpha (excluding uranium)	15 pCi/L[c]	(0.56 Bq/L)	EPA, DOH
Tritium	20,000 pCi/L[c]	(740 Bq/L)	EPA, DOH
Uranium	30 µg/L	(0.03 ppm)	EPA, DOH

(a) DOH = Washington State Department of Health at WAC 246-290.
EPA = U.S. Environmental Protection Agency at 40 CFR 141, 40 CFR 143, and EPA 822-R-96-001.

(b) Standard is for total trihalomethanes (THM).

(c) EPA drinking water standards for radionuclides were derived based on a 4-mrem/yr dose standard using maximum permissible concentrations in water specified in *National Bureau of Standards Handbook 69* (U.S. Department of Commerce, August 1963, as amended).

(d) Beta and gamma radioactivity from anthropogenic radionuclides. Annual average concentration shall not produce an annual dose from anthropogenic radionuclides equivalent to the total body or any internal organ dose >4 mrem/yr. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr. Compliance may be assumed if annual average concentrations of total beta, tritium, and strontium-90 are <50, 20,000, and 8 pCi/L, respectively.

DWS = Drinking water standard (maximum contaminant level for drinking water supplies).

Table D.5. Selected Surface Freshwater Quality Criteria for Toxic Pollutants

Compound	Level that Yields Acute Toxicity, µg/L (ppm)[a]	Level that Yields Chronic Toxicity, µg/L (ppm)[a]	Level to Protect Human Health for the Consumption of Water and Organisms, µg/L (ppm)[b]
Dissolved Metals			
Antimony	--	--	14 (0.014)
Arsenic	360.0 (0.360)	190.0 (0.19)	0.018 (0.000018)
Cadmium	1.6 (0.0016)[c]	0.59 (0.00059)[d]	--
Chromium(VI)	15 (0.015)	10 (0.01)	--
Copper	8.4 (0.0084)[e]	6.0 (0.006)[f]	--
Lead	28 (0.028)[g]	1.1 (0.0011)[h]	--
Mercury	2.1 (0.0021)	--	0.14 (0.00014)
Nickel	750 (0.75)[i]	83 (0.083)[j]	610 (0.61)
Silver	0.94 (0.00094)[k]	--	--
Thallium	--	--	1.7 (0.0017)
Zinc	60 (0.060)[l]	55 (0.055)[m]	--
Total Recoverable Metals			
Chromium(III)[n]	300 (0.30)[o]	96 (0.096)[p]	--
Mercury	--	0.012 (0.000012)	
Selenium	20 (0.02)	5.0 (0.005)	--
Anions			
Cyanide[q]	22.0 (0.022)	5.2 (0.0052)	700 (0.70)
Chloride[r]	860,000 (860)	230,000 (230)	--
Organic Compounds			
Benzene	--	--	1.2 (0.0012)
Carbon tetrachloride	--	--	0.25 (0.00025)
Chloroform	--	--	5.7 (0.0057)
1,2-Dichloroethane	--	--	0.38 (0.00038)
Methylene chloride	--	--	4.7 (0.0047)
Toluene	--	--	6,800 (6.80)
Tetrachloroethene	--	--	0.8 (0.0008)
1,1,2-Trichloroethane	--	--	0.60 (0.0006)
Trichloroethene	--	--	2.7 (0.0027)
Vinyl chloride	--	--	2 (0.002)
1,4-Dichlorobenzene	--	--	400 (0.40)

(a) WAC 173-201A-240. For hardness-dependent criteria, the minimum value of 47 mg $CaCO_3$/L for 1992-2000 water samples collected near the Vernita Bridge by the U.S. Geological Survey is used.
(b) 40 CFR 131.36.
(c) (1.1367 - [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.6. 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 (10 mGy) per day.

Drinking Water Pathway Only (limits from 40 CFR Parts 9, 141, and 142; WAC 246-290; and DOE Order 5400.5)

Radionuclide concentrations in DOE-operated public drinking water supplies shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 mrem (0.04 mSv) per year. 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 Parts 9, 141, and 142 (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 exposure, 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 (1 mSv) per year (but cannot exceed 500 mrem [5 mSv]) per year if unusual circumstances exist that make avoidance of doses greater than 100 mrem (1 mSv) per year to the public impracticable. The 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.

References

40 CFR 61. "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 131.36. "Toxics Criteria for Those States not Complying with the Clean Water Act Section 303(c)(2)(B)." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 141. "National Primary Drinking Water Regulations." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 143. "National Secondary Drinking Water Regulations." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR Parts 9, 141, and 142. "National Primary Drinking Water Regulations; Radionuclides; Final Rule." *Code of Federal Regulations*, U.S. Environmental Protection Agency, and 65 FR 76708, December 7, 2000, *Federal Register*, U.S. Environmental Protection Agency.

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WAC 173-201A. "Water Quality Standards for Surface Waters of the State of Washington." *Washington Administrative Code*, Olympia, Washington.

WAC 173-201A-240. "Toxic Substances." *Washington Administrative Code*, Olympia, Washington.

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WAC 246-290. "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 2006 from Hanford Site cleanup 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 expressed in units of rem (sievert), or more typically the sub-unit 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 operations areas. This appendix describes how the doses in this report were calculated.

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 contribute following 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. The transfer factors used for pathway and dose calculations are documented in PNL-6584 and PNL-3777.

Releases of radionuclides from Hanford Site facilities are usually too small to be measured. 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) and the difference in detectable radionuclide concentrations measured upstream and downstream of the site. Environmental radionuclide concentrations were estimated from the effluent measurements by using 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 - The Hanford Environmental Radiation Dosimetry Software System, Version 1.485* (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 in the following paragraphs.

The RESRAD-BIOTA computer code was used to screen the 2006 radionuclide concentrations in water, soil, and sediment to see if they exceeded established biota concentration guides (e.g., concentrations that could result in a dose rate of 1 rad per day for aquatic biota or 0.1 rad per day for

(a) 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

terrestrial organisms). Both internal and external doses to aquatic, riparian, and terrestrial animals as well as to terrestrial plants are included in the screening process. For analyses with multiple media and multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to its corresponding biota concentration guide. In the initial screening assessment, one compares maximum measured concentrations to the biota concentration guides. If the sum of fractions does not exceed 1, no further analysis is required. However, if the sum of fractions does exceed 1, a second analysis is performed using average concentrations. The screening process is further described in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002).

The computer program, CAP88-PC, was used to calculate an air pathway dose to a maximally exposed individual as required by the U.S. Environmental Protection Agency (EPA) through 40 CFR 61, Subpart H from airborne radionuclide effluent (other than radon) released at U.S. Department of Energy (DOE) facilities. Technical details of the CAP88-PC calculations are provided in the 2006 air emissions report (DOE/RL-2007-01).

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 the following:

- Effective dose equivalent must be used in estimating public doses.
- That calculations of doses to the public from exposures resulting from both routine and unplanned activities must be performed using EPA or DOE dose conversion factors or analytical models prescribed in regulations applicable to DOE operations.
- Doses to the public must be calculated using facility effluent data when environmental concentrations are too low to measure accurately.

The following types of radiological doses were estimated.

Maximally Exposed Individual Dose (mrem [µSv]). 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 Hanford Reach of the Columbia River.
- Recreation along the Hanford Reach of the Columbia River, including boating, swimming, and shoreline activities.

Determination of the Location of the Maximally Exposed Individual. The location of the hypothetical, maximally exposed individual can vary from year to year, depending on the relative contributions of the several sources of radioactive emissions released to the air and effluent released to the Columbia River from Hanford facilities. Based on experience since 1990, three separate locations (Figure 10.13.1) have been used to assess the dose to the maximally exposed individual: 1) the Ringold area, along the east shoreline of the Columbia River 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 Columbia River from Richland. Although the Ringold area is closer than the Riverview area to Hanford facilities that historically released airborne emissions, 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 2002, the maximally exposed individual was located in

the Riverview area. However, from 2003 through 2006, the hypothetical, maximally exposed individual was located across the Columbia River from the 300 Area in the Sagemoor area (Figure 10.13.1).

Ringold Maximally Exposed Individual. Because of its location, an individual in the Ringold area has the potential to receive the maximum exposure to airborne emissions from the 200 Areas, including direct exposure to a contaminated plume, inhalation, external exposure to radionuclides that deposit on the ground, and ingestion of contaminated locally grown food products. In addition, it is assumed that individuals in the Ringold area irrigate their crops with water taken from the Columbia River downstream of where contaminated groundwater originating from the 100 and 200-East Areas enters the river. This results in additional exposure from ingestion of potentially contaminated irrigated food products and potential 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 Columbia River fish.

Riverview Maximally Exposed Individual. Because of its location, an individual in the Riverview area has the potential to receive the maximum exposure to waterborne effluent from Hanford facilities. For the calculation, it was assumed that the Riverview area 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 in the Riverview area irrigate their crops with water taken from the Columbia River. This results in additional exposure from ingestion of potentially contaminated irrigated food products and potential 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 Columbia River 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, cleaning up the site, 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 emissions from research facilities in the 300 Area.

An individual in the Sagemoor area, located approximately 1.4 kilometers (0.87 mile) directly across the Columbia River from the 300 Area, receives the maximum exposure to airborne emissions from the 300 Area. 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 area 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 area irrigation water maximizes the calculated dose from the air and water pathways combined.

80-kilometer (50-mile) Collective Population Doses (person-rem [person-sievert]). 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 kilometers (50 miles) of the site operations areas was calculated to confirm adherence to DOE environmental protection policies, and provide information to the public. The 80-kilometer (50-mile) collective dose is the sum of doses to all individual members of the public within 80 kilometers (50 miles) of the site operations areas.

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 all or part of their municipal water directly and Kennewick indirectly from the Columbia River downstream from the Hanford Site. Approximately 130,000 people in the three cities are assumed to obtain all their drinking water directly from the Columbia River or from wells adjacent to the river.
- ***Irrigated food*** – Columbia River water is withdrawn for irrigation of small vegetable gardens and farms in the Riverview area of Pasco in Franklin County. It is assumed that enough food is grown in this area 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.
- ***Columbia 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 operations areas 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 (33,075 pounds) per year without reference to a specified human group of consumers.

Data for Dose Calculations

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-16623, APP. 1. These distributions are based on 2000 Bureau of the Census data (PNNL-14428). These data influence the population dose by providing estimates of the number of people exposed to radioactive effluent and their proximity to the points of release.

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 the DOE or EPA maximally exposed individuals or individuals for whom average parameter values were used.

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 parameters assumed for maximally exposed and average individuals.

Dose Calculation Documentation

The DOE established the Hanford Dose Overview Panel to promote consistency and defensibility of environmental dose calculations at Hanford. The panel was 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. This panel is no longer functional. 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 a former panel

Table E.1. Food Pathway Parameters Used in Hanford Site Dose Calculations, 2006

Medium	Holdup (days)[a] Maximally Exposed Individual	Holdup (days)[a] Average Individual	Growing Period (days)	Yield kg/m² (lb/yd²)		Irrigation Rate L/m²/mo (gal/yd²/mo)	
Leafy vegetables	1	14	90	1.5	(3.3)	150	(40)
Other vegetables	5	14	90	4	(8.2)	170	(45)
Fruit	5	14	90	2	(4.41)	150	(40)
Cereal	180	180	90	0.8	(1.76)	0	
Eggs	1	18	90	0.8	(1.76)	0	
Milk	1	4	--	--		--	
Hay	[100][b]	[100]	45	2	(4.41)	200	(53)
Pasture	0	0	30	1.5	(3.3)	200	(53)
Red meat	15	34	--	--		--	
Hay	[100]	[100]	45	2	(4.41)	200	(53)
Grain	[180]	[180]	90	0.8	(1.76)	0	
Poultry	1	34	90	0.8	(1.76)	0	
Fish	1	1	--	--		--	
Drinking water[c]	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.
(c) Drinking water holdup in calculations is 1.5 days for 100 Areas releases and 1.0 day for 200 Areas releases.

Table E.2. Dietary Parameters Used in Hanford Site Dose Calculations, 2006

Medium	Consumption: Maximally Exposed Individual		Consumption: Average Individual	
Leafy vegetables	30 kg/yr	(66 lb/yr)	15 kg/yr	(33 lb/yr)
Other vegetables	220 kg/yr	(485 lb/yr)	140 kg/yr	(310 lb/yr)
Fruit	330 kg/yr	(728 lb/yr)	64 kg/yr	(140 lb/yr)
Grain	80 kg/yr	(180 lb/yr)	72 kg/yr	(160 lb/yr)
Eggs	30 kg/yr	(66 lb/yr)	20 kg/yr	(44 lb/yr)
Milk	270 L/yr	(71 gal/yr)	230 L/yr	(61 gal/yr)
Red meat	80 kg/yr	(180 lb/yr)	70 kg/yr	(150 lb/yr)
Poultry	18 kg/yr	(40 lb/yr)	8.5 kg/yr	(19 lb/yr)
Fish	40 kg/yr	(88 lb/yr)	--[a]	
Drinking water	730 L/yr	(193 gal/yr)	440 L/yr	(116 gal/yr)

(a) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg/yr (33,075 lb/yr).

member. Summaries of dose calculation technical details for this report are shown in Tables E.5 through E.10 and in PNNL-16623, 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 2006 are given in Table E.11.

Ambient-Air Inhalation Doses

Radionuclide concentrations measured in ambient air at locations on or near the Hanford Site were used to calculate radiological doses from breathing contaminated air. Inhalation rates were taken from International Commission on Radiological Protection (1994). Occupancy times ranged from 100% at offsite locations to 33% for onsite locations.

Table E.3. Residency Parameters Used in Hanford Site Dose Calculations, 2006

	Exposure (hr/yr)	
Parameter	Maximally Exposed Individual	Average Individual
Ground contamination	4,383	2,920
Air submersion	8,766	8,766
Inhalation[a]	8,766	8,766

(a) Inhalation rates: adult 270 cm^3/sec (16.5 $in.^3$/sec).

Table E.4. Columbia River Recreational Parameters Used in Hanford Site Dose Calculations, 2006

	Exposure (hr/yr)[a]	
Parameter	Maximally Exposed Individual	Average Individual
Shoreline	500	17
Boating	100	5
Swimming	100	10

(a) Transit times for water to irrigation and recreation sites vary by release and receptor locations.

Table E.5. Technical Details of Airborne Release Dose Calculations for the 100-K Area of the Hanford Site, 2006

Facility name	100-K Area
Releases (Ci [Bq])	^{90}Sr (2.3 x 10^{-5} [8.5 x 10^5]), ^{238}Pu (2.2 x 10^{-6} [8.1 x 10^4]), ^{239}Pu (1.5 x 10^{-5} [5.6 x 10^5]), ^{241}Am (1.3 x 10^{-5} [4.8 x 10^5])
Meteorological conditions	2006 annual average, calculated using the GENII Joint Frequency Data (GENJFD) computer code from data collected at the 100-K Area and the Hanford Meteorology Station from January through December 2006
$\overline{X}/Q'$ dispersion factors	Maximally exposed individual, 1.8 x 10^{-8} sec/m^3 at 41 km (25 mi) SE; 80-km (50-mi) population, 4.8 x 10^{-3} person-sec/m^3
Release height	10-m (33-ft) effective stack height
Population distribution	~482,000 (PNNL-14428)
Computer code	GENII, Version 1.485, December 3, 1990 (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 contaminant plume and atmospheric contaminants deposited on the ground Inhalation Ingestion of foods produced locally at Riverview
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.6. Technical Details of Liquid Release Dose Calculations for the 100-K Area of the Hanford Site, 2006

Facility name	100-K Area
Releases (Ci [Bq])	^{90}Sr (1.0×10^{-2} [3.7×10^{8}]), ^{239}Pu (6.6×10^{-5} [2.4×10^{6}])
Mean river flow	3,350 m^3/sec (118,288 ft^3/sec)
Shore width factor	0.2
Population distribution	130,000 for drinking water pathway 125,000 for aquatic recreation pathway 2,000 for consumption of irrigated foodstuffs pathway
Computer code	GENII, Version 1.485, December 3, 1990 (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, river water, and shoreline sediments Ingestion of aquatic foods, assuming a 15,000 kg/yr (33,075 lb/yr) total harvest of Columbia River fish, 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

Table E.7. Technical Details of Airborne Release Dose Calculations for the 200 Areas of the Hanford Site, 2006

Facility name	200 Areas
Releases (Ci [Bq])	200-East Area ^{90}Sr (4.3 x 10^{-5} [1.6 x 10^{6}]), ^{137}Cs (1.3 x 10^{-5} [4.8 x 10^{5}]), ^{238}Pu (2.1 x 10^{-11} [7.8 x 10^{-1}]), ^{239}Pu (1.3 x 10^{-6} [4.8 x 10^{4}]), ^{241}Am (1.8 x 10^{-7} [6.7 x 10^{3}]) 200-West Area ^{90}Sr (3.2 x 10^{-5} [1.2 x 10^{6}]), ^{137}Cs (1.2 x 10^{-7} [4.4 x 10^{3}]), ^{238}Pu (6.0 x 10^{-7} [2.2 x 10^{4}]), ^{239}Pu (3.2 x 10^{-5} [1.2 x 10^{6}]), ^{241}Pu (2.5 x 10^{-5} [9.3 x 10^{5}]), ^{241}Am (6.6 x 10^{-6} [2.4 x 10^{5}])
Meteorological conditions	2006 annual average, calculated using the GENII Joint Frequency Data (GENJFD) computer code from data collected at the Hanford Meteorology Station from January through December 2006
$\overline{X}/Q'$ dispersion factors	Maximally exposed individual, 1.8 x 10^{-8} sec/m^3 at 28 km (17 mi) SE; 80-km (50-mi) population, 2.3 x 10^{-3} person-sec/m^3
Release height	89-m (292-ft) effective stack height
Population distribution	~486,000 (PNNL-14428)
Computer code	GENII, Version 1.485, December 3, 1990 (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 contaminant plume and atmospheric contaminants deposited on the ground Inhalation Ingestion of foods produced locally at Riverview
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 Liquid Release Dose Calculations for the 200 Areas of the Hanford Site Calculated as Difference in Upstream and Downstream Concentrations, 2006

Facility name	200 Areas
Releases (Ci [Bq])	^{3}H (2.7×10^{3} [1.0×10^{14}]), ^{234}U (1.7×10^{0} [6.3×10^{10}]), ^{238}U (2.2×10^{0} [8.2×10^{10}])
Mean river flow	3,350 m^3/sec (118,288 ft^3/sec)
Shore width factor	0.2
Population distribution	130,000 for drinking water pathway 125,000 for aquatic recreation pathway 2,000 for consumption of irrigated foodstuffs pathway
Computer code	GENII, Version 1.485, December 3, 1990 (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, river water, and shoreline sediments Ingestion of aquatic foods, assuming 15,000 kg/yr (33,075 lb/yr) total harvest of Columbia River fish, 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

Table E.9. Technical Details of Airborne Release Dose Calculations for the 300 Area of the Hanford Site, 2006

Facility name	300 Area
Releases (Ci [Bq])	^{3}H (as HT)[(a)] (7.0×10^{1} [2.6×10^{12}]), ^{3}H (as HTO)[(a)] (2.6×10^{2} [9.7×10^{12}]), ^{90}Sr (1.2×10^{-6} [4.6×10^{4}]), ^{131m}Xe (3.1×10^{-8} [1.2×10^{3}]), ^{135}Xe (1.0×10^{-8} [3.7×10^{2}]), ^{137}Cs (6.0×10^{-6} [2.2×10^{5}]), ^{220}Rn (3.0×10^{1} [1.1×10^{12}]), ^{222}Rn (9.1×10^{-1} [3.4×10^{10}]), ^{238}Pu (7.4×10^{-10} [2.7×10^{1}]), ^{239}Pu (1.1×10^{-7} [4.1×10^{3}]), ^{241}Am (4.7×10^{-7} [1.7×10^{4}]), ^{243}Am (3.0×10^{-9} [1.1×10^{2}])
Meteorological conditions	2006 annual average, calculated using the GENII Joint Frequency Data (GENJFD) computer code from data collected at the 300 Area and the Hanford Meteorology Station from January through December 2006
$\overline{X}/Q$' dispersion factors	Maximally exposed individual at residence, 9.0×10^{-7} sec/m^3 at 1.4 km (0.87 mi) E; 80-km (50-mi) population, 1.1×10^{-2} person-sec/m^3
Release height	10-m (33-ft) effective stack height
Population distribution	~349,000 (PNNL-14428)
Computer code	GENII, Version 1.485, December 3, 1990 (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 contaminant plume and atmospheric contaminants deposited on the ground Inhalation Ingestion of foods produced locally at Riverview
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.10. Technical Details of Airborne Release Dose Calculations for the 400 Area of the Hanford Site, 2006

Facility name	400 Area
Releases (Ci [Bq])	3H (as HTO)[(a)] (3.7×10^{-1} [1.4×10^{10}]), ^{137}Cs (7.2×10^{-6} [2.7×10^{5}]), ^{239}Pu (1.2×10^{-6} [4.4×10^{4}])
Meteorological conditions	2006 annual average, calculated using the GENJFD computer code from data collected at the 400 Area and the Hanford Meteorology Station from January through December 2006
X/Q' dispersion factors	Maximally exposed individual at residence, 9.4×10^{-8} sec/m^3 at 11 km (7 mi) SE; 80-km (50-mi) population, 6.5×10^{-3} person-sec/m^3
Release height	10-m (33-ft) effective stack height
Population distribution	~354,000 (PNNL-14428)
Computer code	GENII, Version 1.485, December 3, 1990 (PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
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.
GENJFD = GENII Joint Frequency Data

Table E.11. Annual Dose to Workers in the 400 Area from Ingestion of Drinking Water Obtained from Groundwater Wells, 2006

Radionuclide	Average Drinking Water Activity (pCi/L)	Intake (pCi/yr)	Ingestion Dose Factor (rem/pCi)	Ingestion Dose (rem/yr)
Gross beta	6.14	1,473	5.0×10^{-8}	7.4×10^{-5}
^{228}Ra	0.864	207	1.2×10^{-6}	2.5×10^{-4}
Tritium	2,737	657,000	6.3×10^{-11}	4.1×10^{-5}
Total				**3.6×10^{-4}**

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Appendix F Radionuclides Measured by Gamma Spectroscopy (Gamma Scan)

E. J. Antonio

Gamma rays are a form of high energy electromagnetic radiation that originate from the nucleus of an atom. They have very short wavelengths and can easily penetrate all but the most dense materials. Gamma-emitting radionuclides may be natural in origin, result from Hanford Site operations, or be related to fallout from historic nuclear weapons testing.

Gamma rays can be detected and quantified by inorganic scintillators, which convert energy into visible light. Scintillators may include thallium-activated sodium iodide crystals (NaI[Tl]) or germanium semiconductor detectors and their associated electronics (gamma spectroscopy). A partial list of radionuclides whose activity is measurable using gamma spectroscopy is provided in Table F.1.

Table F.1. Radionuclides Measured by Gamma Spectroscopy

Radionuclide	Symbol	Principal Source
Beryllium-7[(a)]	^{7}Be	Natural - cosmogenic
Sodium-22	^{22}Na	Fission product
Sodium-24	^{24}Na	Fission product
Potassium-40[(a)]	^{40}K	Natural - primordial
Manganese-54	^{54}Mn	Fission product
Cobalt-58	^{58}Co	Fission product
Cobalt-60[(a)]	^{60}Co	Fission product
Iron-59	^{59}Fe	Fission product
Zinc-65	^{65}Zn	Fission 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[(a)]	^{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 monitoring samples.

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