

Hanford Site

Environmental Report for Calendar Year 2015

DOE-RL-2016-33 , Rev 0



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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management



P.O. Box 550

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Executive Summary

Since 1959, the U.S. Department of Energy (DOE) has prepared an annual Hanford Site environmental report in accordance with [DOE Order \(O\) 231.1B](#), *Environment, Safety and Health Reporting* and [DOE O 458.1](#), *Radiation Protection of the Public and the Environment*. The purpose of the *Hanford Site Environmental Report for Calendar Year 2015* is to inform the public, regulators, employees, and other stakeholders of environmental and operating performance during the year. This report summarizes environmental data; environmental management performance; compliance with applicable federal, state, and local regulations; and radiological releases and doses to the public resulting from site operations.

All previous annual Hanford Site environmental reports are available online through Mission Support Alliance, LLC (MSA) at <http://msa.hanford.gov/page.cfm/enviroreports>. The following sections summarize this year's annual report.

Section 1, Introduction

The approximately 580 square mile (mi²; 1,502 square kilometer [km²]) Hanford Site is located along the Columbia River north of the City of Richland in southeastern Washington State. Situated within the semiarid Pasco Basin of the Columbia Plateau, the Hanford Site was established in 1943 to produce plutonium for nuclear weapons. The site has restricted public access and provides a buffer for areas used for former nuclear materials production, waste storage, and waste disposal. Beginning in 1989, the primary mission of the Hanford Site has been to clean up the extensive contamination on the site as a result of plutonium production. The current mission focuses on environmental restoration of the site, focusing on remediation of contaminated areas, facility decontamination and decommissioning, waste management activities and operations, and scientific and environmental research and development. With the late 2015 establishment of the Manhattan Project National Historical Park, within which the Hanford B Reactor and other Hanford Site structures lie, added mission objectives include historic preservation and public education.

The Richland Operations Office (RL) and Office of River Protection (ORP) jointly manage the Hanford Site through several contractors and subcontractors. RL serves as the property owner and is responsible for cleaning up the river corridor (a 51-mi [82 km] stretch of the Columbia River) and the Central Plateau as well as remediating groundwater sitewide. Additionally, RL oversees environmental management operations and landlord services that support the site. RL, the U.S. Fish and Wildlife Service, and the Washington Department of Fish and Wildlife (WDFW) all manage portions of the Hanford Reach National Monument. Uniquely located in three states (Tennessee and New Mexico in addition to Washington state's Hanford Site), the Manhattan Project National Historical Park partners DOE with its oversight and management of the three sites with the National Park Service for visitor services and historical interpretation and preservation.

ORP manages the retrieval, treatment, and disposal of approximately 56 million gallons (gal; 213 million liters [L]) of radioactive tank waste currently stored in 177 underground tanks in Hanford's Central Plateau. ORP is responsible for safely operating the Hanford tank farms, and constructing and operating the Waste Treatment and Immobilization Plant (WTP).

Section 2, Compliance Summary

To ensure the protection of human health and the environment through safe operations, DOE implements compliance programs designed to fulfill requirements of applicable federal, state, and local environmental laws and regulations, and DOE orders, directives, policies, and guidelines. In addition, the Hanford Site operates under permits required under specific environmental protection regulations. Several federal, state, and local regulatory agencies are responsible for monitoring and enforcing compliance, including the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), Washington State Department of Health (WDOH), and the Benton Clean Air Agency. EPA is the primary federal regulatory agency that develops, promulgates, and enforces environmental regulations and standards as directed in statutes enacted by Congress. In addition, the *Hanford Federal Facility Agreement and Consent Order* (also called the Tri-Party Agreement [TPA]) commits DOE to comply with the remedial-action provisions of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) as well as the *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal (TSD) unit regulations and corrective-action provisions.

Tri-Party Agreement. From 1989 through December 31, 2015, a total of 1,265 TPA milestones were completed, and 336 target dates were met. During 2015, 40 specific cleanup milestones were scheduled for completion; of those, 30 milestones were completed on time, no milestones were missed, 5 were in negotiation, and 5 were in dispute resolution. In addition, 4 target dates were met.

Federal Facility Compliance Act. DOE met the annual requirement to report mixed waste information to EPA and the states (*Calendar Year 2014 Hanford Site Mixed Waste Land Disposal Restrictions Full Report*).

Regulatory Inspections. During calendar year (CY) 2015, 86 regulatory agency inspections were conducted at DOE facilities on the Hanford Site: Ecology conducted 48, WDOH 26, EPA (Region 10) 5, City of Richland 2, and DOE 5. There were 27 regulatory agency compliance actions (54 concerns and 72 compliance actions) resulting from inspections that contributed to \$169,722 in fines and penalties for CY 2015.

RCRA. The Ecology and EPA inspections focused on TSD unit compliance with the *Hanford Facility Dangerous Waste Permit* (1994) and [WAC 173-303](#), “Dangerous Waste Regulations.” Waste accumulation and universal waste management areas were also inspected.

CERCLA. Field inspections of institutional controls were conducted in 2015 at waste sites on the Hanford Site. No public trespass events occurred and all approved excavation permits were in place for all active remediation activities. Site contractors provide an annual update on the effectiveness of the institutional controls to EPA and Ecology at the Area Unit Managers Meetings conducted every September.

Hanford Site Emission Sources. The WDOH inspections focused on compliance of major and minor stack air emission units with the Air Operating Permit and Radioactive Air Emissions License FF-01. EPA inspections focused on asbestos management under 40 Code of Federal Regulations (CFR) Part 61, Subpart M “National Emission Standards for Hazardous Air Pollutants (NESHAPs) for Asbestos.” City of Richland inspections are limited to the 300 Area of the Hanford Site and involve implementation of the terms and conditions of the Industrial Wastewater Permit and discharges to the publicly owned treatment works.

Environmental Occurrences. Environmental releases of radioactive and regulated materials from the Hanford Site are reported as legally required under the following categories: Operational Emergency;

Recurring; Category 1 (significant impact); Category 2 (moderate impact); Category 3 (minor impact); and Category 4 (some impact). In 2015, there were no events for Category 1, 2, and 3; however, 46 Category 4 events occurred as a result of the discovery of legacy contamination at the Hanford Site.

Emergency Planning and Community Right to Know Act. The *2015 Hanford Site Toxic Chemical Release Inventory* report was submitted to EPA and Ecology before the annual July 1 deadline. During CY 2015, the Hanford Site exceeded activity thresholds for lead, naphthalene, propylene, toluene, and xylene.

Pollution Prevention Program. In 2015, over 2,248 tons (2,040 metric tons [MT]) of non-hazardous (plastic, aluminum, cardboard, paper, wood, and metal) and hazardous (antifreeze, batteries, bulbs, and oils) wastes were recycled through Hanford Site programs administered through the Mission Support Contract. Along with material recycling and diversion, greenhouse gas (GHG) emissions for FY 2015 decreased from FY 2014, largely due to a decrease in fleet diesel fuel use. In addition, the site reflected a 39% reduction in Scope 3 GHG emissions in FY 2015 from the FY 2008 baseline. Contractors at the Hanford Site continued to divert construction and demolition from landfill disposal, diverting approximately 980% (1,902 MT) of debris from the inert landfill.

Section 3, Environmental Management System

Environmental management performance measures objectives for 2015 included fleet management, alternative fuel use, potable and non-potable water use, electricity use, facility fuel use, facility energy use, electronic product environmental assessment tool, sanitary waste reduction, and regulated waste reduction. Objectives for 2015 were achieved for all performance measures, except for the target objective for standard electricity not met in FY 2015. The alternative fuel use target and electronic product environmental assessment tool were exceeded in 2015.

Section 4, Radiological Protection and Doses

Hanford Site radiation protection program staff conduct ongoing monitoring of external radiation sources; perform environmental radiological surveys; and evaluate potential radiological doses to the public. Results of 2015 monitoring efforts are provided below.

External Radiation Monitoring. Sources of external radiation at the Hanford Site include waste materials associated with former plutonium production and processing facilities; radioactive waste handling, storage, and disposal; and cleanup and remediation activities. In 2015, external radiation fields were monitored at 115 locations near Hanford Site facilities and operations, including the 100-K Area, 100-N Area Shoreline (N Springs), 200 Area, 300 Area, 400 Area, Environmental Restoration Disposal Facility (ERDF), 618-10 Burial Ground, and Integrated Disposal Facility (IDF).

In early 2015, the Hanford External Dosimetry Program's (HEDP) laboratory was relocated from its long-time location near the 300 Area and to between the 200 East and 200 West areas. This relocation introduced two substantial variances for 2015 data: first, approximately 50% higher background dose rate levels were attributable to elevated radon levels inherent in the new HEDP facility, producing artificially decreased dose rate values for 2015 compared to previous years' values. Second, the material used for shielding dosimeters was changed from lead (pre-2015), a substantially better material than the steel shielding used for 2015. The effect of this change was exposing dosimeters to significantly higher background levels and ultimately causing higher dose rate readings. Thus, due to complexities and

uncertainties imparted on 2015 data by these HEDP facility changes, annual data comparisons are impractical and were not reported. Comparative data reporting will resume once the HEDP laboratory background and shielding values are stable.

Radiological Release of Hanford Site Property. No property with detectable residual radioactivity above authorized limits was released from the Hanford Site in 2015.

Radiological Clearance for Potentially Contaminated Personal Property with Hard-to-Detect Radionuclides. More than 19,000 items of personal property were unconditionally released from radiological areas on the Hanford Site; however, the majority of the items did not leave the site. These items primarily consisted of small articles such as flashlights, hard hats, radios, cameras, pens, pencils, respiratory protection, radiological control instruments, and industrial hygiene instruments.

Radiological Clearance for Granular Activated Carbon for Off-site Shipment and Regeneration. A granular activated carbon canister from a soil-vapor extraction system was removed from the system and shipped to an off-site facility for regeneration and reuse. As an estimated value from variance over time with the exact volume processed, approximately 150,000 pounds (lbs; 68,000 kilograms [kg]) of granular activated carbon was shipped off site in 2015 for regeneration.

Potential Radiological Doses to the Public. In 2015, scientists evaluated potential radiological dose to the public and biota resulting from exposure to Hanford Site liquid effluents and airborne emissions to determine compliance with pertinent regulations and limits. The primary sources of radionuclide contamination evaluated in the dose assessment included gaseous emissions from stacks and ventilation exhausts, contaminated groundwater seeping into the Columbia River, and fugitive emissions from areas of contaminated soil and operating facilities. Potential radiological doses from 2015 Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. Radiological doses were assessed in terms of the following:

- Dose to a hypothetical maximally exposed individual (MEI) at an off-site location
- Collective dose to the population residing within 50 mi (80 km) of Hanford Site operation areas
- Doses for air pathways calculated using regulation-specified 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”
- Doses from recreational activities, including hunting and fishing
- Dose to a worker consuming drinking water on the Hanford Site
- Dose to a visitor of the Manhattan Project National Historical Park
- Doses from non-DOE industrial sources on and near the Hanford Site
- Absorbed dose received by biota exposed to radionuclide releases to the Columbia River and to radionuclides in on-site surface water bodies.

The MEI is a hypothetical person whose location and assumed exposures are modeled in such a protective manner that it is highly unlikely any actual off-site individual would have received a higher Hanford-related dose. The dose to the MEI calculated in 2015 from Hanford Site operations was 0.21 mrem (2.1 mSv), which is 0.21% of the 100 mrem (1000 mSv)/yr public dose limit specified in [DOE O 458.1](#). Many different exposure pathways are included in the dose calculations, but ingestion of food containing tritium from 300 Area air emissions was the single largest contributor. Based on the 50-mi (80-km) radius

population exposed to air emissions and the surrounding population exposed to water pathways releases to the Columbia River, the average individual dose from Hanford Site operations in 2015 was protectively estimated to be 0.0058 mrem (0.058 mSv). Doses calculated for recreational activities based on game and fish tissue samples (0.012 mrem (0.12 mSv)/yr), ingestion of Hanford Site drinking water from a 400 Area well (0.021 mrem (0.21 mSv)/yr), and visitors of the Hanford Townsite and White Bluffs Bank locations of the Manhattan Project National Historical Park (0.00034 mrem (0.0034 mSv)/yr) were likewise far below the public dose limit. To place this information into perspective, these doses may be compared with those received from other routinely encountered sources of radiation. A 2009 National Council on Radiation Protection and Measurements report estimated that the overall average exposure to ionizing radiation for the average American is 620 mrem (6,200 mSv)/yr, approximately half of which is related to natural sources and the other half attributable primarily to medical procedures.

Section 5, Environmental Restoration and Waste Management

Below is a waste summary for environmental restoration and waste management activities, including Hanford Site River Corridor closure, cleanup and remediation, facility decommissioning, waste management operations, underground waste storage tank status, construction of the Waste Treatment and Immobilization Plant and its associated facilities, and research activities related to waste cleanup. The following describes important 2015 cleanup and remediation activities at the Hanford Site.

River Corridor. The River Corridor includes the Hanford Site 100 and 300 areas that border the Columbia River. Through 2015, transitions are complete for 190 of 220 mi² (492 of 570 km²) of the River Corridor.

100 Area Waste Sites. The 100 Area waste sites vary in complexity and waste type. Typical waste sites include waste burial grounds, liquid effluent waste sites, burn pits, retired septic systems, piping systems, and miscellaneous waste sites. In 2015, remediation activities focused on hexavalent chromium release sites, pipeline sites, and miscellaneous waste sites. A total of 884,500 tons (802,400 MT) of contaminated soil and debris were removed from 100 Area remediation activities and were disposed of at the ERDF.

100-K Area. The 105-KE Reactor Building continued interim safe storage, reactor penetration sealing engineering, and safe storage enclosure; construction activities on the 100-K Annex in support of sludge removal operations; groundwater pump-and-treat operations; and testing of systems and components to be used to remove K Basins sludge to the Maintenance and Storage Facility in the 400 Area. The K West Basin is the only remaining operating nuclear facility undergoing cleanout that involves removing radioactive contaminated sludge and debris as a precursor to facility deactivation and demolition.

100 Areas Facilities Decommissioning. As of 2015, all deactivation, decommissioning, decontamination, and demolition activities in the 100 Area have been completed.

200 Area (Central Plateau) Facilities Decommissioning. Central Plateau facilities include buildings and associated waste sites in the 200 East, 200 West, and 200 North areas and those on the adjoining Rattlesnake Unit. At the Plutonium Finishing Plant in 2015, the Low-level Waste Treatment Facility, 296Z015 Stack, Low-level Waste Sump Facility, and Closed Loop Cooling System all were demolished and removed from the complex. The 234-5Z Plutonium Finishing Plant removed materials at the following completion milestones: 98% of all gloveboxes and hoods, 77% of all asbestos, and 55% of ducting. The Plutonium Reclamation Plant completed size reduction and seal out of the remaining pencil tanks during 2015.

300 Area Facilities Decommissioning. Deactivation, decommissioning, decontamination, and demolition activities in the 300 Area included completion of the 309 SP-100, MO-391, and MO-868 facilities.

400 Area Facilities – Fast Flux Test Facility Deactivation. The FFTF remains in long-term surveillance and maintenance, and routine surveillances are performed annually.

Solid Waste Management. Solid waste management includes the treatment, storage, and disposal of solid waste produced as a result of Hanford Site operations or received from off-site sources authorized to ship waste to the site. Active on-site solid waste facilities as of 2015 are described below.

Central Waste Complex. Located in the 200 West Area, the CWC receives waste from Hanford Site sources and any off-site sources authorized by DOE to ship waste to the site for treatment, storage, and disposal. Waste received includes low-level, transuranic, or mixed waste, and radioactive waste contaminated with polychlorinated biphenyls. Currently, the volume of waste stored in the CWC Outside Storage Areas is approximately 176,900 ft³ (5,010 m³), with the remaining enclosed area storage totaling approximately 211,600 ft³ (5,992 m³).

Canister Storage Building. Located in the 200 East Area, this 42,000-ft² (3,902-m²) facility stores about 2,300 tons (2,086 MT) of spent nuclear fuel packaged in approximately 400 multi-canister overpacks from the 100-K Basins, 100-N Reactor, and T Plant.

Low-level Burial Grounds. This area consists of eight burial grounds located in the 200 East and 200 West areas that are used to dispose of low-level waste and mixed waste. In 2015, a total of 9,455 ft³ (268 m³) of waste was disposed of in Trenches 31 and 34. Trench 94 (218-E-12B Burial Ground) received no defueled U.S. Navy reactor compartments in 2015, with the total number of reactor compartments received into Trench 94 to date remaining 127.

Environmental Restoration Disposal Facility. ERDF began operations in 1996 and serves as the central disposal site for contaminated waste removed during Hanford Site CERCLA cleanup operations. The largest disposal facility in the DOE complex, ERDF has received 17.5 million tons (15.9 million MT) of contaminated material from DOE and its contractors, with a slight facility expansion approved during 2015.

Liquid Waste Management. The facilities described below are operated on the Hanford Site to store, treat, reduce, and dispose of various types of liquid effluent generated by site cleanup activities. In addition, remediation systems pump and treat contaminated groundwater in the 100-D, 100-H, and 200 West areas.

200 Area Effluent Treatment Facility. Located in the 200 East Area, the ETF treats liquid w to remove toxic metals, radionuclides, and ammonia, in addition to destroying organic compounds. The treated waste is stored in tanks, sampled and analyzed, and discharged to the State-approved Land Disposal Site (616-A Crib). This facility did not operate in 2015 due to a failed heat exchanger.

200 Area Liquid Effluent Retention Facility. Across from the ETF, the LERF consists of three RCRA-compliant surface basins used to store aqueous waste. The volume of wastewater received for LERF basin storage in 2015 was approximately 3.95 million gal (15 million L), which includes pipeline-transported CERCLA-regulated ERDF wastewater (1.74 million gal [6.59 million L]), 242-A Evaporator process condensate (approximately 1.53 million gal [5.79 million L]), and tanker truck wastewater from various other facilities (approximately 0.41 million gal [1.54 million L]). RCRA regulated waste is primarily contributed from 242-A Evaporator process condensate, with other minor contributors of RCRA

waste to include leachate from the mixed waste burial trench. The volume of wastewater being stored in the LERF at the end of 2015 was approximately 17.4 million gal (65.9 million L).

200 Area Treated Effluent Disposal Facility. Located east of the 200 East Area, the TEDF is a collection and disposal system for non-RCRA waste streams and consists of approximately 11 mi (18 km) of buried pipelines connecting three pumping stations, the 6653 Building (known as the disposal sample station), and a 5-acre (ac; 2-hectare [ha]) disposal ponds. The volume of unregulated effluent disposed to the TEDF in 2015 was approximately 238 million gal (901 million L).

242-A Evaporator. The 242-A Evaporator in the 200 East Area concentrates dilute liquid tank waste by evaporation, reducing the volume of liquid waste sent to double-shell tanks for storage and the potential need for other double-shell tanks. In 2015, four operating campaigns were completed at the 242-A Evaporator, creating nearly 2 million gal (7.6 million L) of available storage space in the double-shell tank system.

Underground Waste Storage Tanks. Most Hanford Site waste is stored in 149 large underground single-shell and 28 double-shell tanks grouped into 18 tank farms located on the Central Plateau.

Single-shell Tank System. This system is undergoing closure, as the radioactive and hazardous waste stored in single-shell tanks is being transferred to more safe, double-shell tanks. In 2015, progress continued in retrieving waste from the 16 tanks in C-Farm. Waste transfer is complete for 14 of the 16 tanks, with the remaining two tanks at over 42% (tank C-105) and over 32% (tank C-105) at the end of 2015.

Double-shell Tank System. The double-shell tank system includes 28 double-shell tanks located in the 200 East and 200 West areas. At the end of 2015, approximately 25.8 million gal (97.7 million L) of waste were stored in the double-shell tanks.

Waste Treatment and Immobilization Plant. The WTP is being built on 65 ac (26 ha) on the Central Plateau to treat radioactive and hazardous waste currently stored in 177 underground tanks.

Pretreatment Facility. In 2015, work continued to resolve the remaining technical issues that have impacted design and construction since 2012. Significant progress on the technical issues was made in 2015, and procurement was completed to begin testing of the standard high-solids vessel in 2016.

High-level Waste Vitrification Facility. At this facility, high-level waste is combined with materials in high-temperature melters, poured into waste containers to form a solid, immobilized glass form. Construction in 2015 included the creation of 22 concrete placements.

Low-activity Waste Vitrification Facility. Similar to the high-level facility, low-activity waste is mixed with materials that form a solid, immobilized glass form. For 2015, construction continued on interior equipment and commodities installation.

Analytical Laboratory. Once operational, the laboratory will process about 10,000 waste samples a year to support glass formulation and waste-form compliance. In 2015, workers outfitted the facility with equipment and fixtures prior to a startup group that will test system working order.

Long-term Stewardship. This task focused on documenting completed cleanup actions and facilitating transition of surveillance and maintenance responsibilities within the River Corridor from the cleanup contractor to the site services contractor, MSA. Transition and turnover packages for IU-2/Segment 4a and 100 B/C Area were completed in 2015.

Scientific and Technical Contributions to Hanford Site Cleanup. Pacific Northwest National Laboratory's scientific and technical contributions to Hanford Site cleanup have focused on conducting fundamental engineering development to support resolution of mixing issues associated with the Waste Treatment Plant. Researchers teamed with Savannah River National Laboratory, Catholic University, and the Missouri University of Science and Technology to develop formulations capable of reducing low and high activity waste glass volumes. In addition, the Deep Vadose Zone Applied Field Research initiative led a multi-national laboratory effort to identify research and development needed to define and apply risk-informed remediation approaches successfully for complex sites such as Hanford.

Section 6, Air Monitoring

Hanford Site contractors monitor airborne emissions from site facilities to determine compliance with federal and state regulatory requirements and assess the effectiveness of emission control equipment and pollution management practices. The natural state of air in the outdoor environment, ambient air is also monitored at site facilities, away from facilities, and off site in nearby and distant communities.

Air Emissions. Small quantities of particulate and volatilized forms of radionuclides and nonradioactive chemical pollutants are emitted to the environment from federal and state permitted emission sources. Most facility radioactive air emission units are monitored periodically or continuously if they have the potential to exceed 1% of the standard for public dose at 10 mrem (100 mSv)/yr. Non-radioactive constituents and parameters are monitored directly, sampled, and analyzed or estimated based on inventory usage. Air emission data collected in 2015 were comparable to those collected in 2014. DOE a report of Hanford Site radionuclide air emissions annually submits to EPA and the WDOH in compliance with [40 CFR 61, Subpart H](#), "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities" and [WAC 246-247](#), "Radiation Protection – Air Emissions."

Ambient Air Monitoring Near Facilities and Operations. A network of continuously operating samplers at 60 locations across the Hanford Site was used during 2015 to monitor radioactive airborne materials in air near site facilities and operations. Air samples collected from locations at or directly adjacent to Hanford Site facilities had higher radionuclide concentrations than 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 off site. Concentrations of certain radionuclides were higher and widely variable in different operational areas, and naturally occurring radionuclides, beryllium-7, and potassium-40 were routinely identified.

Hanford Site and Off-site Ambient Air Monitoring. During 2015, ambient air samples were collected from 40 continuously operating samplers in nearby, surrounding, and distant communities to provide background data. Airborne particle samples were collected biweekly at each location and analyzed for gross beta and, at some locations, gross alpha radiation. All sample results for 2015 showed very low concentrations in air, and all radionuclide concentrations were below the EPA standard of 10 mrem (100 mSv)/yr.

Section 7, Water Monitoring

In 2015, water samples were collected and analyzed from seven different sources as described below.

Hanford Site Drinking Water Monitoring. Routine chemical, physical, and microbiological monitoring of Hanford Site drinking water is performed regularly as mandated by EPA's Community Water System

(CWS) requirements. All DOE-owned Hanford Site systems were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels for 2015. Contaminant concentrations measured during the year were similar to those observed in recent years.

Columbia River Water Monitoring. Columbia River water samples were collected in 2015 from fixed-location monitoring stations at Priest Rapids Dam and City of Richland drinking raw water intake facility and were analyzed for radionuclides. Cross-river transects near Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the City of Richland drinking water intake were collected in 2015 and analyzed for radionuclides, metals, and inorganic and organic compounds.

Columbia River Water – Fixed Location Samples. Radiological analyses of Columbia River water samples collected at the fixed locations showed individual radiological contaminant concentrations were below DOE-derived concentration standards.

Columbia River Water – Cross-river Transect Samples. Cross-river transect samples near the Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the City of Richland had higher tritium concentrations near the Benton County (Hanford Site) shoreline compared to the opposite (Grant-Franklin) shoreline. Strontium-90 concentrations in Hanford Reach transect samples were similar to upstream reference concentrations. Uranium concentrations in all transect samples were below the EPA drinking water standard.

Inorganic and organic analyses detected metals and anions in Columbia River transect samples upstream and downstream of the Hanford Site. Aluminum, copper, magnesium, sodium, uranium, and zinc were detected in most samples. All dissolved metal concentrations in river water transect samples were less than the Washington State ambient surface-water quality criteria for protection of aquatic life.

Columbia River Sediment Monitoring. Samples were collected from Columbia River sediments and analyzed for radionuclides and inorganic constituents. Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2015 included cesium-137, uranium-234, uranium-235, uranium-238, plutonium-239/-240, and decay products from naturally occurring radionuclides. The concentrations of all other radionuclides, including strontium-90, were below the required detection limits for most samples.

Detectable amounts of most metals were found in all river sediment samples. Maximum and average concentrations of cadmium, chromium, copper, lead, mercury, nickel, thallium, and zinc were higher for sediment collected in the reservoir upstream of Priest Rapids Dam than in sediment from either the Hanford Reach or McNary Dam. Lead concentrations were detected at higher rates in White Bluffs sediment in comparison to all other sediment collection locations in 2015.

Columbia River Shoreline Seep Water. Samples of Columbia River shoreline seep water and two associated shoreline sediment samples were collected along the Hanford Reach in 2015 and analyzed for radiological, inorganic, and organic contaminants. Radiological contaminants of Hanford Site origin, including gross alpha, gross beta, carbon-14, strontium-90, tritium, and total uranium, were detected in seep water samples. Inorganic and organic contaminants originating from the Hanford Site, including metals and anions of interest (chloride, nitrate, and sulfate) were detected in seep water. Concentrations of volatile organic compounds were near or below the analytical laboratory's required detection limits in all samples. Constituents found above detection limits in the shoreline seep included cesium-137, uranium isotopes, and metals, particularly chromium and hexavalent chromium.

Pond Water and Sediment. West Lake is the only naturally occurring pond on the site, and the area has not received radioactive discharges for some time. Tritium concentrations were below the laboratory-reported detection limit; in addition, West Lake water was analyzed for tritium and uranium-234, -235, and -238. Detections of all radionuclides during 2015 were similar to previously reported measurements.

Off-site Irrigation Water. To assess the potential for Hanford Site-associated contaminants to affect food products irrigated with Columbia River downstream of the site, water samples were collected three times during the irrigation season from a canal east of the Columbia River and from the Horn Rapids irrigation pumping station. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, strontium-90, and tritium. Although tritium results were slightly higher than water collected from the Riverview irrigation system, all radionuclide concentrations were within the historical range, less than the respective DOE-derived concentration standards and Washington state ambient surface-water quality criteria.

Liquid Effluent Monitoring. Liquid effluent disposal is governed by applicable regulations and permits. When discharges occur, sampling and analyzing is performed to identify select radioactive parameters and nonradioactive hazardous materials. Discharge monitoring reports that contain contaminant data from these analyses are submitted to Ecology.

Section 8, Groundwater Monitoring

During Hanford Site operations, chemical and radioactive waste was released into the environment and contaminated soil and groundwater beneath portions of the site, mostly in the 200 East, 200 West, 300, and 100 reactor areas along the river. This section summarizes Hanford Site groundwater monitoring results, including those for RCRA TSD units, CERCLA groundwater operable units, and *Atomic Energy Act of 1954* requirements. DOE publishes details on CERCLA remediation activities (such as pump-and-treat operations) in separate documents that are summarized and referenced in this report. Along with information on well monitoring locations, construction details, and screened intervals, the monitoring data presented can be found through the DOE Environmental Dashboard Application at <https://ehs.hanford.gov/eda/> or on the PNNL-Hanford Online ENvironmental Information eXchange (PHOENIX) website at <http://phoenix.pnnl.gov>. The data and additional groundwater monitoring details are available in the *Hanford Site Groundwater Monitoring Report for 2015*.

Section 9, Soil Monitoring

Soil samples are collected near facilities and operations on the Hanford Site to detect potential migration and deposition of facility emissions and evaluate long-term trends in the environmental accumulation of radioactive materials. A total of 79 samples was collected in 2015 and compared to concentrations of radionuclides measured in samples collected off site at various locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin counties in 2015.

In general, radionuclide concentrations in soil samples collected from or adjacent to waste disposal facilities in 2015 were similar to or slightly elevated compared with the concentrations in samples collected in distant communities. Also, as expected, data showed that concentrations of certain radionuclides in 2015 were higher in different operational areas compared with concentrations measured in distant communities in previous years: historically, predominant radionuclides detected are activation and fission products in the 100 Areas, fission products in the 200 and 600 areas, and uranium in the 300 and 400 areas.

Section 10, Biota Monitoring

DOE conducted agricultural monitoring at several locations that vary annually near the Hanford Site to assess potential contaminant concentrations in food and farm products as a result of site activities. Plant and animal species on the site are also monitored to assess abundance, condition, and population distributions. Data collection and analysis are integrated with environmental monitoring of biotic and abiotic media, and analytical results are used to characterize potential risks or impacts.

Agricultural Monitoring. Samples of milk and several fruit, vegetable, and farm products as well as wine samples were collected in 2015 at eight different locations on and around the Hanford Site. Radionuclide concentrations in most samples were below levels that could be detected by analytical laboratories; however, some potential Hanford Site-produced contaminants (such as tritium) were found at low levels in some samples.

Animal Monitoring. In 2015, four fish and wildlife species were sampled and analyzed for potential Hanford Site contaminants: mountain whitefish, white sturgeon, Nuttall's cottontail rabbit, and Canada goose. All fish and wildlife samples were monitored for strontium-90 and a number of gamma emitters, including cesium-137. Trace metals associated with Hanford Site operations (e.g., copper, lead, and mercury) that have potential to accumulate in certain fish and wildlife tissues were also analyzed. Cesium-137 was found in all the white sturgeon filet samples, and strontium-90 was detected in rabbit bone samples collected in the 300 Area. Trace metals were found above detection limits in most of the tested animal tissues at variable but fairly low concentrations. At this time, no established federal or state criteria are available for trace-metal concentrations in fish tissue.

Vegetation Monitoring. Plant populations and habitats occurring on the Hanford Site are surveyed and monitored to assess potential risks or impacts to biota. Hanford Site and off-site vegetation samples are analyzed for information about atmospheric deposition of contaminants in and around operational areas on site and in uncultivated areas off site. These data provide a baseline against which unplanned releases can be compared. In general, radionuclide concentrations in vegetation samples collected from or adjacent to waste disposal facilities in 2015 were higher than concentrations in samples collected farther away, including concentrations measured off site. Generally, the predominant radionuclides were activation and fission products in the 100 Areas, fission products in the 200 Areas and 600 Area, and uranium in the 300 and 400 areas.

Vegetation Control. Vegetation control activities help prevent, limit, or remove contaminated plants or undesirable plant species. Approximately 5,164 ac (2,090 ha) were treated with herbicides in 2015 on radiological waste sites, around operations areas, and along roadways to keep areas free of deep-rooted vegetation (e.g., Russian thistle, also known as tumbleweed). Follow-up treatments are included in the total treated acres; several areas received more than one herbicide application.

Waste Site Remediation and Revegetation. Waste sites in the 200 East and 200 West areas were designed and constructed with a cap of perennial grass. Integrated Biological Control has been actively restoring vegetative caps on other waste sites.

Section 11, Resource Protection

DOE is responsible for managing and protecting biological and cultural resources on the Hanford Site. Ecological and cultural resource monitoring are conducted to collect and track data needed to ensure compliance with an array of laws, regulations, and policies governing DOE activities.

Ecological Protection. Ecological monitoring data provide baseline information about the plants, animals, and habitats under DOE stewardship at Hanford that is required to make cleanup decisions. During 2015, DOE continued to monitor and evaluate species that are protected by federal or state laws and regulations or are of special interest to the public and stakeholders. Fall Chinook salmon redds, steelhead redds, and bald eagle nesting and night roosting activity were assessed because these species have the potential to be impacted by Hanford Site operations. Additional monitoring efforts included nesting raptors, migratory birds, ground squirrel habitat analysis, reptiles, burrowing owl, jackrabbits, and the American badger.

Endangered and Threatened Species. Two endangered and threatened fish species, spring-run Chinook salmon and steelhead, are known to occur regularly on the Hanford Site. One additional fish species (bull trout) was recorded at the site, but scientists believe that the species is transient. Umtanum desert buckwheat and White Bluffs bladderpod, federally listed as threatened plant species, also occur on the site. No other plants or animals known to occur on the Hanford Site are currently federally listed as threatened or endangered, though the Washington ground squirrel is a candidate for federal listing.

Cultural and Historic Resource Protection. DOE is responsible for managing and protecting the Hanford Site's cultural and historic resources in accordance with applicable federal cultural resources laws and regulations and DOE management plans. Hanford Site archaeologists reviewed 23 undertakings that had the potential to affect cultural resources, of which 9 were identified as No Historic Properties Affected, 11 were determined to have No Adverse Effects, and 3 were identified as having Adverse Effects that required mitigation measures. A total of 4,645 ac (1,880 ha) of new ground was surveyed for cultural resources in 2015.

The Hanford Collection comprises artifacts from the Manhattan Project and Cold War era. In 2015, 70 artifacts were delivered to the 4732-A Artifact Staging Facility, leaving approximately 3.5% of the items scheduled for collection between 2016 and 2048. Also in 2015, Washington State University Tri-Cities (WSU-TC) in Richland, WA was subcontracted to provide management, conservation, and interpretation of the Hanford Collection. A total of 40% of the Collection was moved from the artifact staging facility on the Hanford Site to the WSU-TC Consolidated Information Center curation facility, with the remaining 60% to be transitioned in 2016.

Section 12, Quality Assurance

Quality assurance and control programs for the Hanford Site and off-site environmental surveillance were documented through project-specific quality assurance plans and describe applicable quality assurance elements. Samples were collected and analyzed according to documented standard procedures. Analytical data quality was verified by a continuing program of internal laboratory quality control, participation in inter-laboratory crosschecks, duplicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories. No issues were identified that significantly affected the quality assurance and control for Hanford Site sampling and analytical activities during 2015.

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Acronyms and Abbreviations

AEA	<i>Atomic Energy Act</i>
AFRI	Applied Field Research Initiative
ALARA	as low as reasonably achievable
ALARACT	As Low As Reasonably Achievable Control Technology
ALE	Fitzner/Eberhardt Arid Lands Ecology Reserve
AR/PIR	Administrative Record/Public Information Repository
ARAR	applicable or relevant and appropriate requirement
ASCEM	Advanced Simulation Capability for Environmental Management
ASME	American Society of Mechanical Engineers
ATL	Advanced Technologies and Laboratories, Inc.
BHI	Bechtel Hanford, Inc. (now Bechtel National, Inc., as below)
BNI	Bechtel National, Inc.
BRMP	Biological Resources Management Plan
C&D	construction and demolition
CAFO	Consent Agreement and Final Order
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CFR	<i>Code of Federal Regulations</i>
CHPRC	CH2M Plateau Remediation Company
CHRP	Cultural and Historic Resource Protection
CLUP-EIS	<i>Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement</i> , DOE/EIS-0222-F
COC	contaminant of concern
Council	Hanford Natural Resource Trustee Council
CRR	Cultural Resource Review
CSB	Canister Storage Building
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CVDF	Cold Vacuum Drying Facility
CWC	Central Waste Complex
CY	calendar year
D4	deactivation, decommissioning, decontamination, and demolition
DOE	U.S. Department of Energy
DOECAP	DOE Consolidated Audit Program
DOE-HQ	U.S. Department of Energy, Headquarters
DCG	Derived Concentration Guides
DNFSB	Defense Nuclear Facility Safety Board
DST	double-shell tank
DWS	drinking water standard
EA	environmental assessment
Ecology	Washington State Department of Ecology
EDP	environmental data point
ETF	200 Area Effluent Treatment Facility
EIS	Environmental Impact Statement
EM	U.S. Department of Energy, Office of Environmental Management
EMS	Environmental Management System
EMSL	Environmental Molecular Sciences Laboratory, a DOE user facility on the PNNL campus

EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act of 1986
ERDF	Environmental Restoration Disposal Facility
ERT	electrical resistance tomography
ETF	Effluent Treatment Facility
EVOC	(HAMMER) Emergency Vehicle Operations Course
FBR	fluidized bed reactors
FFTF	Fast Flux Test Facility
FONSI	finding of no significant impact
FR	<i>Federal Register</i>
FS	feasibility study
FY	fiscal year
GEA	gamma energy analysis
GHG	greenhouse gases
GIS	Geographic Information Systems
GPS	Global Positioning System
HAB	Hanford Advisory Board
HAMMER	Volpentest HAMMER Federal Training Center
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
HCP-EIS	<i>Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement</i>
HEDP	Hanford External Dosimetry Program
HEPA	high-efficiency particulate absorber
HLW	high-level waste
HPMC	HPMC Occupational Medical Services
HRNM	Hanford Reach National Monument
HRS	Hazard Ranking System
HSS	U.S. Department of Energy, Office of Health, Safety, and Security
HTO	tritiated water vapor
HQ	U.S. Department of Energy, Headquarters
IAP	Injury Assessment Plan
IC	institutional control
ICRP	International Commission on Radiological Protection
IDF	Integrated Disposal Facility
IRT	Independent Review Team
ISCORS	Interagency Steering Committee on Radiation Standards
ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
ISS	interim safe storage
IT	Information Technology
KBC	K Basins Closure Project
LERF	Liquid Effluent Retention Facility (200 Area)
LLBG	low-level burial ground
LLW	low-level waste
LLWMA	Low-level Waste Management Area
LOSS	large on-site sewer systems
LTS	long-term stewardship
MAPEP	Mixed Analyte Performance Evaluation Program

MARS	Mobile Arm Retrieval System
MBTA	<i>Migratory Bird Treaty Act of 1918</i>
MEI	maximally exposed individual
MRAD	Environmental Resource Associates
MNA	monitored natural attenuation
MSA	Mission Support Alliance, LLC
NCRP	National Council on Radiation Protection and Measurements
NEPA	<i>National Environmental Policy Act of 1969</i>
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	<i>National Historic Preservation Act of 1966</i>
NLOP	North Load-out Pit
NOAA	National Oceanic and Atmospheric Administration
NOC	Notice of Construction
NPL	National Priorities List
NPS	National Park Service
NRDWL	Nonradioactive Dangerous Waste Landfill
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRDA	natural resource damage assessment
NRHP	National Register of Historic Places
OEA	Office of Independent Enterprise Assessments
OFI	opportunities for improvements
ORP	U.S. Department of Energy, Office of River Protection
OSHA	Occupational Safety and Health Administration
OSS	on-site sewer systems
OU	operable unit
P&T	pump and treat
PCB	polychlorinated biphenyl
PED	Preliminary Estimate of Damage
PPF	Plutonium Finishing Plant
PHOENIX	PNNL-Hanford Online Environmental Information eXchange
PNL	Pacific Northwest Laboratory (pre-1995 name)
PNNL	Pacific Northwest National Laboratory (1995 and later)
PQL	practical quantitation limit
PRF	Plutonium Reclamation Facility
PRTR	Plutonium Recycle Test Reactor
PRZ	Periodically Rewetted Zone
PT	pretreatment
PUREX	Plutonium/Uranium Extraction (Plant)
QA	quality assurance
QC	quality control
QRA	quantitative risk assessment
RBDA	risk-based disposal approval
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
RCW	<i>Revised Code of Washington</i>
REDOX	reduction/oxidation (Plant)
RESRAD	RESidual RADioactive

RI	remedial investigation
RFI/CMS	RCRA facility investigation/corrective measures study
RFID	radiofrequency identification
RL	U.S. Department of Energy, Richland Operations Office
ROD	record of decision
RPD	relative percent difference
RUM	Ringold Formation upper mud unit
SARA	<i>Superfund Amendments and Reauthorization Act</i>
SCWE	Safety Conscious Work Environment
SDWA	Safe Drinking Water Act
SEP	special environmental project
SHPO	Washington State Historic Preservation Office
SOW	statement of work
SST	single-shell tank
SWL	Solid Waste Landfill
TCP	Traditional Cultural Property
TEDF	Treated Effluent Disposal Facility (200 Area)
THP	total petroleum hydrocarbons
TLD	thermoluminescent dosimeter
TPA	Tri-Party Agreement (official name <i>Hanford Federal Facility Agreement and Consent Order</i>)
TRIDEC	Tri-Cities Economic Development Council
TPA agencies	U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology
TSCA	<i>Toxic Substances Control Act</i>
TSD	treatment, storage, and disposal
TWG	Technical Work Group
U.S.C.	<i>United States Code</i>
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey
VOA	volatile organic analyses
VPP	Voluntary Protection Program
VPPPA	Voluntary Protection Program Participants Association
WAC	<i>Washington Administrative Code</i>
WBGT	wet-bulb global temperature
WCH	Washington Closure Hanford, LCC
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington State Department of Health
WESF	Waste Encapsulation and Storage Facility
WHCWG	(Washington) Wildlife Habitat Connectivity Working Group
WIPP	Waste Isolation Pilot Plant
WMA	waste management area
WNHP	Washington Natural Heritage Program
WRAP	Waste Receiving and Processing (Facility)
WRPS	Washington River Protection Solutions, LLC
WSCF	Waste Sampling and Characterization Facility
WTP	Waste Treatment and Immobilization Plant

Units of Measure and Symbols

ac	acre(s)
Bq	becquerel
C	Celsius
CO ₂ e	carbon dioxide equivalent
cm	centimeter(s)
dpm	disintegrations per minute
F	Fahrenheit
ft	foot/feet
g	gram(s)
gal	gallon(s)
ha	hectare(s)
kg	kilogram(s)
in.	inch(es)
km	kilometer(s)
L	liter(s)
lb(s)	pound(s)
m	meter(s)
mi	mile(s)
min	minute(s)
mg	milligram(s)
mL	milliliter(s)
mrem	millirem
MT	metric tons
pCi	picocuries
ppm	parts per million
rem	roentgen equivalent in man
Sv	sievert
[unit] ²	square unit of measure
[unit] ³	cubed unit of measure
yr	year(s)
°	degree(s)
μ	microgram(s)
μS	microsiemen(s)
μSv	millisievert(s)
/	per
%	percent

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1.0 Introduction

PA Hartsock

Since 1959, the U.S. Department of Energy (DOE) has published the Hanford Site Environmental Report annually to inform the public, regulators, stakeholders, and other interested parties of the site's environmental performance during the year. This calendar year (CY) 2015 report includes a description of the Hanford Site mission; compliance with applicable federal, state, and local environmental laws, regulations permits, executive orders, and DOE policies and directives; and descriptions of summary data from environmental programs. Previous years' annual environmental reports are available at <http://msa.hanford.gov/page.cfm/enviroreports> and include sections that describe the following:

- Site compliance with federal, state, and local environmental standards and requirements
- Site operations, including environmental restoration efforts and cleanup and closure activities
- Environmental management performance
- Environmental occurrences and responses
- Effluents and emissions from site facilities
- Results of on- and off-site environmental and groundwater monitoring efforts
- Cultural and biological resource assessments.

Additional detail is provided in the appendices, and descriptions of specific analytical and sampling methods used for 2015 monitoring efforts are provided in the latest version of the *Hanford Site Environmental Monitoring Plan* ([DOE/RL-91-50](#)).

Section 1.0 provides information about the Hanford Site location and detail the environmental setting, mission, management, primary operations and activities, and climate and meteorology. The report also discusses stakeholder involvement, the role of Native American tribes, and Hanford regulatory oversight.

1.1 Hanford Site Location

The Hanford Site is located within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State and occupies approximately 580 square miles (mi²; 1,502 square kilometers [km²]) north of the confluence of the Yakima and Columbia rivers. With restricted public access, the diverse geographic features and land (Figure 1.1) provide a buffer for areas once used for nuclear materials production and waste storage and disposal. The Columbia River flows through the northern part of the site and forms part of the eastern site boundary before turning south. Rattlesnake Mountain and the Yakima and Umtanum ridges form the southwestern and western boundaries, and the Saddle Mountains form the northern boundary. The closest population centers include Richland, Pasco, and Kennewick, collectively known as the Tri-Cities, which are located to the southeast of the site ([PNNL-6415, Rev. 18](#)).

The climate of the Hanford Site is influenced by the Pacific Ocean and Cascades to the west, along with other mountain ranges to the north and east. In addition to the Columbia River, natural surface waters include Rattlesnake and Snively springs and West Lake. With its shrub-steppe ecosystem, the site contains terrestrial and aquatic species, some of which are considered rare and/or declining or are of significant interest to federal, state, or tribal governments.



Figure 1.1. Detailed Geography of the Hanford Site, Hanford Reach National Monument (HRNM), and DOE Portions of the Hanford Site

1.2 Hanford Site Mission

The Hanford Site played a pivotal role in the nation's defense for over 40 years. During World War II and the Cold War, Hanford Site facilities were primarily dedicated to the production of plutonium to fuel atomic weapons and management of the resulting legacy waste. With the signing of the *Hanford Federal Facility Agreement and Consent Order* known as the Tri-Party Agreement (TPA; [Ecology/EPA/DOE 1989a](#)) by the Washington Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and DOE (collectively, TPA agencies), the primary mission shifted to developing new waste treatment and disposal technologies and characterizing and cleaning up the contamination from historical operations. The Hanford Site's current mission focuses on environmental restoration, which includes remediation of contaminated areas, decontamination and decommissioning of Hanford Site facilities, waste management (specifically, waste storage, treatment, and disposal), and related scientific and environmental research and development of waste management technologies. In addition, the recently established Manhattan Project National Historical Park, of which the Hanford B Reactor and other Hanford Site structures are a part, focuses on historic preservation and public education.

1.3 Primary Operations and Activities

The major DOE operational, administrative, research, and historically preserved areas in and around the Hanford Site include the following:

100 Area. The 100 Area consists of six distinct sites (100-B/C, 100-D, 100-F, 100-H, 100-K, and 100-N) along the Columbia River shore in the northern portion of the Hanford Site. These sites were the location of nine nuclear reactors that have since been retired. Collectively, the 100 Area occupies approximately 4 mi² (11 km²). Now part of the Manhattan Project National Historical Park, the B Reactor National Historic Landmark is located in the 100-B Area. As the first industrial-scale nuclear reactor, B Reactor produced plutonium for the world's first nuclear detonation (Trinity Test) and the atomic bomb that was detonated over Nagasaki, Japan in 1945.

200 Area. The 200-East and 200-West Areas cover approximately 6 mi² (16 km²) and are located on the Central Plateau between 5 and 7 mi (8 and 11 km) south and west of the Columbia River. The plateau surface is approximately 328 feet (ft; 100 meters [m]) above the level of the Columbia River and about 280 ft (85 m) above the underlying water table. These areas contain underground waste storage tanks and housed facilities known as separations plants that extracted plutonium from dissolved irradiated fuel. The 200-North Area covers approximately 58.6 acres (ac; 23.7 hectares [ha]) with operations mainly focused on irradiated nuclear fuel interim storage. Thermal cooling of the spent fuel required water that was disposed of at several sites in the 200-North Area. Remediation of these sites is ongoing.

300 Area. The 300 Area is located just north of Richland and covers approximately 0.6 mi² (1.5 km²). From the early 1940s until the start of the environmental cleanup mission in 1989, nuclear fuel fabrication and research and development activities were performed at the 300 Area. Remediation of waste sites and decommissioning of 300 Area facilities is ongoing.

400 Area. The 400 Area is located northwest of the 300 Area and covers approximately 0.23 mi² (0.61 km²). This area includes the Fast Flux Test Facility (FFTF), a nuclear reactor designed and used to

test various types of nuclear fuel, produce medical and industrial isotopes, and conduct cooperative international research. The FFTF operations were discontinued in 1992, and the facility is now in a low-cost, long-term surveillance and maintenance condition.

600 Area. The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas.

1100 Area. The former 1100 Area is located between the 300 Area and Richland, covering 1.2 mi² (3.1 km²). In October 1998, this area was transferred to the Port of Benton as part of DOE's 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 (off site). This area includes the DOE scientific user facility Environmental Molecular Sciences Laboratory (EMSL), Pacific Northwest National Laboratory (PNNL), and other DOE and contractor facilities (mostly office buildings) generally located in the northern part of Richland.

700 Area (off site). The 700 Area includes DOE administrative buildings in central Richland.

Volpentest HAMMER Federal Training Center. Hazardous Materials Management and Emergency Response (HAMMER) is a worker safety training facility located on the Hanford Site near Richland and is used by site contractors, federal and state agencies, tribal governments, and private industry. HAMMER contracts with emergency response agencies and offers classes in fire suppression, hostage rescue, high-speed pursuit, and drug enforcement. The center works with the U.S. Department of State to train international border patrol agents and homeland security staff. The facility consists of a 0.12-mi² (0.31-km²) main site and a 15.6-mi² (40.4-km²) law enforcement and security training site.

Non-DOE Operations and Activities on Hanford Site Leased Land. Energy Northwest operates a commercial nuclear power reactor at the Columbia Generating Station north of the 300 Area on 1,090 ac (440 ha). U.S. Ecology Washington operates a commercial low-level radioactive waste burial site located west of the 200 East Area on 99 ac (40 ha). West of the 400 Area, the California Institute of Technology and Massachusetts Institute of Technology jointly operate the Laser Interferometer Gravitational-Wave Observatory sponsored by the National Science Foundation.

Non-DOE Nuclear Operations Near the City of Richland. AREVA NP, Inc. operates a commercial nuclear fuel fabrication facility near the southern boundary of the Hanford Site, and Perma-Fix Northwest, Inc. operates a low-level, mixed low-level radioactive waste processing facility located immediately adjacent to the southern boundary of the Hanford Site on 53 ac (21 ha). In addition, Westinghouse Electric Company operates the Richland Service Center, which provides chemical cleaning, decontamination, and related chemical and waste processing services to the nuclear industry.

Hanford Reach National Monument. Designated in June 2000 by Presidential Proclamation ([65 FR 37253](#)), the Hanford Reach National Monument (Figure 1.2) covers 195,000 ac (78,900 ha). The purpose of the monument is to protect the nation's only non-impounded stretch of the Columbia River upstream of Bonneville Dam and the remaining shrub-steppe ecosystem that once blanketed the Columbia River Basin. The monument is divided into five distinct administrative units: Rattlesnake (Fitzner/Eberhardt Arid Lands Ecology [ALE] Reserve), Columbia River Corridor, Ringold, Wahluke, and Saddle Mountain. Additionally, the U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), and DOE-Richland Operations Office (-RL) manage portions of the monument. The DOE-RL

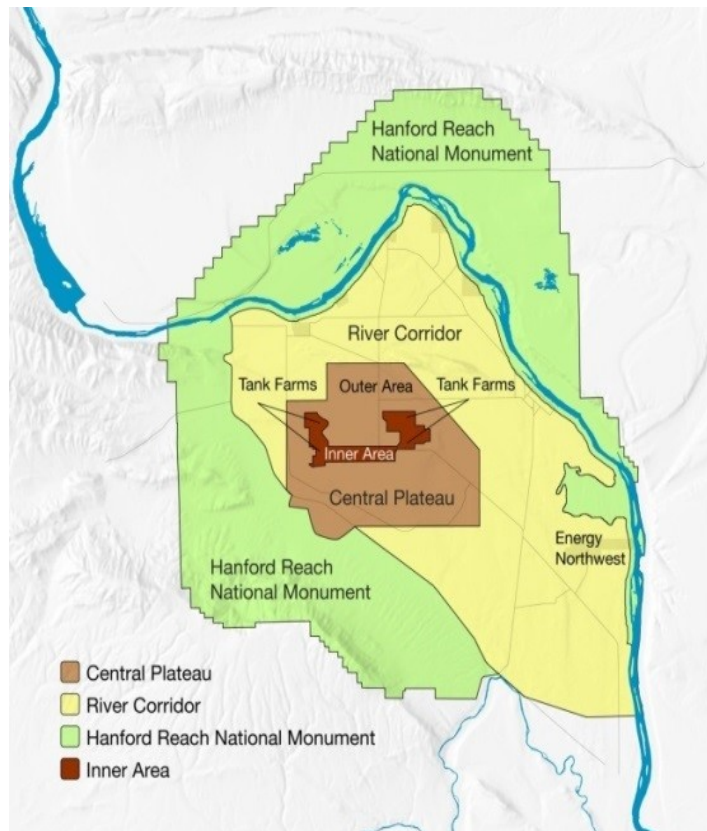


Figure 1.2. Hanford Site Area Overview

oversees a 14-mi² (36.4-km²) area of the monument north and west of State Highway 24 and south of the Columbia River in Benton County known as McGee Ranch/Riverlands. DOE also manages the River Corridor Unit, which includes Hanford Reach islands (Benton County) and a 0.25-mi (0.4-km) wide strip of land along the Hanford Reach shoreline from Vernita Bridge to north of the 300 Area. This 39-mi² (101-km²) area in Benton, Franklin, and Grant counties also includes the 9.9-mi² (25.6-km²) Hanford Site Dunes north of Energy Northwest.

Manhattan Project National Historical Park.

Established in November 2015 after a 15-year effort, one of the nation's newest national parks is located in three areas of the United States (Oak Ridge, TN; Los Alamos, NM; and Hanford, WA), areas that played critical roles in the research and development of the first nuclear

bombs used in World War II. These sites were also at the origin of developing the national laboratory system that has given rise to U.S. scientific and technological advancement and capabilities. Key structures on the Hanford Site that are part of the permanently preserved park include:

- Bruggemann's Agricultural Warehouse Complex (existed during or since approximately/circa [ca.] 1900–1943) – The last remaining building from an irrigated farm, orchard, and fruit packing and shipping facility.
- B Reactor National Historic Landmark – The B Reactor was the world's first full-scale plutonium production reactor.
- Allard (Hanford Irrigation District) Pump House (ca. 1908) – With an irrigation canal headwall, businesses such as a hotel, pharmacy, mercantile and telephone companies, and real estate office created opportunity and industry in the towns of Hanford and White Bluffs.
- First Bank of White Bluffs (ca. 1907–1909) – The first European-American settlement of the late 1800s, White Bluffs was located in what was known as Washington territory. The bank represents the last remaining building of the pre-WWII town.
- Historic Hanford High School (ca. 1916) – The building served two generations of Hanford students and doubled as a hall for public meetings and social events.

These historical buildings represent some of the only remaining evidence of the agricultural towns of Hanford and White Bluffs and offer insight into the initial original settlement of the American West.

1.4 Hanford Site Management

PA Hartsock

DOE is responsible for operating the Hanford Site. DOE-RL and the Office of River Protection (ORP) jointly manage the site through several contractors and their subcontractors. Each contractor is responsible for the safe and environmentally sound maintenance of activities or facilities; waste management; evaluation and determination of all discharges to the environment; and for monitoring any potential effluent to ensure environmental regulatory compliance. DOE, USFWS, and WDFW each manage portions of the Hanford Reach National Monument, as described above. The Manhattan Project National Historical Park is a partnership between DOE, with existing and continuing oversight and management of multiple locations (including Hanford), and the U.S. Department of Interior's National Park Service as interpreter, offering visitor services and assistance with historical preservation.

The **DOE-Richland Operations Office** serves as the Hanford Site property owner and oversees cleanup along the Columbia River and in Hanford's Central Plateau, including groundwater and waste site cleanup; management of solid waste, spent nuclear fuel and sludge; facility cleanout, deactivation and demolition; environmental restoration; plutonium management; and all site support services. The principal contractors for RL and their respective responsibilities include the following:

- [Mission Support Alliance, LLC](#) (MSA) was awarded the Mission Support Contract for the Hanford Site in 2009. MSA is a joint venture between Lockheed Martin, Jacobs, and Centerra Group as well as several partners with specialized Hanford expertise. MSA is responsible for site infrastructure services for the Hanford Cleanup mission, including but not limited to roads and transportation services; electrical and water services; facility maintenance; emergency response (fire and patrol) services; network and software engineering; cyber security and records management; and environmental compliance and clean energy solutions.
- [CH2M Plateau Remediation Company](#) (CHPRC) was awarded the Plateau Remediation Contract in 2008. CHPRC is responsible for the safe environmental cleanup of the Central Plateau at the Hanford Site, including waste retrieval and fuels management, groundwater and vadose zone remediation, demolition of facilities and canyons, closure of the Plutonium Finishing Plant (PFP), and remediating the 100-K Area along the Columbia River, which includes preparing for treatment of highly radioactive sludge that is now in the K-West Basin, where it will be stored until it can be treated.
- [Washington Closure Hanford, LLC](#) (WCH) was awarded the River Corridor Closure Contract in 2005. WCH consists of AECOM (which acquired the former URS Corporation in late 2014), Bechtel National, Inc. (BNI), and CH2M (formerly CH2M HILL). WCH workers are responsible for cleaning up waste sites at Hanford, decontaminating and decommissioning former plutonium production nuclear reactors and surplus facilities, and disposing of contaminated waste. WCH is expected to complete its mission for DOE-RL during 2016.
- [HPMC Occupational Medical Services](#) (HPMC) was awarded the occupational medical contract for the Hanford Site in 2012. HPMC is responsible for the health and safety needs of more than 10,000 Hanford workers, providing occupational medical services to DOE and Hanford employees. HPMC has clinics in Richland and the Hanford 200-West Area.

The **DOE Office of River Protection** was established by Congress in 1998 as a field office to manage the retrieval, treatment, and disposal of approximately 53 million gallons (gal; 200 million liters [L]) of radioactive tank waste currently stored in 177 underground tanks in the central part of the site. The tank waste is material left over from years of WW II and post-war production of nuclear weapons fuel. In support of this mission, ORP is responsible for the safe operation of the tank farms and construction and operation of the Waste Treatment and Immobilization Plant (WTP) located on the Central Plateau. ORP and its principal contractors and their respective responsibilities include the following:

- [Advanced Technologies and Laboratories International, Inc.](#) (ATL) was awarded the Laboratory Analytical Services and Testing contract in 2009. ATL operates the 222-S Laboratory Complex, the primary on-site laboratory for analysis of highly radioactive samples in support of all Hanford projects. Located in the 200-West Area, the ATL is equipped and staffed to receive, analyze, and store samples and report analytical results to the appropriate contractor. Each year, technicians test some 25,000 samples of materials in support of the Hanford cleanup mission.
- [Bechtel National Inc.](#) (BNI) was awarded the contract to design, construct, and start the WTP in 2000. When complete, the WTP will be used to transform approximately 53 million gal (200 million L) of radioactive and chemical wastes being stored in underground tanks at the Hanford 200 Area into a stable glass form for permanent disposal.
- [Washington River Protection Solutions LLC](#) (WRPS) was awarded the Tank Operations Contract in 2008. WRPS consists of AECOM, Energy Solutions, and AREVA as the primary subcontractor. WRPS is responsible for safely managing the underground waste storage tanks until the waste is prepared for disposal. The waste is stored in 149 older single-shell tanks and 28 newer and safer double-shell tanks that are grouped into 18 farms located in the 200 Area on the Hanford Site Central Plateau.

The **DOE Office of Science** manages DOE's science and technology programs, goals, and objectives at the Hanford Site. Its principal contractor is [PNNL](#), which has been operated by Battelle Memorial Institute for DOE since 1965. As one of 10 DOE national laboratories, PNNL is responsible for conducting research and delivering scientific solutions from multiple scientific disciplines to solve energy, environmental, and national security challenges. PNNL supports not only DOE but also the U.S. Department of Homeland Security, National Nuclear Security Administration, and other government agencies, universities, and industries.

1.5 Climate and Meteorology

GE Gutierrez, PJ Perrault

The Hanford Meteorology Station is located on the Hanford Site Central Plateau. Meteorologists take meteorological measurements to support Hanford Site operations, emergency preparedness and response, and atmospheric dispersion calculations for dose assessments. Support is provided through weather forecasting and by maintaining and distributing meteorological and climatological data. Forecasting is provided to help manage weather-dependent operations. Climatological data are provided to help plan weather-dependent activities and to assess the environmental effects of site operations.

Hanford Meteorology Station staff members rely on data provided by the Hanford Meteorological Monitoring Network, which consists of 29 remote monitoring stations that transmit data to the Hanford Meteorology Station through radio telemetry every 15 min. There are three towers that are 10 ft (3 m) high, 22 towers that are 30 ft (9 m) high, 3 towers that are 200 ft (61 m) high, and one 400-ft (121-m) tower. Meteorological information collected at these stations includes wind speed, wind direction, temperature, precipitation, atmospheric pressure, dewpoint temperature, wet-bulb global temperature (WBGT), solar radiation, relative humidity, and subsurface soil temperature; however, not all data are collected at all stations.

Regional temperatures, precipitation, and winds are affected by mountain barriers. Beyond the city of Yakima to the northwest, the Cascade Mountain Range greatly influences the climate of the Hanford Site because of its rain-shadow effect. The Rocky Mountains and mountain ranges in southern British Columbia in Canada protect the region from severe, cold polar air masses moving southward across Canada and winter storms associated with them.

Prevailing wind direction on the Central Plateau is from the northwest all year long, with a secondary wind 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 wind speeds are lowest during winter months, averaging about 6–7 miles per hour (mph; 3 meters per second [m/s]), and highest during summer, averaging about 8–9 mph (4 m/s). Wind speeds well above average are usually associated with southwesterly winds. However, summer drainage winds are generally northwesterly and frequently exceed 30 mph (13 m/s). These winds are most prevalent over the northern portion of the Hanford Site. Figure 1.3 shows the 2015 wind roses, diagrams showing direction and frequencies of wind, measured at a height of 30 ft (9 m) for 28 meteorological monitoring stations.

Note: Stations 19 and 32 are 10 ft (3 m) tall and are located within 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 atmospheric dispersion-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 poor dispersion conditions primarily during winter that are associated with stagnant air in stationary high-pressure systems.

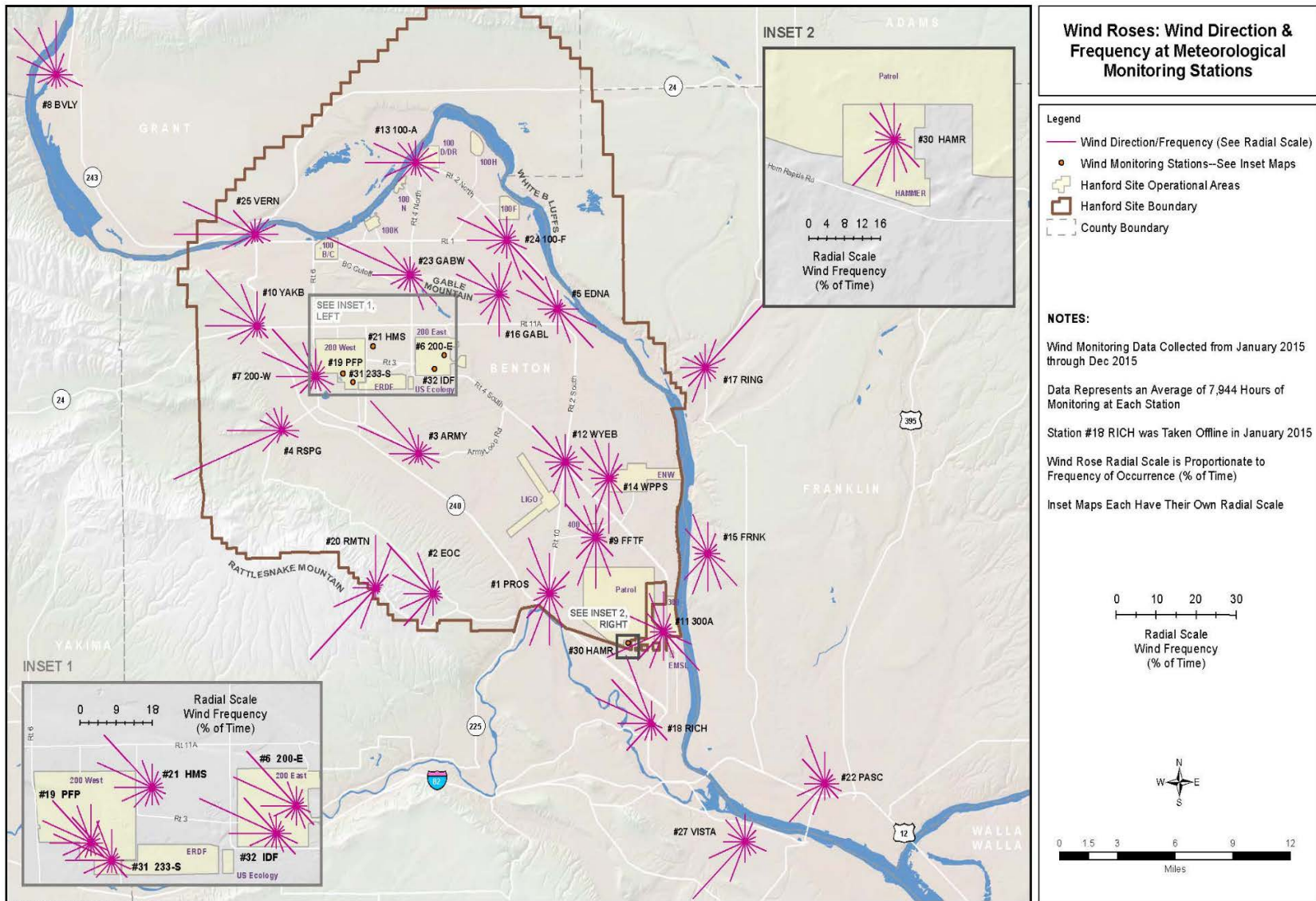


Figure 1.3. Meteorological Monitoring Network Wind Roses from 2015
measured at a height of 30 ft (9 m)

1.5.1 Historical Climatological Information

The following climatological information is for the Hanford Meteorological Station covering 1945 to 2015.

Temperature. The normal annual average temperature at the Hanford Meteorological Station is 53.9° Fahrenheit (F; 12.2° Celsius [C]). The monthly average temperature ranges from a high of 77.1°F (25.1°C) in July to a low of 31.1°F (−0.5°C) in December. The record highest monthly average temperature is 82.8°F (28.2°C) recorded in July 2014, and the record lowest monthly average temperature is 12.1°F (−11.1°C) recorded in January 1950. The highest daily temperature ever recorded at the Hanford Meteorological Station is 113°F (45°C) on three separate occasions: August 1961, July 2002, and July 2006. The lowest daily temperature ever recorded has been −23°F (−31°C) in February 1950.

Relative Humidity. The normal annual relative humidity at the Hanford Meteorological Station is 55.3%. Relative humidity is highest during winter (December and January), averaging 77.2%, and is lowest during summer (June through August), averaging 36.5%. The record highest monthly average relative humidity is 90.5% recorded in December 1950. The record lowest monthly average relative humidity is 21.9%, recorded in July 1959. The hourly relative humidity has ranged from 100% to 6%.

Precipitation. Normal annual precipitation at the Hanford Meteorological Station is 7.08 in. (17.98 cm). Most precipitation occurs during the winter, with more than half of the annual amount occurring between November and February. During the wettest year on record in 1995, the area received 12.31 in. (31.23 cm) of precipitation; the driest in 1976 received 2.99 in. (7.59 cm). The highest 24-hr total of precipitation was 1.91 in. (4.9 cm) recorded in October 1957. The normal seasonal snowfall is 14.7 in. (37.3 cm). The record highest seasonal snowfall total is 56.1 in. (142.5 cm) recorded in the 1992–93 season. The record lowest seasonal snowfall total is 0.3 in. (0.8 cm) recorded in the 1957–58 season. The most snowfall from a single storm is 12.4 in. (31.5 cm) recorded in February 1993. The record for snow depth is 15.6 in. (39.6 cm) in December 1985.

Wind Speed. The normal annual wind speed at the Hanford Meteorological Station is 7.6 mph (3.4 m/sec). The monthly average wind speed ranges from a high of 9.0 mph (4.0 meters per second) in June to a low of 5.9 mph (2.6 m/s) in December. The record highest monthly average wind speed is 11.1 mph (5.0 m/s) on multiple dates: April 1959 and 1972, and February 1999. The record lowest monthly average wind speed is 2.9 mph (1.3 m/s) in November 1956 and January 1985. The record highest daily wind speed is 33.7 mph (15.1 m/s) recorded in January 1972, and the record lowest daily wind speed is 0.3 mph (0.1 m/s) in January 1982 and November 1989. The record highest peak wind gust is 80 mph (36 m/s) in January 1972. The record highest hourly wind speed is 51 mph (23 m/s) in January 1972.

Pressure. The normal annual station pressure at the Hanford Meteorological Station is 29.213 in. of mercury. The monthly average station pressure ranges from a high of 29.329 in. in December to a low of 29.129 in. in August. The record highest monthly station pressure was 29.638 in. in December 1985, and the record lowest pressure was 28.999 in. in February 1998. The record highest hourly station pressure was 30.23 in. (adjusted sea level pressure of 1053.8 millibars [mb]) in January 1979. The record lowest hourly station pressure is 28.10 in. (adjusted sea level pressure of 977.3 mb) in December 1951.

Miscellaneous Weather. Daily and monthly averages and extremes of ambient temperature, dew point temperature, wet bulb temperature, pressure, wind, precipitation, sky cover, fog, solar radiation, relative humidity, thunderstorms, and other miscellaneous weather phenomena for 1945 through 2004 are reported in the 2004 climatological summary with historical data ([PNNL-15160](#)).

1.5.2 Monitoring

The average temperature for 2015 was 57.5°F (14.2°C), which was 3.6°F above normal. This made 2015 the warmest year on record. During 2015, 10 months were warmer than normal, two months were cooler than normal, and June had the greatest positive departure at 9.4°F above normal. The months of February, March, June, and October 2015 all broke records for highest mean monthly temperature for their respective month. September had the greatest negative departure at -1.2°F below normal.

Precipitation totaled 6.48 in. (16.46 cm), which is 92% of normal precipitation (7.08 in. [17.98 cm]). Greatest monthly total of precipitation was 1.49 in. (3.78 cm) in May, and lowest monthly total was a trace in August. May 12 and 13 had the greatest 24-hour precipitation at 1.34 in. (3.4 cm). Snowfall for 2015 totaled 10.8 in. (27.4 cm), which was 70% of normal (15.3 in. [38.6 cm]). On April 25, a trace amount of hail [0.25 in. (0.64 cm)] fell at the Hanford Meteorological Station. The average is approximately one occurrence of hail every 2 years, and there has been at least one occurrence of hail each of the last 3 years.

Average wind speed was 8.0 mph (3.6 m/s), which was 0.4 mph (0.2 m/s) above normal. Occurring on November 17, the peak gust for the year was SW at 72 mph (32.2 m/s), the highest gust ever recorded in November. Peak gusts of 55 mph (25 m/s) were recorded in August and October. The peak gust recorded on August 29 out of the west is tied for the third highest gust ever recorded for August. These wind events caused blowing dust with reduced visibility, dropping to as low as 0.25 mi. In November, the highest recorded wind on Rattlesnake Mountain was a sustained SW wind of 95 mph (42.5 m/s) with gusts up to 115 mph (51 m/s).

The growing season was 201 days in 2015. The last frost in spring was April 16, and the first frost in fall was November 4. The longest growing season was 2014 with 224 days, and the shortest growing season was 1974 at 142 days.

Monthly and annual climatological data collected at the Hanford Meteorology Station is provided in Table 1.1. Real-time and historical data from the Hanford Meteorology Station are available at <http://www.hanford.gov/hms>, which includes hourly weather observations, 15-min data, monthly climatological summaries, and historical data.

Table 1.1. Meteorology Station* Monthly and Annual Climatological Data

Month	Temperature (°F)						Precipitation (in)						Relative Humidity (%)		Average Speed (mph)	15-m Wind †			
	Averages			Extremes			Snowfall					Peak Gusts							
	Daily Maximum	Daily Minimum	Monthly	Departure ‡	Highest					Departure ‡	Total	Departure ‡	Average	Departure ‡		Departure ‡	Speed (mph)	Direction	Date
Jan	39.3	29.4	34.4	+1.0	58	18	11	1	0.67	−0.27	0.4	−4.2	87.8	+8.0	4.8	−1.5	41	WSW	18
Feb	55.2	35.4	45.3	+7.1	65	10	22	23	0.42	−0.28	T	−2.3	67.2	−3.5	7.2	+0.3	48	SW	7
Mar	64.8	38.3	51.5	+5.0	78	27	21	4	0.65	+0.08	0	−0.4	54.5	−2.7	7.6	−0.3	50	SW	15
Apr	68.7	40.4	54.6	+1.1	86	28	32	16§	0.09	−0.46	0	0	40.2	−8.1	9.2	+0.7	45	SW	10
May	80.5	52.4	66.5	+4.4	94	29	40	6	1.49	+0.98	0	0	40.7	−2.5	8.6	−0.2	47	WNW	24
Jun	93.7	64.3	79.0	+9.4	111	28	53	13	0.13	−0.38	0	0	25.4	−14.2	9.5	+0.5	43	S	28
Jul	96.5	66.2	81.4	+4.3	108	3	55	23	0.05	−0.13	0	0	25.6	−8.5	9.3	+0.7	43	WNW	18
Aug	93.0	62.8	77.9	+2.1	107	2§	53	31	T	−0.18	0	0	28.8	−6.9	9.0	+1.1	55	W	29
Sep	79.9	50.5	65.2	−1.2	97	12	40	15	0.06	−0.25	0	0	39.9	−3.1	7.7	+0.4	46	NW	5
Oct	72.1	47.6	59.9	+6.8	86	10	38	21	0.28	−0.21	0	0	53.3	−2.8	7.8	+1.1	55	WSW	10
Nov	47.9	31.7	39.8	−0.7	66	17	14	28§	0.60	−0.35	3.4	+1.4	70.7	−3.2	7.9	+1.2	72	SW	17
Dec	41.4	28.2	34.8	+3.7	66	8	14	31	2.04	+0.84	7.0	+1.1	82.9	+1.7	7.1	+1.2	47	SW	9
Year**	69.4	45.6	57.5	+3.6	111	Jun 28	11	Jan 1	6.48	−0.60	10.8	−4.4	51.4	−3.9	8.0	+0.4	72	SW	Nov 17

Note: Refer to Appendix A, Table A.2, Conversion Table, in the Helpful Information section for unit conversion information.

*The Hanford Meteorology Station is 25 mi (40 km) northwest of Richland, WA at latitude 46°34'N, longitude 119°35'W, elevation 733 ft (223 m)

†Measured on a tower 50 ft (15 m) above ground

‡Departure columns indicate positive or negative departure of meteorological parameters from 30-year (1981–2010) climatological normal.

§Latest of multiple occurrences

**Yearly averages, extremes, and totals

1.6 Stakeholder Involvement

DOE encourages information exchange and public involvement in discussions and decision making regarding Hanford Site cleanup and remediation actions. Active participants include the public; Native American tribes; federal, state, and local government agencies; advisory boards; activist groups; and other entities in the public and private sectors. The roles and involvement of select stakeholders are described in the following sections.

1.6.1 Role of Native American Tribes

JA Conrad

The role of Native American tribes at the Hanford Site is guided by *Department of Energy American Indian Tribal Government Interactions and Policy* ([DOE O 144.1](#)), which communicates departmental, programmatic, and field responsibilities for interacting with American Indian governments. This Order incorporates policy and consultation guidance in working with Native American tribes. DOE 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. The policy outlines the trust relationship that DOE has with Native American tribes and commits the agency to institute government-to-government relations with the tribes. [DOE O 144.1](#) Attachment 3, “Office of Environmental Management, Office of Nuclear Energy, Office of Science, and the National Nuclear Security Administration (NNSA) Framework to Provide Guidance for Implementation of U.S. Department of Energy’s American Indian and Alaska Native Tribal Government Policy,” provides additional guidance on how tribal consultation is to be conducted.

The U.S. government has a unique political and legal relationship with tribal governments as defined by treaties, the U.S. Constitution, court decisions defining the federal trust responsibility, and executive orders. Additional federal laws and regulations requiring DOE to consult with Native American tribes on certain issues include the *American Indian Religious Freedom Act* ([42 U.S.C. 1996](#)), the *National Environmental Policy Act of 1969* (NEPA; [42 U.S.C. 4321 et seq.](#)), *Archaeological Resources Protection Act of 1979* ([16 U.S.C. 470](#)), *National Historic Preservation Act of 1966* (NHPA; [16 U.S.C. 470](#)), and the *Native American Graves Protection and Repatriation Act of 1990* ([Public Law 101-601](#)).

As Hanford Site cleanup progresses, Native American tribes review various aspects of cleanup activities, including how these activities will affect cultural, natural, and biological resources, and the tribes’ future ability to use and consume the resources that once existed at the site.

DOE works primarily with [The Nez Perce Tribe](#), Confederated Tribes of the Umatilla Indian Reservation ([CTUIR](#)), and Confederated Tribes and Bands of [Yakama Nation](#), all of with whom the U.S. government negotiated treaties (*Treaty with The Nez Percés* [[U.S. Government 1855a](#)]; *Treaty of Walla Walla* [[U.S. Government 1855b](#)]; *Treaty with The Yakama* [[U.S. Government 1855c](#)]) in 1855. Each Treaty included provisions that reserved the rights of Native American tribes to fish at all usual and accustomed places, hunt, gather roots and berries, and pasture horses and cattle on open and unclaimed land, among other rights. Located in Priest Rapids, [the Wanapum](#), which once resided on lands that are now the Hanford Site with historic ties to the area, has a long-standing relationship with DOE. Additionally, DOE provides financial assistance through cooperative agreements with the Nez Perce Tribe, CTUIR, and Confederated Tribes and Bands of Yakama Nation, and supports tribal involvement in decisions made at Hanford.

Funding enables Native American tribes to retain staff to facilitate reviews and comment on site-related draft documents and plans as well as participate in meetings and activities. Tribal experts in tribal culture, history, and resources often contribute their insight and expertise to Hanford Site decision-making processes and activities. Further information regarding the DOE Tribal Program is available at <http://www.hanford.gov/page.cfm/inp>.

1.6.2 Cultural and Historic Resource Consultations

MK Wright

The NHPA ([16 U.S.C. 470](#)) requires DOE to consult with the Washington State Historic Preservation Officer, Native American tribes, local government representatives, the public, and other interested parties on cultural and historic resource matters. Regulations require that DOE solicit and gather input from Native American tribes and interested parties, obtain concurrence from the Washington State Historic Preservation Officer on the identification of cultural resources, evaluate the significance of these resources, and assess impacts of DOE activities on cultural resources. The *Hanford Cultural Resources Management Plan* ([DOE/RL-98-10](#)) provides guidance to DOE on cultural and historic resources issues.

DOE's Cultural and Historic Resource Protection ([CHRP](#)) program consults with the Washington State Historic Preservation Officer, the Nez Perce Tribe, CTUIR, Confederated Tribes and Bands of Yakama Nation, and the Wanapum through individual meetings and discussions, field walk-downs, and project comment resolution. Tribal cultural experts discuss project scope and design on a monthly basis with DOE, tribal representatives, and other interested parties.

DOE also consults with the Washington State Historic Preservation Officer and other parties that express an interest in historic resources located on the Hanford Site, including groups such as the B Reactor Museum Association, White Bluffs Pioneers, Benton County Historical Society, East Benton County Historical Museum, and Franklin County Historical and Museum Society.

1.6.3 Hanford Natural Resource Trustee Council

SH Wisness

The *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA; [42 U.S. Code \[U.S.C.\] 9601](#)) and implementing regulations in [40 CFR 300](#), "National Oil and Hazardous Substances Pollution Contingency Plan," establish DOE as both the CERCLA lead response agency at departmental facilities and a trustee for natural resources under its jurisdiction. As the lead response agency, DOE must conduct response actions to correct or mitigate threats to human health and the environment that result from the release of hazardous substances during the execution of its assigned missions. CERCLA also provides authority for assessment and restoration of natural resources that have been damaged by a hazardous substance release or response.

Under CERCLA, the United States is liable for damages or injury to, destruction of, or loss of natural resources resulting from release of hazardous substances or from removal or remedial activities made necessary because of such releases, including the cost of assessing such damage. The President of the United States by [Executive Order 12580](#), "Superfund Implementation," appointed the Secretary of Energy as the primary trustee for all natural resources located on, over, or under DOE-administered land, including the Hanford Site.

Natural resource trustees are government officials who act on behalf of the public when there is injury to, destruction of, loss of, or threat to natural resources (for which they have management responsibility) from contaminant release. Federal, state, and tribal entities are authorized to act as trustees pursuant to CERCLA, Section 301(c), which covers Natural Resource Damage Assessments (NRDAs). Trustees for the Hanford Site include:

- DOE on behalf of the U.S. federal government
- U.S. Department of the Interior through the USFWS
- U.S. Department of Commerce through the National Oceanic and Atmospheric Administration
- State of Washington (through Ecology) in consultation with the WDFW
- State of Oregon through the Oregon Department of Energy
- Nez Perce Tribe
- CTUIR
- Confederated Tribes and Bands of the Yakama Nation (Yakama Nation).

Established in 1996 via a Memorandum of Agreement ([DOE et al. 1996](#)), the [Hanford Natural Resource Trustee Council](#) (Council) is a voluntary association of trust organizations. Members collaborate and coordinate on issues, documents, and actions concerning natural resources. The primary purpose of the Council is to facilitate the coordination and cooperation of the trustees in their efforts to mitigate 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 on all substantive decisions.

Hanford NRDA work in FY 2015 was focused primarily on continuation of five injury studies initiated in prior years and the start of five new studies based on the Injury Assessment Plan (IAP). The Council prioritized the list of studies from the IAP that is subject to funding availability. Implementation of the IAP is a dynamic, iterative process, and the list of studies is subject to change as additional data becomes available during the injury assessment process. The Council's goal is to complete the injury assessment and prepare a Restoration Plan by 2024. Planning efforts resulted in an update of a Project Execution Plan (PEP) that defines the overall work scope, schedule, and budget for the Hanford injury assessment and establishes the means to execute, monitor, and control the project in a disciplined manner. The PEP is updated annually based on actual budgets and new information gained from the injury assessment process.

Ten initial injury studies are ongoing: five studies initiated in prior years and five new studies for FY 2015. Of the studies initiated in prior years, a final report summarizing results of a Groundwater Contaminant Plume Mapping study was drafted by the contractor (USGS), a Mussel Toxicity Study (also USGS) is nearing completion, and three tribal service loss studies are in various stages of completion. The five new injury studies initiated during the year address: 1) determination of groundwater services and valuation; 2) inventory of terrestrial habitat disturbance/injury; 3) compilation of data characterizing re-establishment of terrestrial habitat, including recovery trajectories; 4) scoping for near shore aquatic injury assessment; and 5) scoping for evaluation of contaminant concentrations in soils of non-process areas.

The Council continued to meet monthly to plan, organize, implement, and direct Hanford NRDA activities. Technical work groups (TWGs) also meet regularly to assist in study development, oversee studies, review environmental/contaminant release data, and make recommendations to the Council. Each TWG prepared (and the Council approved) updated 5-year work plans providing a prioritized list of tasks, task descriptions, and sequencing information for TWG work. A data management system for the Hanford NRDA was developed and approved for implementation in FY 2016. A process for setting up and maintaining the Council Administrative Record (AR) and case file is also expected to be implemented in FY 2016. Information about the Council, including its objectives, history, and projects, is available online at <http://www.hanford.gov/page.cfm/hnrtc>.

1.6.4 Public Involvement in Hanford Site Decisions

KL Holmes

RL and ORP believe that public involvement is essential to the ultimate success of Hanford Site cleanup. Both field offices have staff members who coordinate, plan, and schedule public participation activities for DOE on the Hanford Site.

Previously known as the *Community Relations Plan*, the *Hanford Public Involvement Plan* ([TPA 2012](#)) serves as the overall guidance document for public participation and outreach activities at Hanford. The document outlines the public participation processes used by the TPA agencies and offers ways in which the public can be involved in Hanford Site cleanup decision-making processes. The first plan was developed and approved with public input in 1990 and was last revised in November 2012.

A key goal of public involvement is to facilitate broad-based participation and obtain stakeholder and public perspectives on Hanford Site cleanup decisions. DOE uses various forums to inform the public about upcoming public involvement and participation opportunities, including but not limited to the following:

Hanford Cleanup Line. The TPA agencies strive to provide a timely response to all information requests that come in by telephone. The former 1-800 number dedicated to Hanford calls that provided approximately 20 years of service will be transitioned in favor of increasing use of other media formats. On public involvement materials, the phone number listed for information purposes will be (509) 372-7950, a weekday-staffed line at Ecology. This number is advertised in a variety of ways, including within TPA announcements; in media formats such as newspaper articles, brochures, and meeting notices; and on Hanford Site fact sheets.

Listserv Notices and Printed Mailings. The TPA agencies use a Listserv to communicate electronically about upcoming public involvement activities, along with information on ways to be involved in Hanford cleanup decisions. To be added to the Listserv or to the printed mailing list, send an email to Hanford@ecy.wa.gov or call (509) 372-7950.

Hanford Site Public Involvement Activities. Available at <http://www.hanford.gov>, the Hanford Site Events Calendar provides an overview of public involvement opportunities for the coming months and identifies current forums and emerging opportunities to inform and involve stakeholders and the public.

TPA Agencies Public Involvement Calendar for the Hanford Site. Available on the Hanford Advisory Board (HAB) communications website (<http://www.hanford.gov/page.cfm/PICCSummary>), a public involvement calendar is available that frequently provides upcoming key public activities, including HAB meeting dates and locations.

TPA Agencies Public Involvement Summary. Each year since the early 2000s, the TPA agencies have distributed an annual survey to encourage feedback, share information, and provide education about the Hanford Site cleanup. What began as a challenging, hand-written response interpretation and information gathering at biennial meetings has become an annual electronic survey. This year's publication is available for review ([TPA 2016a](#)) and promotes and encourages the sharing of links through a wide variety of online media. Previous years public involvement summary reports can be found online at https://issuu.com/hanford_edoutreach.

Hanford Site Informational Links. Information concerning Hanford Site events, issues, cleanup activities, and public involvement opportunities is available at <http://www.hanford.gov/>.

Comment and Response Documents. Following a DOE or TPA public comment period, a comment and response document is developed to record public comments received on an issue. Comment and response documents are distributed to members of the public who provide comments or request a copy. These documents are also available at the DOE Public Reading Room (Washington State University Tri-Cities Consolidated Information Center, 2710 University Dr., Richland, WA); on the TPA AR Public Information Repository (PIR) website ([TPA 2016b](#)); and, for proposed changes to the TPA that underwent public comment, on the TPA website at <http://www.hanford.gov/page.cfm/TriParty/ModificationsforPublicComment>.

Informational Public Meetings. All TPA quarterly public involvement planning, semiannual, and special meetings and workshops are open to the public. In addition, the TPA agencies welcome opportunities for co-sponsoring meetings organized by local, state, and tribal governments and citizen groups.

Hanford Site cleanup documents are also available to the public through the TPA AR PIR website ([TPA 2016b](#)). Responsible federal and state governments provide the public a variety of opportunities to offer input and influence Hanford Site cleanup decisions, including informal and formal public comment periods, such as those described in [Ecology/EPA/DOE 1989a](#), CERCLA, RCRA, and NEPA; HAB meetings; State of the Hanford Site presentations; and other Hanford Site-related public involvement and information meetings, workshops, or activities.

For more information about Hanford Site cleanup activities, contact the TPA agencies at the following contact numbers:

RL	(509) 376-7501
ORP	(509) 372-8656
Hanford Site Cleanup Line/Ecology	(509) 372-7950
EPA	(509) 376-8631

For more information about Hanford Site public involvement, visit the Hanford Site website at <http://www.hanford.gov>.

1.6.5 State of Oregon

KL Holmes

DOE recognizes Oregon's unique role and interests at the Hanford Site and its concerns with protecting Columbia River resources. DOE is interested in sharing, facilitating, and accommodating the exchange of information with the State of Oregon. RL and ORP entered into a Memorandum of Understanding ([DOE-](#)

[RL and Office of River Protection 2004](#)) with the State of Oregon to consult (and whenever possible, cooperate) on Hanford Site environmental issues. DOE will consult with and include the Oregon Department of Energy in planning and conducting Hanford Site-related public involvement activities in the State of Oregon.

1.6.6 Hanford Advisory Board (HAB)

KL Holmes

The HAB is a broadly representative body consisting of a balanced mix of members that represent diverse interests affected by Hanford Site cleanup decisions. The TPA agencies created the HAB in 1994 and was ultimately chartered as one of eight environmental management site-specific advisory boards across the country. The HAB comprises 32 members and their alternates, including representatives from the Nez Perce Tribe and the Confederated Tribes and Bands of the Yakama Nation. A representative of the CTUIR participates on the board in an ex-officio status. Current members with their affiliations are listed on the HAB website at <http://www.hanford.gov/page.cfm/hab>.

The HAB assists the broader public in becoming more informed and meaningfully involved in Hanford Site cleanup decisions through its open public meetings. Board members' formal advice on cleanup issues reflects the values of its constituents. Copies of their advice and DOE's responses are on the HAB website for Advice and Responses at <http://www.hanford.gov/?page=453>. Additional information about the HAB, including its charter (operating ground rules), is available at <http://www.hanford.gov/?page=449>.

1.7 Hanford Site Regulatory Oversight

PA Hartsock

Several federal, state, and local regulatory agencies are responsible for monitoring and enforcing compliance with applicable environmental regulations at the Hanford Site, including the EPA, Ecology, Washington State Department of Health (WDOH), and the Benton Clean Air Agency.

1.7.1 Environmental Regulations

The EPA is the primary federal regulatory agency that develops, promulgates, and enforces environmental regulations and standards as directed in federal statutes. In some instances, EPA has delegated authority to the state or enabled the state program to operate in lieu of the federal program when the state's program meets or exceeds EPA requirements. In other activities, the state program is assigned direct environmental oversight of the DOE program, as provided by federal law. Where federal regulatory oversight is not delegated or only partially authorized to the state, the EPA Pacific Northwest Regional Office (Region 10) 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.

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

RE Piippo, CP Noonan

The TPA is an agreement ([Ecology/EPA/DOE 1989a](#)) among the TPA agencies to achieve environmental regulation compliance on the Hanford Site with CERCLA and RCRA treatment, storage, and disposal (TSD) unit regulations and corrective action provisions. The TPA is an interagency agreement under

CERCLA, Section 120, a corrective action order under RCRA, and a consent order under the Revised Code of Washington (RCW), “Hazardous Waste Management” ([RCW 70.105](#)) that 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. Attachment 2 of the TPA Action Plan ([Ecology/EPA/DOE 1989b](#)) describes how public information and involvement activities are conducted for TPA decisions.

The TPA has evolved as Hanford Site cleanup has progressed. Since its initial publication in 1989, the TPA agencies have negotiated changes to the agreement to meet the changing conditions and needs of cleanup activities on the Hanford Site. All significant changes undergo a process of public involvement designed to enhance communication and address public concerns prior to final approvals. Revision 8 of the TPA was published in July 2011. As new change control forms are approved through the TPA change control process, they are incorporated into the TPA. Printed copies of Revision 8 of the TPA are publicly available at DOE’s Public Reading Room located in the Washington State University Tri-Cities Consolidated Information Center, 2770 University Dr., Richland, WA and at public information repositories in Seattle and Spokane, WA and Portland, OR. To be placed on the mailing list to obtain TPA information, call the Hanford Cleanup Line at (509) 372-7950 or e-mail to Hanford@ecy.wa.gov.

1.7.2.1 Tri-Party Agreement Milestone Status

The TPA commits DOE to comply with the remedial-action provisions of CERCLA as well as with *Resource Conservation and Recovery Act of 1976* (RCRA; [42 U.S.C. 6901](#)) TSD unit regulations and corrective-action provisions, including Washington State’s implementing regulations (Washington Administrative Code [[WAC](#)] [173-303](#), “Dangerous Waste Regulations”). From 1989 through December 31, 2015, a total of 1,265 TPA milestones were completed, and 336 target dates were met. During 2015, 40 specific cleanup milestones were scheduled for completion; of those, 30 milestones were completed on time, no milestones were missed, 5 were in negotiation, and 5 were in dispute resolution. In addition, 4 target dates were met.

1.7.2.2 Tri-Party Agreement Approved Modifications

During 2015, 11 negotiated change control forms to the TPA were approved and can be viewed on the TPA website at <http://www.hanford.gov/c.cfm/tpa/>.

1.8 Additional Hanford Area Websites

PA Hartsock

Company or Organization	Website
AECOM (formerly URS Corporation)	http://www.aecom.com/
AREVA Inc. (branch local to Richland, WA)	http://us.aveva.com/en/home-427/areva-inc-richland-fuel-production.html
City of Kennewick	http://www.go2kennewick.com/
City of Pasco	http://www.pasco-wa.gov/
City of Richland	http://www.ci.richland.wa.us/
City of West Richland	http://www.westrichland.org/
Environmental Molecular Sciences Laboratory (EMSL)	https://www.emsl.pnl.gov/emslweb/
Hanford's Environmental Restoration Disposal Facility	http://www.hanford.gov/page.cfm/erdf
Geology of Washington, Columbia Basin	http://www.dnr.wa.gov/programs-and-services/geology/explore-popular-geology/geologic-provinces-washington/columbia-basin
Hanford Reach National Monument	http://www.fws.gov/refuge/hanford_reach/
Hanford Site Tours	http://www.hanford.gov/page.cfm/HanfordSiteTours
Lockheed Martin Corporation	http://www.lockheedmartin.com/
Manhattan Project National Historical Park (Hanford-specific portion)	https://www.nps.gov/mapr/hanford.htm
Mission Support Alliance	https://msa.hanford.gov/
Pacific Northwest National Laboratory	http://www.pnnl.gov/
Pacific Northwest Seismic Network	http://pnsn.org/
Perma-Fix Northwest Richland	http://www.perma-fix.com/facilities/pf_nuclear_richland/
Port of Benton	http://www.portofbenton.com/
Tri-Cities Visitor & Convention Bureau	http://www.visittri-cities.com/
Volpentest HAMMER Federal Training Center	http://www.hammertraining.com/
Washington Department of Fish & Wildlife	http://wdfw.wa.gov/
Washington State Department of Ecology (Hanford-specific information)	http://www.ecy.wa.gov/programs/nwp/index.html

2.0 Compliance Summary

PA Hartsock

For the protection of human health and the environment through safe operations, the Hanford Site has compliance programs designed to meet federal, state, and local environmental laws, regulations, and requirements and comply with DOE orders, notices, directives, policies, and guidance. These measures include specific requirements, actions, plans, and schedules identified in the TPA and other compliance or consent agreements. RL and ORP recognize the importance of maintaining a proactive program of self-assessment and regulatory reporting to ensure that environmental compliance is achieved and maintained at the Hanford Site. This report fulfills reporting requirements for the annual compliance status under the environmental standards specified in [DOE O 231.1B](#), *Environmental, Safety and Health Reporting*.

Section 2.0 summarizes the laws and regulations that govern Hanford Site activities with regard to federal environmental protection statutes and associated state and local environmental regulations. This section discusses both permits required under specific environmental protection regulations and EPA- or Ecology-issued notices of violation or non-compliance. Notices of violation are the regulatory means of informing organizations that their work activities are not meeting requirements; notices of non-compliance are informal notifications of regulatory violations.

2.1 Hazardous Materials and Waste Management Statutes and Regulations

This section provides compliance information regarding federal environmental statutes and regulations related to hazardous materials and waste management at the Hanford Site.

2.1.1 Federal Facility Compliance Act of 1992

RE Piippo, CP Noonan

Enacted by Congress on October 6, 1992, the *Federal Facility Compliance Act of 1992* ([Public Law 102-386](#)) amends Section 6001 of the RCRA to specify that the U.S. waives sovereign immunity from civil and administrative fines and penalties for RCRA violations. In addition, the RCRA requires EPA to conduct annual inspections of all federal facilities. Authorized states are given authority to conduct inspections of federal facilities to enforce compliance with state hazardous waste programs. A portion of [Public Law 102-386](#) also requires DOE to provide mixed waste information to EPA and the states. DOE provides this information annually as part of the Hanford Site Mixed Waste Land Disposal Restrictions Summary Reports pursuant to TPA Milestone M-26. In 2015, *Calendar Year 2014 Hanford Site Mixed Waste Land Disposal Restrictions Full Report* ([DOE/RL-2015-08](#)) met the reporting requirement.

2.1.2 Resource Conservation and Recovery Act of 1976

DI Weyns

Congress enacted RCRA in 1976 to protect human health and the environment. In 1984, the *Hazardous and Solid Waste Amendments* ([Public Law 98-616](#)) reauthorized RCRA, imposing new requirements on hazardous waste management. RCRA's central principle is to establish cradle-to-grave management to track hazardous waste from its generation to TSD. The Hanford Site dangerous waste activities are subject to applicable provisions of [WAC 173-303](#), "Dangerous Waste Regulations," including provisions of the Chapter as applied in the TPA.

2.1.2.1 Hanford Facility RCRA Permit

JK Perry

EPA assigned the Hanford Site a single EPA identification number for permitting purposes (WA7890008967); as such, the Hanford Site is a single RCRA facility, though there are numerous TSD units spread over large geographic areas. The permit is issued to eight permittees: RL and ORP as the owners/operators, and six of their contractors: BNI, CHPRC, MSA (the permit identifies MSA as a permittee but not a co-operator), PNNL, WCH, and WRPS. Washington state dangerous waste regulations ([WAC 173-303](#)) require Ecology to reissue a permit after a term of up to 10 years. The initial permit was issued on September 27, 1994, for a 10-year term. DOE submitted a permit renewal application on March 30, 2004. The permit expired on September 27, 2004; since that time, Ecology has been endeavoring to prepare and issue a new permit. Until a new permit is issued, DOE continues to operate under the expired permit *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste* ([Ecology 1994](#)).

In May 2012, Ecology issued a draft *Hanford Facility Dangerous Waste Permit* ([Ecology 2012](#)), incorporating the remaining TSD units not previously clean closed. Ecology received more than 4,000 comments on the draft *Hanford Facility Dangerous Waste Permit* during the comment period held from May 1 to October 22, 2012. Ecology received approximately 1,800 comments from the public and 3,000 comments from DOE. Issues raised during the comment period identified substantial new questions; as a result, Ecology plans to make revisions and reopen the public comment period for the draft renewal permit. Ecology expects this process to take several years, with the process to include the following activities:

- Review and evaluate the comments received from the first comment period
- Revise the permit based on significant information and issues raised
- Re-issue the permit with revisions and responses to the original comments
- Reopen the comment period for sections that were changed
- Prepare responses to the next round of public comments
- Issue the final permit.

No TSD unit additions or deletions occurred during 2015; however, modifications were submitted to change requirements for the following TSD units pursuant to [WAC 173-303-830](#), "Permit Changes:"

- Liquid Effluent Retention Facility (LERF) and 200 Area Effluent Treatment Facility (ETF; Operating Unit Group 3)
- 242-A Evaporator (Operating Unit Group 4)
- 325 Hazardous Waste Treatment Unit (Operating Unit Group 5)
- WTP (Operating Unit 10)
- Integrated Disposal Facility (IDF; Operating Unit 11)
- 400 Area Waste Management Unit (Operating Unit Group 16).

2.1.2.2 Regulatory Agency Inspections

JW Cammann

The Regulatory Agency Inspection Database includes documentation for regulatory agency inspections of DOE facilities on the Hanford Site. Regulatory agency inspections can result in noncompliance or enforcement actions for alleged violations of applicable federal, state, and local laws and regulations. As such, the Regulatory Agency Inspection Database links to the Environmental Action Tracking System. The Environmental Action Tracking System documents alleged regulatory noncompliance and enforcement actions and their status for the Hanford Site (see Section 2.9).

During CY 2015, 86 regulatory agency inspections were conducted at DOE facilities on the Hanford Site: Ecology conducted 48, WDOH 26, EPA (Region 10) 5, the City of Richland 2, and DOE 5.

Ecology inspections were conducted primarily by the Nuclear Waste Program Office located in Richland, WA. Located in Union Gap, WA, the Central Regional Office of Ecology also conducted inspections of DOE facilities on and off the Hanford Site to evaluate hazardous and toxic waste management. EPA Region 10 inspections are focused primarily on asbestos and asbestos-containing material management, including oversight of Ecology inspections under EPA-delegated authority. WDOH inspections were performed by the Office of Radiation Protection, Richland, WA. The WDOH Office of Drinking Water in Spokane, WA also performed sanitary surveys of drinking waste systems. City of Richland inspections are focused on the 300 Area of the Hanford Site to evaluate compliance with Industrial Wastewater Discharge Permit (CR-IU-010) requirements, including the monitoring of wastewater discharges to the publicly owned treatment works. DOE inspections are required under the terms and conditions of the RCRA permit and are supported by the Hanford Site contractors responsible for the facilities being inspected.

Regulatory agency inspections can result in alleged violations of regulations and other concerns. If deemed appropriate, regulatory agencies may initiate a variety of enforcement and compliance actions, which are discussed further in Section 2.9.

2.1.2.2.1 RCRA Inspections

The Ecology and EPA inspections focused on TSD unit compliance with the *Hanford Facility Dangerous Waste Permit* ([Ecology 1994](#)) and [WAC 173-303](#), “Dangerous Waste Regulations.” The TSD units and other facilities inspected during 2015 included the following:

- 200 Area Effluent Treatment Facility (ETF)
- 1706-KE
- 222-S Laboratory
- 2355 Warehouse
- 207-A Retention Basin
- 242-A Evaporator
- 300/400 Area facilities
- 325 and 331 Buildings
- 350 Complex
- B Plant
- Integrated Disposal Facility (IDF)
- LERF
- Central Waste Complex (CWC)
- Centralized Consolidation/Recycle Center
- Low-level Burial Grounds (LLBG) Trenches 31 and 34
- LLBG Trench 94
- PUREX Storage Tunnel
- Tank Farms
- T-Plant
- Waste Receiving and Processing (WRAP) Facility
- 90-day accumulation areas
- Satellite accumulation areas
- Universal waste management operations.

Section II.O of the RCRA permit addresses general inspection requirements. General inspections are conducted in addition to the TSD unit inspections specified in Parts III, V, and/or VI of the RCRA permit. The RCRA permit requires general inspections of the 100, 200-East, 200-West, 300, and 400 Areas and the Columbia River shoreline. Inspections are performed annually in these areas by DOE and Hanford contractors to identify and correct potential malfunctions, deterioration, operator errors, and discharges, which may cause or lead to the release of dangerous waste constituents to the environment, or that threaten human health. In accordance with RCRA permit requirements, Ecology is notified of the general inspections at least 7 days in advance to allow their participation. RCRA permit general inspection summary reports are maintained in the Hanford Facility Operating Record and Regulatory Agency Inspection Database.

2.1.2.2.2 Clean Air Act Inspections

In 2015, the WDOH inspections focused on compliance of major and minor stack air emission units as well as diffuse and fugitive emission sources, with the Hanford Site Air Operating Permit and Radioactive Air Emissions License FF-01. Some EPA inspections focused on asbestos management under the *Clean Air Act of 1963* and [40 CFR 61](#), “National Emission Standards for Hazardous Air Pollutants” (NESHAP) Subpart M, “National Emission Standard for Asbestos.”

2.1.2.3 RCRA Groundwater Monitoring

MJ Hartman

The Soil and Groundwater Remediation Project (see Section 8) conducts the RCRA groundwater monitoring for the Hanford Site. In 2015, 14 RCRA sites were monitored to determine if contaminated groundwater with dangerous constituents was present, seven sites were monitored to assess the extent of known contaminants, and two sites were monitored under corrective action programs.

LERF (Section 5.3.4.2) and IDF (Section 5.3.3.7) are two of the 14 TSD units operating under Part III of the RCRA permit (WA7890008967). Since June 2006, IDF was operated under a unit-specific groundwater monitoring plan. Because the unit has not yet received waste, monitoring is performed under a Pre-Active Life Program (standby mode).

The other 12 TSD units monitored under RCRA are scheduled to be closed under Part V of the RCRA permit (WA7890008967). Chapter 8 includes a summary of groundwater monitoring activities for these sites during 2015. The detailed groundwater monitoring information for 2015 will be available in September 2016 with the release of *Hanford Site Groundwater Monitoring Report for 2015* (DOE/RL-2016-09).

Groundwater monitoring is required for three regulated, non-RCRA waste facilities. The 200 Area Treated Effluent Disposal Facility ([TEDF], Section 5.3.4.3) and the State-Approved Land Disposal Site (Section 5.3.4.1) are monitored under [WAC 173-216](#), “State Waste Discharge Permit Program.” The Solid Waste Landfill is monitored for compliance with requirements in [WAC 173-350](#), “Solid Waste Handling Standards.” Wells near these facilities were monitored in 2015 for waste constituents specified in the facility permits.

2.1.3 Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

JW Cammann

In 1980, Congress passed the CERCLA to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. Because nuclear production and disposal facilities at the Hanford Site resulted in past releases of hazardous substances, pollutants, or contaminants, the facility is subject to CERCLA provisions.

For waste sites where hazardous substances, pollutants, or contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure, CERCLA requires a review every 5 years to evaluate the implementation and performance of a remedy to determine if the remedy is or will be protective of human health and the environment. The 5-year review requirement applies to all remedial actions selected under CERCLA Section 121. The CERCLA Five-Year Review Report documents the methods, findings, and conclusions of the 5-year reviews, which can require institutional controls and/or National Resource Damage Assessment and Restoration Program mitigation. The results of the three 5-year reviews conducted since 2000 are documented in the *USDOE Hanford Site First Five-Year Review Report* ([EPA 2001a](#)); the *Second CERCLA Five-Year Review Report for the Hanford Site* ([DOE/RL-2006-20](#)); and the *Hanford Site Third CERCLA Five-Year Review Report* ([DOE/RL-2011-56](#)).

During CY 2015, work continued on the *Fourth CERCLA Five-Year Review Report*. The final report is planned for issuance by May 4, 2017. This new issuance date was negotiated between DOE-RL and EPA to allow consideration of 5 years of groundwater monitoring and pump and treat data.

2.1.3.1 Superfund Amendments and Reauthorization Act of 1986

The *Superfund Amendments and Reauthorization Act* (SARA; [Public Law 107-377](#)) amended CERCLA on October 17, 1986. SARA reflected EPA's experience in administering the complex Superfund program during its first 6 years and made several important changes and additions to the program. SARA:

- Stressed the importance of permanent remedies and innovative treatment technologies in cleaning up hazardous waste sites
- Required Superfund actions to consider the standards and requirements found in other state and federal environmental laws and regulations
- Provided new enforcement authorities and settlement tool
- Increased state involvement in every phase of the Superfund program
- Increased the focus on human health problems posed by hazardous waste sites
- Encouraged greater citizen participation in making decisions on how sites should be cleaned up
- Increased the size of the trust fund to \$8.5 billion.

SARA also required EPA to revise the [Hazard Ranking System](#) (HRS) to ensure that it accurately assessed the relative degree of risk to human health and the environment posed by uncontrolled hazardous waste sites that may be placed on the National Priorities List (NPL).

2.1.4 Emergency Planning and Community Right-to-Know Act of 1986

GM Fritz

Title III of SARA, also known as the *Emergency Planning and Community Right-to-Know Act of 1986* (EPCRA), requires owners and operators of facilities that handle certain hazardous chemicals on site to provide information on the release, storage, and use of these chemicals to organizations responsible for emergency response planning. EPCRA has four major provisions: emergency planning, emergency release notification, hazardous chemical inventory reporting, and toxic chemical release inventory reporting. Table 2.1 summarizes sections of EPCRA and its requirements, including two annual reports: the *Tier Two Emergency and Hazardous Chemical Inventory*, which provides information about hazardous chemicals stored at each facility in amounts exceeding minimum threshold levels and the *Toxic Chemical Release Inventory*, which describes total annual releases of certain toxic chemicals and associated waste management activities. Table 2.2 provides an overview of reporting under the EPCRA during 2015.

Table 2.1. Emergency Planning and Community Right-to-Know Act Requirements Summary

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
302	40 CFR 355, "Emergency Planning and Notification"	Presence of an extremely hazardous substance in quantity equal to or greater than threshold planning quantity at any one time.	Within 60 days of threshold planning quantity exceedance	Local Emergency Planning Committee; State Emergency Response Commission
		Change occurring at a facility that is relevant to emergency planning.	Within 30 days after change has occurred	Local Emergency Planning Committee
304		Release of an extremely hazardous substance or a CERCLA hazardous substance in quantity equal to or greater than reportable quantity.	Initial notification: immediate (within 15 min of knowledge of reportable release). Written follow-up within 14 days of release.	Local Emergency Planning Committee; State Emergency Response Commission
311	40 CFR 370, "Hazardous Chemical Reporting"	The presence at any one time at a facility an Occupational Safety and Health Administration (OSHA) hazardous chemical in quantity $\geq 10,000$ lbs (4,500 kg) or an extremely hazardous substance in quantity equal to or greater than threshold planning quantity or 500 lbs (230 kg), whichever is less.	Revised list of chemicals due within 3 months of a chemical exceeding a threshold	Local Emergency Planning Committee; State Emergency Response Commission; Local Fire Departments
312		The presence at any one time at a facility an OSHA hazardous chemical in quantity equal to or greater than 10,000 lbs (4,500 kg), or an extremely hazardous substance in quantity equal to or greater than threshold planning quantity or 500 lbs (230 kg), whichever is less.	Annually by March 1	Local Emergency Planning Committee; State Emergency Response Commission; Local Fire Departments
313	40 CFR 372, "Toxic Chemical Release Reporting"	Manufacture, process, or use at a facility, any listed Toxic Release Inventory chemical in excess of threshold amount during a CY. Thresholds are 25,000 lbs (11,300 kg) for manufactured or processed or 10,000 lbs (4,500 kg) for otherwise used except for persistent, bio-accumulative, toxic chemicals with thresholds under 100 lbs (45 kg).	Annually by July 1	EPA; State Emergency Response Commission

Table 2.2. Emergency Planning and Community Right-to-Know Compliance Reporting

Section	Description of Reporting	Status	Notes
302	Emergency planning notifications	Yes	
304	Extremely hazardous substance release notification	Not required	No releases occurred
311	Material safety data sheet	Yes	
312	Chemical inventory	Yes	
313	Toxic release inventory	Yes	

The *2015 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2016-24) was submitted to Ecology's Community Right-To-Know Unit; local emergency planning committees for Benton, Franklin, and Grant counties; and the City of Richland and Hanford Site Fire Department before the annual March 1 deadline. The Hanford Site had 41 hazardous chemicals that exceeded the reporting thresholds. One chemical category (lead acid batteries, which contain sulfuric acid, an extremely hazardous substance) exceeded the reporting threshold for off-site locations (700 Area, 1100 Area, and the Federal Building). Table 2.3 lists the average quantities of the 10 hazardous chemicals stored in greatest quantity on the Hanford Site in 2015.

Table 2.3. Average Quantity of the 10 Hazardous Chemicals Stored in Greatest Quantities

CAS#	Chemical	TPQ	Average Amount (lbs/kg)
7440-23-5	Sodium	10,000	4,624,378/2,097,583
7647-14-5	Sodium chloride	10,000	3,299,181/1,496,483
7664-93-9	Sulfuric acid	500	347,833/157,774
00-00-0	Lead acid batteries	500	332,921/151,010
00-00-0	Diesel fuel (Grades 1 and/or 2)	10,000	601,273/273,058
65997-15-1	Portland Cement	10,000	303,936/137,863
1305-78-8	Calcium oxide	10,000	240,738/109,197
681-74-8	Fly Ash (Class F)	10,000	220,694/100,105
148-60-7	Silica, Crystalline-Quartz	10,000	170,368/77,278
00-00-0	Gasoline	10,000	170,196/77,200

The *2015 Hanford Site Toxic Chemical Release Inventory* report (DOE/RL-2016-38) was submitted to EPA and Ecology before the annual July 1 deadline. During CY 2015, the Hanford Site exceeded activity thresholds for lead, naphthalene, propylene, toluene, and xylene. Information concerning these chemicals is described in Table 2.4.

Table 2.4. Toxic Chemicals Exceeding Reporting Thresholds

Chemical	CAS No.	Non-Exempt Use Description
Lead	7439-92-1	Ammunition fired during range practice by Hanford Safeguards and Security
Naphthalene	91-20-3	Diesel used for stationary equipment
Propylene	115-07-1	Propane gas used site-wide
Xylene	1330-20-7	Gasoline used for stationary equipment
Toluene	108-88-3	Gasoline used for stationary equipment

2.1.5 Reportable Releases

TH Pysto

Federal regulations establish reporting requirements for certain environmental releases, which are reported to the National Response Center, the federal central point of contact for reporting hazardous substances and oil spills. Reportable releases include spills or discharges of hazardous substances to the environment, other than releases permitted under state or federal law. CERCLA Section 103 requires reporting for 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. Washington State regulations ([WAC 173-303-145](#), “Spills and Discharges into the Environment”) also require that spills or non-permitted discharges of dangerous waste or hazardous substances to the environment be reported. The requirement applies to spills or discharges onto the ground, into groundwater or surface water (Columbia River), or in the air such that human health or the environment are threatened, regardless of the quantity of dangerous waste or hazardous substance.

During the reporting period, hazardous substance releases were conservatively assessed under [WAC 173-303-145](#), and notifications were provided to Ecology for various spills and releases. These spills were cleaned up, and materials were disposed in accordance with applicable requirements.

2.1.6 Toxic Substances Control Act

DI Weyns

The Hanford Site has a well-structured program that complies with the *Toxic Substances Control Act* (TSCA; [Public Law 94-469](#)) requirements that primarily involve regulation of polychlorinated biphenyls (PCB). 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.” Background information regarding Hanford Site PCB management activities are as follows:

- PCB wastes on the Hanford Site are stored and/or disposed of in accordance with [40 CFR 761](#)
- Some radioactive PCB waste remains in extended 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](#)
- Signed on August 31, 2000, the *Framework Agreement for Management of Polychlorinated Biphenyls (PBCs) in Hanford Tank Waste* ([EPA et al. 2000](#)) resulted in the TPA agencies and DOE contractors working together to resolve the regulatory issues associated with managing PCB waste at the WTP, tank farms, and affected waste management units adjacent to the tank farms.
- RL submitted the *2015 Polychlorinated Biphenyl Annual Report* ([DOE/RL-2016-39](#)) and *2015 Hanford Site Polychlorinated Biphenyl Annual Document Log* ([DOE/RL-2016-40](#)) to EPA on June 28, 2016 as required by [40 CFR 761.180](#), “Records and Monitoring.” These documents describe the PCB waste management and disposal activities occurring on the Hanford Site.
- Work performed under risk-based disposal approvals (RDBA) continued in 2015, including but not limited to single-shell tank (SST) waste retrieval activities in accordance with EPA Phase I and II RDBAs for the use of double-shell tank (DST) PCB remediation waste in accordance with

[40 CFR 761.61\(c\)](#), “PCB Remediation Waste.” **Note:** Phase I identifies general conditions that apply to the overall strategy and retrieval process, and Phase II identifies tank-specific conditions.

- Work was performed at the 242-A Evaporator under the RBDA for the 200 Area Liquid Waste Processing Facilities.
- The EPA’s 2005 RBDA letter allowed for the solidification of the K-Basins North Load-Out Pit (NLOP) sludge, which was a multi-phasic (mixture of liquid and non-liquid phases) PCB remediation waste. The waste was solidified at the Hanford Site T Plant facility to meet radiological treatment standards in preparation for disposal.
- Condition 5 of the NLOP RBDA, requires DOE to submit to EPA plans and schedules for final decontamination and/or disposal of the NLOP treatment system. As of 2015, DOE is developing plans to place additional K-Basins sludge containers in T Plant, which will require removal of the NLOP treatment equipment. When the K-Basins Sludge Project is finalized, EPA will be notified of plans to decontaminate or dispose of the NLOP treatment equipment.

2.1.7 National Environmental Policy Act of 1969 (NEPA)

ES Pennala

NEPA was enacted so that potential impacts, technical factors, and costs are considered during federal decision making. NEPA requires that an environmental impact statement (EIS) be prepared for major federal agency actions that have the potential for significant effects to human health or the environment. A record of decision (ROD) documents decisions concerning EIS proposed actions. An environmental assessment (EA) is prepared when it is uncertain if a proposed action would require preparation of an EIS. A Finding of No Significant Impact (FONSI) may be issued to present the reasons why an action will not have a significant effect on human health or the environment and therefore not require the preparation of an EIS. A supplement analysis is prepared to consider significant new information or changed circumstances relevant to environmental concerns and bearing on the proposed action or its impacts.

Certain proposed actions may be categorized into classes that have been analyzed and determined to have no significant environmental impact individually or cumulatively ([10 CFR 1021](#), “National Environmental Policy Act Implementing Procedures,” Subpart D, “Typical Classes of Actions,” Appendices A and B). Known as categorical exclusions, these actions are exempt from NEPA EA or EIS requirements if certain eligibility criteria per [10 CFR 1021.410](#) (proposed action fits classes of actions, has no extraordinary circumstances, and is not segmented into smaller actions to avoid significance or is connected to other actions with potentially significant impacts) and integral element conditions ([10 CFR 1021](#), Subpart D, Appendix B) are met. Some categorical exclusions are applicable to general DOE actions and do not require written documentation for application.

2.1.7.1 Hanford Site Environmental Impact Statements

The following subsections summarize the status of NEPA documentation planned or underway at the Hanford Site during CY 2015. The NEPA documentation for the Hanford Site is available online at <http://www.hanford.gov/page.cfm/OfficialDocuments/Documents>. Ongoing EISes related to the Hanford Site are described in the following sections.

2.1.7.1.1 Natural Gas Pipeline EIS (DOE/EIS-0467)

On January 23, 2012, DOE published “Notice of Intent To Prepare an Environmental Impact Statement for the Acquisition of a Natural Gas Pipeline and Natural Gas Utility Service at the Hanford Site, Richland, WA, and Notice of Floodplains and Wetlands Involvement (DOE/EIS-0467)” in the *Federal Register* ([77 FR 3255](#)). The EIS would evaluate the environmental impacts of a proposal to enter into a contract with Cascade Natural Gas Corporation supplier in Washington State to construct, operate, and maintain a natural gas pipeline. The pipeline would deliver natural gas to support the WTP (Section 5.6) and the 242-A Evaporator (Section 5.4.4.4) operations in the 200-East Area. The proposed pipeline would begin from a new interconnect tap on the existing Williams Northwest Pipe transmission line in Franklin County north of the Pasco, WA airport and run westerly across non-DOE lands under the Columbia River, crossing near the Hanford Site 300 Area before turning northwest and paralleling Route 4S. The pipeline would terminate at the WTP and 242-A Evaporator.

Preparation of the draft Natural Gas Pipeline EIS continued during CY 2015. Activities included evaluating Proposed Action and No Action Alternative as well as pipeline route alternatives and 200-East Area interface options (direct piping of natural gas to the WTP and 242-A Evaporator steam boilers or direct piping of natural gas to a new steam plant to be constructed with steam piped to the boilers). The Final Natural Gas Pipeline EIS will contain comments made to the draft EIS and responses to the comments, and will identify a preferred main pipeline route alternative and a preferred 200-East Area interface option. The schedules for the issuance and publication of the draft (for public comment) is on hold. Workshops are planned in FY 2016 to determine a path forward. Final EIS and ROD are yet to be determined.

2.1.7.1.2 Final Long-Term Management and Storage of Elemental Mercury Supplemental Environmental Impact Statement (DOE/EIS-0423-S1)

Pursuant to the *Mercury Export Ban Act of 2008* ([Public Law 110-414](#)), DOE was directed to designate a facility or facilities for the long-term management and storage of elemental mercury generated within the United States. As a result, DOE issued the *Final Long-Term Management and Storage of Elemental Mercury Environmental Impact Statement* (Mercury Storage EIS; [DOE/EIS-0423](#)) in January 2011 that evaluated environmental impacts associated with the reasonable alternatives for managing and storing elemental mercury at seven candidate locations (Colorado, Idaho, Missouri, Nevada, South Carolina, Texas, and Washington); and identified the Waste Control Specialists, LLC, site near Andrews, Texas, as the Preferred Alternative for the long-term management and storage of elemental mercury. On June 5, 2012, DOE announced an intent to prepare a supplement ([DOE/EIS-0423-S1](#)) to the January 2011 EIS to evaluate alternatives for a facility at and near the Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM.

Based on analysis in this SEIS and public comment, DOE has not changed its Preferred Alternative, the Waste Control Specialists, LLC, site near Andrews, Texas. DOE will issue a Record of Decision no sooner than 30 days after publication of the EPA Notice of Availability for the *Final Mercury Storage SEIS* in the *Federal Register*. The selection of a site will be based on the January 2011 *Mercury Storage EIS*, this *Mercury Storage SEIS*, and other appropriate factors and will be announced in a Record of Decision in the *Federal Register*.

2.1.7.2 Hanford Site Environmental Assessments

Ongoing environmental assessments related to the Hanford Site are described in the following sections.

2.1.7.2.1 *Draft Environmental Assessment for Closure of Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill (DOE/EA-1707)*

This draft environmental assessment ([DOE/EA-1707](#)) provides information and analyses of proposed DOE activities associated with closure of the DOE Hanford Site's Nonradioactive Dangerous Waste Landfill (NRDWL) and the Solid Waste Landfill (SWL) located southeast of the Central Plateau off Army Loop Road (Section 5.2.2.2.2). Work on [DOE/EA-1707](#) has been temporarily suspended. The final EA and FONSI are on hold pending program priority decisions.

2.1.7.2.2 *Final Environmental Assessment for Proposed Conveyance of Land at the Hanford Site, Richland, Washington (DOE/EA-1915)*

On September 19, 2012, DOE published “Notice of Intent To Prepare an Environmental Assessment (EA) for the Proposed Conveyance of Land at the Hanford Site, Richland, WA and Notice of Potential Floodplain and Wetland Involvement” in the *Federal Register* ([77 FR 58112](#)). DOE announced its intent to prepare an EA to assess the potential environmental effects of conveying approximately 1,641 ac (664 ha) of Hanford Site land to a local economic development organization. Conveyance of the land could include title transfer, lease, easement, license, or a combination of these realty actions. The Tri-City Development Council (TRIDEC), a DOE designated Community Reuse Organization and 501(c)(6) nonprofit corporation, submitted a proposal to DOE in May 2011 (amended October 2011) requesting the transfer of the approximately 1,641 ac (664 ha) of land located in the southeastern corner of the Hanford Site near the City of Richland in Benton County, WA for economic development purposes. Due to continuing mission needs on some of the requested lands, DOE began assessing a 4,413-ac (1786 ha) area to identify sufficient land that would be suitable for conveyance to TRIDEC for economic development.

On December 19, 2014, Congress passed the *Carl Levin and Howard P. “Buck” McKeon National Defense Authorization Act for Fiscal Year 2015* ([Public Law 113-291](#)), which contains language directing DOE to transfer 1,641 ac (664 ha) of land to the west of Hanford’s 300 Area (the land conveyance area) to TRIDEC by September 30, 2015. Conveyance of land from DOE ownership will necessitate modification of the *Hanford Facility Resource Conservation and Recovery Act Permit* (see Section 2.1.2.1). Based on the analysis presented in the Final EA, which considered comments received on the Draft EA and the commitments specified in the Mitigation Action Plan, DOE determined that the Proposed Action will not constitute a major federal action significantly affecting the quality of the human environment within the meaning of NEPA. Therefore, the preparation of an EIS was not required, and DOE issued a FONSI on September 30, 2015.

2.1.7.2.3 *Draft Programmatic Environmental Assessment for Recycle of Scrap Metals Originating from Radiological Areas (DOE/EA-1919)*

During CY 2015, work continued on completing the *Programmatic Environmental Assessment for the Recycle of Scrap Metals Originating from Radiological Areas* ([DOE/EA-1919](#)). DOE senior managers are reviewing the EA and comment response document. The EA evaluates alternatives for the management of scrap metal originating from DOE radiological control areas, including a proposed action to allow for the recycle of uncontaminated scrap metal that meets *Radiation Protection of the Public and the Environment*

([DOE O 458.1](#)) requirements. Metals with volumetric radioactive contamination are not included in the scope of this Programmatic EA. DOE plans to complete the Programmatic EA, issue a FONSI, or prepare a Programmatic EIS prior to deciding whether to implement a change to the policy established ([Richardson 2000](#)) that imposed an agency-wide suspension on unrestricted release of scrap metal recycling that originated from radiological areas at DOE facilities. The policy was in response to public concerns about potential effects of radioactivity in or on metal recycled from DOE facilities.

2.1.7.2.4 Final Environmental Assessment for Expansion of Borrow Areas on the Hanford Site (DOE/EA-1934)

The *Environmental Assessment for Expansion of Borrow Areas on the Hanford Site* ([DOE/EA-1934 \[2013\]](#)) evaluated the potential environmental impacts of expansion or continued use of existing sand and gravel pits located on the Hanford Site (Pits F, H, N, 6, 9, 18, 21, 23, 24, 30, and 34) and established one new borrow area source in the 100 Area for ongoing construction activities and fill material following remediation activities. The scope of this EA did not include borrow sources for silt-loam material. On October 15, 2013, the *Expansion of Borrow Areas on the Hanford Site Mitigation Action Plan for DOE/EA-1934* ([WCH-561](#)) was issued. The purpose of the proposed action in this EA is to meet DOE's need to secure raw aggregate sand and gravel material (approximately 10,714,000 bank cubic meters) to support ongoing environmental cleanup restoration projects (backfill of remediated waste sites), as well as construction and maintenance activities across the Hanford Site. Although final remedial action decisions have yet to be made for some cleanup work, the proposed action would support the projected needs for sand and gravel for approximately 10 years.

Section 4.g of [DOE Order 451.1B](#), Chg 3, *National Environmental Policy Act Compliance Program*, requires “[t]racking and annually reporting progress in implementing a commitment for environmental impact mitigation that is essential to render the impacts of a proposed action not significant, or that is made in a record of decision.” Required by [DOE Order 451.1B](#), the *Mitigation Action Plan Annual Report Calendar Year 2015* ([DOE/EA-1934 \[2016\]](#)) was issued in February 2016.

2.1.7.3 Hanford Site Categorical Exclusions

Categorical exclusions encompass classes of actions that DOE has analyzed and determined do not individually or cumulatively have a significant effect on human health or the environment and for which neither an EA nor an EIS is required ([76 FR 63764](#), “National Environmental Policy Act Implementing Procedures”).

On August 9, 2012, the DOE NEPA Compliance Officer directed the elimination of 16 site-wide categorical exclusions (effective December 31, 2012) and requested Hanford Site contractors to submit for approval annual categorical exclusions for routine and recurring work activities in accordance with the provisions of the newly modified NEPA implementing procedures. Activity-specific categorical exclusions continue to be submitted to the DOE NEPA compliance officer for non-routine, non-recurring, project-specific work activities. A standard format was developed for use by the DOE NEPA compliance officer to perform and document the results of NEPA review screening activities. The compliance officer approved 21 annual categorical exclusions on December 31, 2015 to cover routine and recurring work activities planned to be performed during FY 2016.

2.1.8 Institutional Controls Plan

R Ranade

The *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions* ([DOE/RL 2001-41](#)) describes the institutional controls for the Hanford Site in accordance with CERCLA and/or RCRA decision documents. The CERCLA decision documents present the selected remedial actions chosen in accordance with CERCLA as amended by the SARA and implemented under [40 CFR 300](#). CERCLA decision documents are developed as part of the cleanup mission at the Hanford Site, which began in 1989 following the end of the national defense mission. The selected remedies chosen may include institutional controls and the CERCLA decision documents identify the specific requirements for these controls.

Institutional controls (ICs) are primarily administrative in nature and typically are used to augment the engineered components of a selected remedy to minimize the potential for human exposure to residual contaminants. Active ICs, such as controlling access to the Hanford Site or activities that may affect remedial action, are generally employed during remediation. After remediation is completed, passive ICs are employed such as permanent markers, retaining public records and archives, or sustaining regulations regarding land or resource use. Some active ICs such as monitoring and controlling access to the area also may be employed after remediation is completed.

Through contractors, DOE conducts ICs assessments as required by the CERCLA and/or RCRA decision documents annually. Hanford Site CERCLA 5-year review addresses a “roll up” of 5-year review of the annual assessments. The “roll up” serves as a means to evaluate the effectiveness of the ICs. The contractors provide an annual update on the effectiveness of the ICs to EPA and Ecology at the area unit managers meetings each September. Minutes from the unit managers’ meeting are available on the TPA AR PIR website ([TPA 2016b](#)).

The MSA Long-term Stewardship (LTS) organization is responsible for managing ICs related to Hanford Site access control and the wastes sites in the 100-F Area and the 100-K Area. In CY 2015, the warning signs along the Hanford Site boundary and at the entrance of 100-F Area were in place, and no broken fences were observed. Review of excavation permits and Site evaluation process was used to ensure compliance with ICs restricting drilling or excavation into deep zone (below 15 ft [4.6 m]).

The MSA LTS Program also conducted an IC assessment at the 300 Area Fire Station to ensure that their operational procedures did not conflict with IC identified in the final 300 Area ROD. The 300 Fire Station is compliant with the required ICs.

The River Corridor Project has a number of institutional controls in both interim action and final ROD documents. In CY 2015, access controls were in place and active for the River Corridor Project, and no public trespass events at waste sites were reported. In addition, approved excavation permits were in place for all active remediation activities assessed. Warning signs were in place at access road entrances to active remediation in the 100 and 300 areas. Required shoreline signage checked during the 2015 institutional controls assessment was present at the 300 Area and at the reactor in the 100 Area.

The operable units in the Central Plateau Project also has a number of institutional controls in both interim and final ROD documents. In CY 2015, an assessment of institutional controls at 200-UP-1 Operable Unit, 221 U Facility, and 200 ZP 1 Operable Unit did not identify deficiencies.

2.1.9 Federal Insecticide, Fungicide, and Rodenticide Act

JM Rodriguez

EPA administers the *Federal Insecticide, Fungicide, and Rodenticide Act* ([7 U.S.C. 136 et seq.](#)). The Washington State Department of Agriculture administers standards to regulate implementation of the Act in the state, including the “Washington Pesticide Control Act” ([RCW 15.58](#)), “Washington Pesticide Application Act” ([RCW 17.21](#)), and rules relating to general pesticide use codified in [WAC 16-228](#), “General Pesticide Rules.” Commercial pesticides are applied on the Hanford Site by commercial pesticide operators that are listed on one of two commercial pesticide applicator licenses and by a licensed private commercial applicator.

2.2 Radiation Protection Statutes and Regulations

JW DeMers

The Hanford Site is subject to radiation protection statutes and regulations designed to protect the health and safety of the public, workforce, and the environment. Relevant laws and regulations are described in the following sections.

2.2.1 Atomic Energy Act of 1954

To ensure proper management of radioactive materials, the *Atomic Energy Act of 1954* (AEA; [42 U.S.C. 2011 et seq.](#)) and its amendments include provisions to delegate roles and responsibilities to control radioactive materials and nuclear energy primarily to DOE, the U.S. Nuclear Regulatory Commission (NRC), and EPA. Through the AEA, DOE regulates the control of radioactive materials under its authority, including the TSD of low-level radioactive waste from its operations. Sections of the AEA authorize DOE to establish radiation protection standards for itself and its contractors. Accordingly, DOE promulgated a series of regulations (e.g., [10 CFR 820](#), “Procedural Rules for DOE Nuclear Activities;” [10 CFR 830](#), “Nuclear Safety Management;” and [10 CFR 835](#), “Occupational Radiation Protection”). Additional DOE directives to protect public health and the environment from potential risks associated with radioactive materials include [DOE O 435.1](#), Chg. 1, *Radioactive Waste Management* and [DOE O 458.1](#), *Radiation Protection of the Public and Environment*. Hanford Site operations are subject to these regulations and directives.

DOE directives may be accessed via the Departmental Directives Program website at <https://www.directives.doe.gov/>. DOE technical standards may be accessed via the DOE Office of Environment, Health, Safety & Security website at <http://energy.gov/ehss/services/nuclear-safety/departement-energy-technical-standards-program>.

2.2.2 DOE O 458.1, Radiation Protection of the Public and the Environment

The purpose of [DOE O 458.1](#) is to establish standards and requirements for conduct of DOE and DOE contractor operations with respect to radiological protection of the public and the environment. This order was developed and issued consistent with DOE’s policy to implement legally applicable radiation protection requirements; consider and adopt, as appropriate, recommendations by authoritative organizations (e.g., the National Council on Radiation Protection and Measurements [NCRP] and the International Commission on Radiological Protection [ICRP]); and adopt and implement standards generally consistent with those of the NRC for DOE facilities and activities not subject to NRC authority.

Specifically, relative to guidance, standards, and regulatory requirements existing at the time of its issuance, this order adopted applicable standards issued by the NCRP and ICRP, incorporated regulatory requirements applicable to DOE operations, and consolidated and upgraded DOE guidance for contaminated property.

[DOE O 458.1](#) applies to all DOE elements and contractors performing work for DOE, as provided by law and/or contract, and as implemented by the appropriate contracting officer. This Order was developed and issued under the authority of the AEA as amended, which authorizes DOE to provide for the radiological health and safety of the public for operations conducted under DOE direction.

Relative to the radiological health and safety of the public, the goals of [DOE O 458.1](#) are to ensure that DOE operations achieve the following:

- Maintain radiation exposures to the public within established limits
- Control radioactive contamination through the management of real and personal property
- Ensure potential exposures to the public are as far below established limits as is reasonably achievable
- Ensure DOE facilities have the capabilities, consistent with the types of operations conducted, to monitor routine and non-routine releases and to assess doses to the public.

In addition to providing radiological protection to the public, the objective of [DOE O 458.1](#) is to provide radiological protection of the environment to the extent practical.

[DOE O 458.1](#) also provides derived concentration guide values as reference values for conducting radiological environmental protection programs at operational DOE facilities and sites. Table 2.5 provides the radiation standards (dose limits) for protection of the public from all routine DOE concentrations. These DOE-derived concentration guide values are based on a committed dose standard of 100 mrem (1 mSv) due to ingestion, inhalation, or direct exposure during a given year, and are provided for three exposure pathways: ingestion of water, inhalation of air, and immersion in a gaseous cloud. This order also provides radiological protection requirements and guidelines for cleanup of residual radioactive material, management of the resulting wastes and residues, and clearance of property. These requirements and guidelines are applicable at the time the property is released.

Table 2.5. Radiation Standards for Public Protection from All Routine DOE Concentrations

All Pathways (DOE O 458.1)		
Effective dose equivalent for any member of the public from all routine DOE operations [†] shall not exceed values below.		
	Effective Dose Equivalent[‡]	
	mrem/yr	mSv/yr
Routine public dose	100	1
Potential authorized temporary public dose [§]	500	5
Dose to Native Aquatic Animal Organisms from Liquid Discharges (DOE O 458.1)		
Radioactive material in liquid waste discharged to natural waterways shall not cause an absorbed dose ^{**} to native aquatic animal organisms that exceed 1 rad (10 milligray [mGy]) per day.		
Drinking Water Pathway Only: 40 CFR Parts 9, 141, and 142 (65 FR 76708 , "National Primary Drinking Water Regulations; Radionuclides; Final Rule"); WAC 246-290 , "Group A Public Water Supplies;" and DOE O 458.1		
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)/yr. DOE operations shall not cause private or public drinking water systems downstream of the facility discharge to exceed the radiological drinking water limits in 40 CFR Parts 9, <i>OMB Approvals Under the Paperwork Reduction Act</i> ; 141, <i>National Primary Drinking Water Regulations</i> ; and 142, <i>National Primary Drinking Water Regulations Implementation</i> .		
Air Pathways Only (40 CFR 61, "National Emission Standards for Hazardous Air Pollutants")		
	Effective Dose Equivalent[‡]	
	mrem/year	mSv/year
Public dose limit at location of maximum annual air concentration as a consequence of routine DOE operations [†]	10	0.1

mrem = millirem; mSv = millisievert; rem = roentgen equivalent in man; Sv = sievert

*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.

[†]Routine DOE operations imply normal, planned activities and do not include actual or potential accidental or unplanned releases.

[‡]Effective dose equivalent is expressed in rem (or mrem) and Sv (or mSv).

[§]Authorized temporary annual dose limits may be greater than 100 mrem (1 mSv)/yr but cannot exceed 500 mrem (5 mSv)/yr if unusual circumstances exist that make avoidance of doses impracticable to the public. DOE-RL is required to request and receive specific authorization from DOE-HQ for an increase from the routine public dose limit to a temporary annual dose limit.

^{**}Absorbed dose is expressed in rad (or millirad) with the corresponding value in gray (or mGy) in parentheses.

2.2.3 DOE O 435.1, Radioactive Waste Management

OA Farabee, JA Reddick

The purpose of [DOE O 435.1](#) is to establish requirements to manage all high-level waste (HLW), transuranic waste, and low-level waste (LLW), including the radioactive component of mixed waste (HLW, transuranic waste, and LLW containing chemically hazardous constituents) in a safe manner that is protective of the worker, public health, and the environment. The order takes a cradle-to-grave approach to managing waste and includes requirements for waste generation, storage, treatment, disposal, and post-closure monitoring of facilities.

Radioactive waste shall be managed such that the requirements of other DOE orders, standards, and regulations are met, including [10 CFR 835](#); [DOE O 440.1B](#), *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees*; and [DOE O 458.1](#), *Radiation Protection of the Public and the Environment*.

2.3 Air Quality Statutes and Regulations

RA Kaldor

Below is information on federal, state, and local statutes applicable to the Hanford Site air quality program.

2.3.1 Air Quality Regulatory Authority

The federal *Clean Air Act* was enacted to protect and enhance air quality and is the legal basis for federal, state, and local air quality regulations. Originally passed in 1963, the law has been revised extensively on numerous occasions. The most recent revision, the *Clean Air Act Amendments of 1990* ([Public Law 101-549](#)) provides the framework for a significant portion of current federal air quality regulations. The Washington Clean Air Act ([RCW 70.94](#)), which parallels and supplements federal law, has been revised periodically to keep pace with federal changes. EPA provides high-level programmatic oversight of the air quality program on the Hanford Site and has delegated authority for implementing applicable *Clean Air Act* regulations to designated state and local regulatory agencies.

WDOH regulates radioactive air emissions on the Hanford Site by enforcing applicable federal requirements in [40 CFR 61](#) (NESHAPs) Subparts A and H and state requirements in [WAC 173-480](#), “Ambient Air Quality Standards and Emission Limits for Radionuclides” and [WAC 246-247](#), “Radiation Protection – Air Emissions.” Federal regulations for radioactive air emissions are contained in [40 CFR 61, Subpart H](#), “National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities.”

Ecology regulates criteria and toxic air pollutant emissions at the Hanford Site by enforcing applicable federal requirements in [40 CFR 52](#), “Approval and Promulgation of Implementation Plans;” [40 CFR 60](#), “Standards of Performance for New Stationary Sources;” [40 CFR 61](#); [40 CFR 63](#), “NESHAPs for Source Categories;” [40 CFR 68](#), “Chemical Accident Prevention Provisions;” and [40 CFR 82](#), “Protection of Stratospheric Ozone;” as well as the state requirements in [WAC 173-400](#), “General Regulations for Air Pollution Sources;” [WAC 173-460](#), “Controls for New Sources of Toxic Air Pollutants;” [WAC 173-480](#); and [WAC 173-491](#), “Emission Standards and Controls for Sources Emitting Gasoline Vapors.” Criteria and toxic air pollutant emissions are often referred to as nonradioactive air emissions at the Hanford Site. Criteria pollutants are particulate matter, nitrogen oxides, sulfur oxides, carbon monoxide, lead, and volatile organic compounds. Toxic air pollutants are other chemical contaminants as regulated by Washington State.

The Benton Clean Air Agency regulates demolition and asbestos renovation activities at the Hanford Site in accordance with federal requirements in [40 CFR 61, Subpart M](#), “National Emission Standard for Asbestos.” The Benton Clean Air Agency also regulates outdoor burning activities at the Hanford Site in accordance with state requirements in [WAC 173-425](#), “Outdoor Burning.”

2.3.2 Air Permits

Hanford Site contractors evaluate each proposed new or modified emission unit using the new source review requirements of radioactive air emissions ([WAC 246-247](#), “Radiation Protection – Air Emissions”) and criteria and toxic air pollutants ([WAC 173-400-110](#), “New Source Review (NSR) for Sources and Portable Sources” and [WAC 173-460-040](#), “New Source Review”) to determine whether a notice of construction application must be submitted to the WDOH and/or Ecology (as applicable) for approval before construction or operation of the proposed source.

Hanford Site radioactive air emission sources are operated in accordance with the Radioactive Air Emissions License for the Department of Energy Richland Operations Office Hanford Site, License FF-01 issued by the WDOH in February 2012. The FF-01 license is a compilation of all applicable radioactive air emission requirements and is renewed every 5 years. For each emission unit, the FF-01 license includes either an approval to modify/construct or an operating license. Overall, Hanford Site radioactive air emissions are controlled to sufficiently low levels to ensure the resultant exposure to any off-site individual remains well below the 10 mrem (100 mSv)/yr specified in [40 CFR 61.92](#), “Standard.” Hanford Site radioactive air emissions data are published annually in the radionuclide air emissions report for the Hanford Site ([DOE/RL-2016-10](#), *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2015*).

As a major source of air pollutants, the Hanford Site is subject to the air operating permit requirements in [40 CFR 70](#), “State Operating Permit Programs” and [WAC 173-401](#), “Operating Permit Regulation.” In coordination with WDOH and the Benton Clean Air Agency, Ecology issued Renewal 2 of the Air Operating Permit for a period of 5 years, effective April 1, 2013. Renewal 2 was issued to incorporate new WDOH and Ecology air emission licenses, approval orders, and updated regulatory requirements. The Air Operating Permit is a compilation of applicable *Clean Air Act* requirements for both radioactive and criteria/toxic air pollutant emissions, including the radioactive air emissions license FF-01 issued by WDOH and Notice of Construction Approval Orders issued by Ecology. The Air Operating Permit requires the submittal of semiannual reports to the regulatory agencies documenting the status of required monitoring and permit deviations. In addition, an annual report documenting the compliance status of Hanford Site emission sources against applicable *Clean Air Act* requirements, and an annual report that documents total emissions of criteria and toxic pollutants is also required.

The WDOH, Ecology, and the Benton Clean Air Agency conduct inspections of Hanford Site emission sources to verify compliance with applicable *Clean Air Act* requirements. Hanford Site contractors and DOE actively work to resolve any potential compliance issues identified during these inspections. During 2015, regulatory agencies conducted over 28 *Clean Air Act* inspections on the Hanford Site. A total of nine violations were alleged involving airborne radioactive materials at the 618-10 Burial Ground, operation of 222-SE engine in excess of 100 hours in a calendar year, and failure to monitor stack air emissions continuously or operating outside sampling system design parameters at PUREX, B-Plant, and the Canister Storage Building (also see Section 2.1.2.2.2).

2.4 Water Quality Statutes and Regulations

M Kamberg

This section provides information on federal, state, and local requirements and permits for water quality protection.

2.4.1 Federal Permit – Discharges to Columbia River

The *Clean Water Act of 1977*, as amended, applies to discharges to surface waters in the United States. At the Hanford Site, regulations are applied through [40 CFR 122](#), “EPA Administered Permit Programs: The National Pollutant Discharge Elimination System.” DOE does not currently have any discharges to the Columbia River requiring permits.

2.4.2 State Waste Discharge Permit – Discharges to the Soil Column/Groundwater

Ecology's Wastewater Discharge Permit program regulates discharges to state waters, including groundwater. Four Ecology state waste discharge permits, all held by DOE, were in effect during 2015: ST-4500, ST0004502, ST0004511, and ST0045514. Ecology's wastewater discharge permits page is located at <http://www.ecy.wa.gov/programs/nwp/permitting/wwd/index.html>.

Two Ecology general permits for sand and gravel were in effect (and issued to Bechtel National Inc.) during 2015: WAG-50-5180 and WAG-50-5181. WDOH issues annual permits to DOE to operate Hanford Site on-site sewage systems, which include some holding-tank sewage systems. Most on-site sewage systems (septic systems) operate under permits issued by the WDOH.

2.4.3 Local Discharge Permit – Discharges to the City of Richland Sewer

The City of Richland regulates industrial wastewater discharges to its sewer collection system in accordance with City of Richland Code [Chapter 17.30](#), *Richland Pretreatment Act*. DOE holds Permit No. CR-IU010, which allows discharges from the 300 Area facilities.

2.4.4 Safe Drinking Water Act of 1974 (SDWA)

BR Stenson

The *Safe Drinking Water Act of 1974* (SDWA; [42 U.S.C. 300f](#)) established a cooperative program among local, state, and federal agencies to institute 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 SDWA. To obtain primacy, states were required to meet certain criteria, including adoption of regulations equal to or more stringent than EPA regulations.

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

The SDWA was amended in 1986 and 1996 (*Safe Drinking Water Act Amendments*, [Public Law 104-182](#)). Although 1986 amendments included provisions that emphasized treatment to ensure safe drinking water, 1996 amendments focused on source water protection, water system improvements funding, operator training, public information, and strengthening EPA's scientific work, including a risk and cost benefit analysis in establishing drinking water standards (DWS). Between 1975 and 2006, these amendments resulted in the development of 18 new drinking water regulations. Post-1996 regulations have included more complex compliance determinations and more advanced treatment technologies. Based on site-specific conditions, many public water systems are either using or investigating new treatment technologies to comply with the increasingly complex requirements.

The EPA's microbial and disinfection byproduct rules include nine drinking water regulations, address acute threats from microbial contamination and chronic threats from disinfectant residuals and disinfection byproducts. These rules limit disinfectant residuals and disinfection byproducts in the distribution systems while improving particle removal in the drinking water treatment plants. In 2015, affected Hanford Site water systems demonstrated compliance with the filtration and disinfection treatment technique requirements and limits for disinfectant residuals and disinfection byproducts.

To protect worker health using public water supplies on the Hanford Site, water systems were monitored during 2015 for microbiological, chemical, physical, and radiological constituents. There were no microbiological detections during the 2015 monitoring cycle, and all chemical concentrations in drinking water were well below the maximum contaminant levels established by EPA. Table 2.6 provides selected drinking water standards. System-specific information and analytical results for 2015 radiological monitoring are summarized in Section 7.1.3. Table 2.7 provides the selected surface freshwater quality criteria for toxic pollutants, and Table 2.8 provides the Washington State water quality criteria for the Hanford Reach of the Columbia River.

Table 2.6. Selected Drinking Water Standards

Constituent		DWS*	Agency†
Antimony	6 µg/L	0.006 ppm	EPA, WDOH
Arsenic	10 µg/L	0.01 ppm	EPA, WDOH
Barium	2,000 µg/L	2 ppm	EPA, WDOH
Cadmium	5 µg/L	0.005 ppm	EPA
Carbon tetrachloride	5 µg/L	0.005 ppm	EPA, WDOH
Trihalomethanes‡	80 µg/L	0.08 ppm	EPA
Chromium	100 µg/L	0.1 ppm	EPA, WDOH
cis-1,2-Dichloroethene	70 µg/L	0.07 ppm	EPA, WDOH
Copper	1,300 µg/L	1.3 ppm	EPA
Cyanide	200 µg/L	0.2 ppm	EPA, WDOH
Fluoride	4 mg/L	4 ppm	EPA, WDOH
Lead	15 µg/L	0.015 ppm	EPA
Mercury (inorganic)	2 µg/L	0.002 ppm	EPA, WDOH
Methylene chloride	5 µg/L	0.005 ppm	EPA, WDOH
Nitrate, as NO ₃ ⁻	10 mg/L	10 ppm	EPA, WDOH
Nitrite, as NO ₂ ⁻	1.0	1.0 ppm	EPA, WDOH
Selenium	50 µg/L	0.05 ppm	EPA, WDOH
Tetrachloroethene	5 µg/L	0.005 ppm	EPA, WDOH
Thallium	2 µg/L	0.002 ppm	EPA, WDOH
Trichloroethene	5 µg/L	0.005 ppm	EPA, WDOH
Antimony-125	300 pCi/L§	11.1 Bq/L	EPA
Beta particle and photon activity	4 mrem/yr**	40 µSv/yr	EPA, WDOH
Carbon-14	2,000 pCi/L§	74.1 Bq/L	EPA
Cesium-137	200 pCi/L§	7.4 Bq/L	EPA
Cobalt-60	100 pCi/L§	3.7 Bq/L	EPA
Iodine-129	1 pCi/L§	0.037 Bq/L	EPA
Ruthenium-106	30 pCi/L§	1.11 Bq/L	EPA
Strontium-90	8 pCi/L§	0.296 Bq/L	EPA, WDOH
Technetium-99	900 pCi/L§	33.3 Bq/L	EPA
Total alpha (excluding uranium)	15 pCi/L§	0.56 Bq/L	EPA, WDOH
Tritium	20,000 pCi/L§	740 Bq/L	EPA, WDOH
Uranium	30 µg/L	0.03 ppm	EPA, WDOH

Bq=Becquerel, L=liter, pCi=picocuries, mg=milligrams, ppm=parts per million, yr=year, µg=micrograms

*Maximum contaminant level for drinking water supplies.

†WDOH at [WAC 246-290](#); EPA at [40 CFR 141](#), "National Primary Drinking Water Regulations;" [40 CFR 143](#), "National Secondary Drinking Water Regulations;" and *Drinking Water Regulations and Health Advisories* ([EPA 1996](#)).

‡Standard is for total trihalomethanes.

§EPA DWSs 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 1963](#), as amended).

**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.

Table 2.7. Selected Surface Freshwater Quality Criteria for Toxic Pollutants

Compound	Level that Yields Acute Toxicity*		Level that Yields Chronic Toxicity*		Protective Level for Human Health Consumption of Water and Organisms†	
	µg/L	ppm	µg/L	ppm	µg/L	ppm
Dissolved Metals						
Antimony	—	—	—	—	14	0.014
Arsenic	360.0	0.360	190.0	0.19	0.018	0.000018
Cadmium	1.6	0.0016‡	0.59	0.00059§	—	—
Chromium (VI)	15	0.015	10	0.01	—	—
Copper	8.4	0.0084**	6.0	0.006††	—	—
Lead	28	0.028‡‡	1.1	0.0011§§	—	—
Mercury	2.1	0.0021	—	—	0.14	0.00014
Nickel	750	0.75***	83	0.083†††	610	0.61
Silver	0.94	0.00094‡‡‡	—	—	—	—
Thallium	—	—	—	—	1.7	0.0017
Zinc	60	0.060§§§	55	0.055****	—	—
Total Recoverable Metals						
Chromium(III)††††	300	0.30‡‡‡‡	96	0.096§§§§	—	—
Mercury	—	—	0.012	0.000012	—	—
Selenium	20	0.02	5.0	0.005	—	—
Anions						
Cyanide*****	22.0	0.022	5.2	0.0052	700	0.70
Chloride†††††	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
<p>*WAC 173-201A-240, “Toxic Substances.” For hardness-dependent criteria, a minimum value of 47 mg CaCO₃/L for 1992–2010 USGS water samples collected near Vernita Bridge is used. Ppm values equivalent to reported µg/L concentrations are shown.</p> <p>†40 CFR 131.36, “Toxics Criteria for those States not Complying with Clean Water Act Section 303(c)(2)(B)”</p> <p>‡(1.1367 - [ln(hardness)] 0.04184) exp (1.128[ln(hardness)] - 3.828) Hardness expressed as mg CaCO₃/L</p> <p>§(1.1017 - [ln(hardness)] 0.04184) exp (0.7852[ln(hardness)] - 3.490)</p> <p>** (0.960) exp (0.9422[ln(hardness)] - 1.464)</p> <p>†† (0.960) exp (0.8545[ln (hardness)] - 1.465)</p> <p>‡‡ (1.4620 - [ln (hardness)] 0.1457) exp (1.273[ln (hardness)] - 1.460)</p> <p>§§ (1.4620 - [ln (hardness)] 0.1457) exp (1.273[ln (hardness)] - 4.705)</p> <p>*** (0.998) exp (0.8460 [ln (hardness)] + 3.3612)</p> <p>††† (0.997) exp (0.8460 [ln (hardness)] + 1.1645)</p> <p>‡‡‡ (0.85) exp (1.72[ln (hardness)] - 6.52)</p> <p>§§§ (0.978) exp (0.8473 [ln (hardness)] + 0.8604)</p> <p>**** (0.986) exp (0.8473 [ln (hardness)] + 0.7614)</p> <p>†††† Where methods to measure trivalent chromium are unavailable, these criteria are to be represented by total recoverable chromium.</p> <p>‡‡‡‡ (0.316) exp (0.8190 [ln(hardness)] + 3.688).</p> <p>§§§§ (0.860) exp (0.8190 [ln(hardness)] + 1.561).</p> <p>***** Criteria based on weak and dissociable method.</p> <p>††††† Dissolved in association with sodium.</p>						

Table 2.8. Washington State Water Quality Criteria for the Columbia River, Hanford Reach*

Parameter	Permissible Levels
Fecal coliform	<ul style="list-style-type: none"> Geometric mean value less than or equal to 100 colonies/0.026 gal (100 mL) Not $\geq 10\%$ of samples may exceed the geometric mean value of 200 colonies/0.026 gal (100 mL).
Dissolved oxygen	>8 mg/L (8 ppm)
Temperature	<ul style="list-style-type: none"> Less than or equal to 18°C (64°F) as a result of human activities 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 0.54°F (0.3°C). 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 5.04°F (2.8°C).
pH	6.5 to 8.5 range; less than 0.5 unit induced variation
Turbidity	Turbidity shall be ≤ 5 nephelometric turbidity units over background turbidity when 50 nephelometric units or fewer and shall not increase $>10\%$ when 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 the <i>National Interim Primary Drinking Water Regulations</i> (EPA 1975) or in subsequent revisions thereto (Table 2.1).
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 (Table 2.8).
* WAC 173-201A , "Water Quality Standards for Surface Waters of the State of Washington"	

2.5 Natural and Cultural Resources

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

2.5.1 Ecological Compliance

JA Pottmeyer

DOE policies require that all Hanford Site projects with the potential to affect biological resources adversely conduct an ecological compliance review before the project starts. DOE uses the review to determine if the project will comply with the *Endangered Species Act of 1973* ([16 U.S.C. 1531](#)), the *Migratory Bird Treaty Act of 1918* (MBTA; [16 U.S.C. 703](#)), and the *Bald and Golden Eagle Protection Act* ([16 U.S.C. 668–668c](#)) as well as [Executive Order 11988](#), "Floodplain Management" ([32 CFR 644.320](#)) and [Executive Order 11990](#), "Protection of Wetlands" ([32 CFR 644.319](#)). The review also addresses 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. When adverse effects are identified, mitigation actions are prescribed. Mitigation actions may include avoidance of significant resources, minimization of effects, and rectification or compensation if resources are affected.

There were 188 ecological compliance reviews performed during 2015, including 155 reviews to support general Hanford Site activities and 33 reviews for River Corridor environmental restoration activities. By comparison, 212 ecological compliance reviews were performed in 2014, including 125 reviews to support general Hanford Site activities and 87 reviews for River Corridor environmental restoration activities.

2.5.1.1 Endangered Species Act of 1973 (16 U.S.C. 1531)

Several protected species of plants and animals exist on the Hanford Site and along the Hanford Reach of the Columbia River. Upper Columbia River Steelhead trout (*Oncorhynchus mykiss*) and spring-run Chinook salmon (*Oncorhynchus tshawytscha*) are listed under the *Endangered Species Act of 1973* (16 U.S.C. 1531) as either threatened or endangered (50 CFR 17, “Endangered and Threatened Wildlife and Plants,” Subpart B, “Lists”) and occur on site. Critical habitat for these species has been designated within the Hanford Reach. The *Threatened and Endangered Species Management Plan: Salmon and Steelhead* (DOE/RL-2000-27) is in place for these species. The bull trout (*Salvelinus confluentus*) is also listed under 16 U.S.C. 1531 and may occasionally occur in the Hanford Reach; critical habitat for bull trout was designated in the Hanford Reach in 2010 (USFWS 2010). Two plant species, the Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Physaria douglasii* ssp. *tupleshensis*) are now listed under 16 U.S.C. 1531. Other species on the Hanford Site are listed by the WDFW as endangered, threatened, or sensitive (see Section 11.2).

2.5.1.2 Migratory Bird Treaty Act (16 U.S.C. 703)

The MBTA prohibits taking or disturbing listed migratory birds or their feathers, eggs, or nests. Over 100 species of birds that regularly occur on the Hanford Site are protected under this 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 as described in the *Hanford Site Biological Resource Management Plan* (DOE/RL-96-32). When applicable, ecological reviews produce recommendations to minimize adverse impacts to migratory birds, such as performing work outside of the nesting season and minimizing the loss of habitat. Hanford Site biologists maintain migratory bird permits issued by the USFWS (MB14155A-2 and MB81249A-1) that allow for certain MBTA-related actions. A report of all activities conducted under this permit is provided to USFWS annually.

2.5.1.3 Bald and Golden Eagle Protection Act (16 U.S.C. 668)

16 U.S.C. 668 provides for the protection of the bald eagle and golden eagle by prohibiting, except under certain specified conditions, the taking, possession, or commerce of such birds. A revised *Bald Eagle Management Plan for the Hanford Site, South Central Washington* (DOE/RL-94-150) was published in 2013 to direct Hanford Site activities in accordance with current federal and state regulations and guidelines. This management plan outlines seasonal access restrictions around documented nesting and communal roosting sites at the Hanford Site between November 15 and March 15, and establishes guidelines for the protection of perches, roosts, and alternative nest sites. When applicable, ecological reviews have produced recommendations to minimize adverse impacts to bald eagles, including performing work outside of the winter season; staying out of established buffer areas; or entering buffer areas at mid-day, minimizing impacts by avoiding eagle roosting periods.

DOE continued to maintain a bald eagle take permit from the USFWS (MB30480-A-1) to cover potential disturbance to eagles using the night roosts in the vicinity of the 100 HX pump-and-treat system between 100-H and 100-D Areas.

2.5.1.4 Executive Orders 11988 and 11990

Executive Order 11988 and Executive Order 11990 and require federal agencies to minimize the loss or degradation of wetlands on federal lands, and account for floodplain management when developing water-

and land-use plans, respectively. DOE implements the requirements of these two executive orders through [10 CFR 1022](#), “Compliance with Floodplain and Wetlands Environmental Review Requirements.” It is DOE policy to 1) restore and preserve natural and beneficial values served by floodplains; 2) minimize the destruction, loss, or degradation of wetlands; and 3) preserve and enhance the natural and beneficial value of wetlands. Compliance with these executive orders, as well as the wetland provisions of the *Clean Water Act of 1977* ([33 U.S.C. 1251](#)), are implemented at the Hanford Site through the ecological compliance review process in conjunction with the appropriate site environmental compliance officers. The compliance process includes the identification, protection, and when necessary, mitigation of wetlands and floodplains on the Hanford Site.

2.5.2 Cultural Resource Compliance

CD Currie

The *Department of Energy Management of Cultural Resources* ([DOE P 141.1](#)) requires compliance with cultural resource-related laws and regulations to include the *Antiquities Act of 1906* ([16 U.S.C. 433](#)), *Historic Sites Act of 1935* ([16 U.S.C. 461](#)), *National Historic Preservation Act of 1966* ([16 U.S.C. 470](#)), NEPA ([42 U.S.C. 4321 et seq.](#)), *Archaeological and Historic Preservation Act of 1974* ([16 U.S.C. 469](#)), *American Indian Religious Freedom Act of 1978* ([42 U.S.C. 1996](#)), *Archaeological Resources Protection Act of 1979* ([16 U.S.C. 470](#)), and *Native American Graves Protection and Repatriation Act* ([Public Law 101-601](#)).

Regulations applicable to cultural resources include [36 CFR 60](#), “National Register of Historic Places;” [36 CFR 63](#), “Determinations of Eligibility for Inclusion in the National Register of Historic Places;” [36 CFR 65](#), “National Historic Landmarks Program;” [36 CFR 79](#), “Curation of Federally-Owned and Administered Archaeological Collections;” [36 CFR 800](#), “Protection of Historic Properties;” [43 CFR 7](#), “Protection of Archaeological Resources;” and [43 CFR 10](#), “Native American Graves Protection and Repatriation and Regulations.”

Executive orders applicable to cultural resources include [Executive Order 11593](#), “Protection and Enhancement of the Cultural Environment” (36 FR 8921); [Executive Order 13007](#), “Indian Sacred Sites” (61 FR 26771); [Executive Order 13175](#), “Consultation and Coordination with Indian Tribal Governments” (65 FR 67249); [Executive Order 13287](#), “Preserve America” (68 FR 10635); and Presidential Proclamation 7319, *Establishment of the Hanford Reach National Monument* ([65 FR 37253](#)). Refer to Section 11.3 for details regarding Hanford Site Cultural Resource programs.

2.6 Sustainability Statutes

Information regarding additional statutes is presented in the following sections.

2.6.1 Chemical Management Systems

ML Hermanson

Hanford Site contractors developed and documented formal systems to manage chemicals. Chemical management systems apply to the acquisition, use, storage, transportation, and final disposition of chemicals, including hazardous chemicals as defined in [29 CFR 1910](#), “Occupational Safety and Health Standards,” [Subpart Z](#), “Toxic and Hazardous Substances.” Chemical management systems are reviewed periodically, and improvements are made as needed.

2.6.2 Pollution Prevention Program (42 U.S.C. 133)

SW Davis

The *Pollution Prevention Act of 1990* ([42 U.S.C. 133](#)) requires that pollution be prevented or reduced at the source whenever possible, and pollution that cannot be prevented be recycled or treated in an environmentally safe manner. The Hanford Site Pollution Prevention Program was created to address these requirements. DOE is responsible for the Hanford Site Pollution Prevention Program and provides program implementation guidance to Hanford Site contractors. The Pollution Prevention Program reflects federal and DOE policies to reduce, reuse, and/or recycle wastes, as established by [42 U.S.C. 133](#).

[Executive Order 13423](#), “Strengthening Federal Environmental, Energy, and Transportation Management” (72 FR 3919); [Executive Order 13514](#), “Federal Leadership in Environmental, Energy, and Economic Performance” (74 FR 52117); and [DOE O 436.1](#), *Departmental Sustainability*, establish pollution prevention and environmental stewardship requirements. In accordance with these requirements, pollution prevention and waste minimization activities are documented, tracked, and reported. Table 2.9 summarizes Hanford Site pollution prevention and waste minimization quantities recycled in FY 2015.

Table 2.9. Recycle Quantities

Material	FY 2015 Total (MT)
Non-hazardous Solid Wastes	
Cardboard	76.03
CI Shredded Paper	505.64
Furniture	141.4
Plastic Bottles	31.92
Tires	44.28
Wood Pallets	41.88
Brass Metals	0.00
Ferrous Metal	146.47
Non-ferrous Metals	39.85
Software/Media	6.89
Aluminum Cans	805
MSA Zero Waste Picnic	0.002
WCH Scrap Metal	100.29
Subtotal	1939.652
Regulated Solid Wastes	
Aerosol Cans	0.00
Antifreeze	3.82
Antifreeze – Fleet	0
Ballasts	2.08
Batteries	4.05
Fluorescent Bulbs	5.26
Lamps	2.29
Lead Acid Batteries	15.35
Lead Acid Batteries (Fleet)	10.27
PCB Waste Oil <50ppm	0
Toner Cartridges	8.69
Used Engine Oils (Fleet)	18.79
Used Oil	25.3
WCH Cartridge	4.18
Subtotal	100.08
TOTAL	2039.732

2.6.2.1 Pollution Prevention and Waste Minimization Accomplishments and Awards

The Hanford Site did not receive any DOE, federal agency, state agency, or industry-sponsored awards for pollution prevention and waste minimization accomplishments in CY 2015.

2.6.2.2 Accomplishments

The Hanford Site has recycled 76% of non-hazardous solid waste and certain hazardous waste, excluding construction and demolition (C&D) debris. In 2015, 2,040 MT of non-hazardous (plastic, aluminum, cardboard, paper, wood, and metal) and hazardous (antifreeze, batteries, bulbs, and oils) wastes were recycled through Hanford Site programs administered through the Mission Support Contract. Along with material recycling and diversion, the site strives to reduce greenhouse gases (GHG) Scopes 1, 2 and 3. Emissions for FY 2015 decreased from FY 2014 largely due to a decrease in fleet diesel fuel use, with 71,050 MT of carbon dioxide equivalent (CO₂e) compared with 102,645 MTCO₂e from the FY 2008 baseline and 78,690 MTCO₂e reported for FY 2014. There was a 39% reduction in Scope 3 GHG emissions for the Hanford Site in FY 2015 from the FY 2008 baseline: emissions in FY 2015 were 25,312 MTCO₂e, whereas emissions in FY 2008 were 41,381 MTCO₂e. GHG emissions from employee commuting, business travel, off-site wastewater treatment, and contracted solid waste disposal are primarily dependent on work locations and the number of workers employed at the Hanford Site.

During 2015, contractors at the Hanford Site continued to divert C&D from landfill disposal. The Hanford Site diverted approximately 980% (1,902 MT) of C&D debris from the inert landfill, disposing 478.5 MT of debris to the landfill. Hanford continues to implement additional power management initiatives. There were several ongoing power management and other environmentally preferable initiatives throughout 2015, including the following:

- Thin Client (Zero Clients) implementation (replacing desktop computers with energy efficient Thin Clients). Implementation of the Thin Client (Zero Clients) and this category of products are not covered by ENERGY STAR™ or EPEAT, but have superior energy efficiency.
- Increased use of “Convenience Copiers” allowed for removal of standalone and network printers.
- 100% of the equipment on the Hanford Site is set to automatic duplexing, including printers, copiers, and multi-function devices.
- Over 717 computers, monitors, printer, televisions, and servers were recycled through a certified recycler.

2.6.3 Environmental Orders

CJ Clement, SW Davis

One DOE order and two Presidential Executive Orders addressing sustainability are complied with at the Hanford Site.

[Executive Order 13423](#) established a policy for federal agencies to conduct legally, environmentally, economically, and fiscally sound environmental, transportation, and energy-related activities in an integrated, efficient, continuously improving, and sustainable manner. The order established goals for the following areas: improved energy efficiency; reduced greenhouse gas emissions; use of renewable energy sources; renewable energy generation; reduced water consumption; acquisition of bio based, environmentally preferable, energy-efficient, water-efficient, and recycled products; reduced use of toxic and hazardous chemicals and materials; increased waste minimization, prevention, and recycling; use of sustainable building practices; reduced use of

petroleum products for vehicles; and electronics stewardship. In addition, [Executive Order 13423](#) requires that an Environmental Management System (EMS) be established as the mechanism for managing environmental goals, as well as other impacts to the environment from Hanford Site operations, and establishing environmental objectives and targets. The order also requires establishing environmental management training, environmental compliance review and auditing, and leadership awards to recognize outstanding environmental, energy, or transportation management performance.

[Executive Order 13514](#) states that federal agencies shall increase energy efficiency; measure, report, and reduce their greenhouse gas emissions from direct and indirect activities; conserve and protect water resources through efficiency, reuse, and storm water management; eliminate waste, recycle, and prevent pollution; leverage agency acquisitions to foster markets for sustainable technologies and environmentally preferable materials, products, and services; design, construct, maintain, and operate high performance sustainable buildings in sustainable locations; strengthen the vitality and livability of the communities in which federal facilities are located; and inform federal employees about and involve them in the achievement of these goals. In addition, [Executive Order 13514](#) requires that targets for baseline Scope 1 (generated from site operations and activities) and Scope 2 (associated with the purchase of energy [electricity, heat, or steam] used by site contractors) greenhouse gas emissions, along with 2020 reduction targets, be established.

Similar numbers for Scope 3 (emissions associated with ancillary activities related to Hanford Site operations, including business travel, employee commuting, vendor activities, delivery services) emissions must be established. [Executive Order 13514](#) also sets goals for improved water use efficiency and management, promotion of pollution prevention and waste elimination, advancement of regional and local integrated planning, implementation of sustainable building lifecycle management practices, advancement of sustainable acquisition, and promotion of electronics stewardship. [Executive Order 13514](#) requires continued implementation of a formal sustainable EMS.

[DOE O 436.1](#) requires developing a Site Sustainability Plan integrated with the Hanford Site operational plans. In addition, the order requires developing an EMS certified to or conforms with the ISO 14001:2004 standard, submittal of sustainability goal data and reports as well as EPCRA reporting. Implementation of DOE orders and executive orders by Hanford Site contractors is addressed in Section 3.0.

As the Hanford Site services and infrastructure contractor, MSA updated the sustainability plan for the Hanford Site in 2015 with input from DOE and Hanford Site contractors. The plan describes the energy management program and identifies planned energy efficiency, water conservation, transportation fleet management, and sustainable buildings activities, as required by [DOE O 436.1](#). Environmental objectives developed in 2010 were maintained in 2015, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship (see Section 3.0).

2.7 Occurrence Reporting and Processing of Operations Information

TH Pysto

Releases of radioactive and regulated materials to the environment are reported to DOE and other federal and state agencies as required by law. The specific agencies notified depend on the type, amount, and location of each release event. This section addresses releases or potential releases to the environment that may not be documented by other reporting mechanisms during the reporting period. All Hanford Site

occurrences are reported to the Hanford Emergency Operations Center Shift Office and subsequently recorded in 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](#), *Occurrence Reporting and Processing of Operations Information*). The following sections summarize occurrences that may have impacted the Hanford Site environment in 2015. The occurrences are arranged according to significance category, which are assigned based on the nature and severity of the occurrence. The categories include Operational Emergency; Recurring; or Category 1 (significant impact), Category 2 (moderate impact), Category 3 (minor impact), and Category 4 (some impact).

2.7.1 Operational Emergency; Recurring; or Category 1

There were no Hanford Site environmental occurrences ranked as Operational Emergency, Recurring, or Category 1, Significant Impacts.

2.7.2 Operational Emergency; Recurring; or Category 2

There were no Hanford Site environmental occurrences ranked as Operational Emergency, Recurring, or Category 2, Moderate Impacts.

2.7.3 Operational Emergency; Recurring; or Category 3

There were no Hanford Site environmental occurrences ranked as Operational Emergency, Recurring, or Category 3, Minor Impacts.

2.7.4 Operational Emergency; Recurring; or Category 4

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. Summarized below is a Category 4 occurrence with potential environmental implications that occurred on the Hanford Site during the reporting period, and the discoveries of legacy contamination.

Discovery of Legacy Contamination. Each year on the Hanford Site, legacy contamination is spread from environmental conditions. Some contamination is discovered during routine survey work. Biological vectors also spread contamination; tumbleweeds, rodents, and birds are all common biological vectors. Tumbleweeds have a deep taproot that can sequester contamination from below the soil surface into the plant body on the surface. Rodents eat vegetation located in contaminated areas and deposit contaminated feces outside of the contaminated area. Birds build nests and occasionally use materials from contaminated areas, resulting in contamination transfer to uncontaminated areas. Of these three biological vectors, contaminated tumbleweeds occur most frequently and have the potential to transfer contamination the farthest distance from the original locations. High winds may contribute to the spread of legacy contamination beyond posted areas. Reports of legacy contamination that are discovered throughout the year are consolidated into quarterly reports. In 2015, there were 46 documented occurrences of legacy contamination.

2.8 Standards and Permits

JK Perry, RA Kaldor, M Kamberg, JW Wilde

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 are listed in Table 2.10.

Table 2.10. Environmental Permits**Dangerous Waste Permit (RCRA)**

Hanford Facility RCRA Permit (WA7890008967) was issued on September 27, 1994 and has undergone several revisions. The permit expired on September 27, 2004; however, Permit WA7890008967, Rev. 8C remains in effect until a new permit is issued. Ecology issued a draft permit for public review and comment, from May 1, 2012 through October 22, 2012 ([Ecology 2012](#)). Ecology received more than 4,000 comments on the draft permit, including approximately 1,800 comments from the public and 3,000 comments from the DOE. Because information and arguments brought up during the comment period raised substantial new questions, Ecology plans to revise the draft permit and reopen the comment period (see Section 2.1.2.1).

Air Permits

Hanford Site Air Operating Permit 00-05-006, Renewal 2, covers operations on the Hanford Site having a potential to emit airborne emissions. This permit was effective on April 1, 2013 and expires March 31, 2018. The permit is intended to provide a compilation of applicable *Clean Air Act* requirements for radioactive and non-radioactive emissions at the Hanford Site. It will be implemented through federal and state programs (see Section 2.3.2).

Radioactive Air Emissions License for the Department of Energy Richland Operations Office Hanford Site (License FF-01) is issued to RL by WDOH. This permit was effective February 23, 2012 and expires December 31, 2017. The FF-01 license is a compilation of all applicable radioactive air emission requirements.

Drinking Water Permits

ID# 00177 J is a permit to operate the 100-K Area drinking water system. WDOH issues the permit.

ID# 00100 4 is a permit to operate the 200-West Area drinking water system. WDOH issues the permit.

ID# 41840 8 is a permit to operate the 300 Area drinking water system. WDOH issues the permit.

ID# 41947 0 is a permit to operate the 400 Area drinking water system. WDOH issues the permit.

Wastewater Permits

Permit CR-IU010, 300 Area Industrial Wastewater Discharge Permit, is issued to RL by the City of Richland. Permit CR-IU010 governs the discharges from the 300 Area facilities into the City of Richland sewer collection system.

HAN002 through HAN075 permit on-site sewage systems to operate on the Hanford Site. WDOH issues these permits.

Permit ST-0004500, *State Waste Discharge Permit*, allows treated wastewater from the Effluent Treatment Facility to be discharged to the State-Approved Land Disposal Site. This permit is effective until December 31, 2019.

Permit ST0004502, *State Waste Discharge Permit*, allows treated effluent from the 200-East and 200-West Areas to be discharged to the 200 Area Treated Effluent Disposal Facility. This permit is effective until June 30, 2017.

Permit ST0004511 is a Categorical State Waste Discharge Permit that authorizes the discharge of wastewater from maintenance, construction, and hydro testing activities and allows for cooling water, condensate, and industrial storm water discharges at the Hanford Site. This permit was issued January 1, 2014 and expires February 16, 2019.

Permit ST0045514, *State Waste Discharge Permit*, is for the 200-West Area Evaporative Sewage Lagoon a domestic wastewater treatment facility located northeast of the 200-West Area. The facility consists of double-lined evaporative lagoons and is designed to have no liquid discharge to the ground. The system provides domestic wastewater treatment for the 200-West and 600 Areas, and treatment for domestic wastewater hauled from the 200-East Area and other locations within the site.

Permit WAG-50-5180, Washington State Sand and Gravel General Permit for the Concrete Batch Plant in the 200-East Area. The Concrete Batch Plant supports construction of WTP; its primary function is making concrete. The permit provides coverage for discharges of process water and storm water associated with Ready Mix Concrete operations. Bechtel National is the permit owner. This permit expired October 1, 2015; however, a renewal application was submitted allowing the permit to remain in effect through the remainder of 2015.

Permit WAG-50-5181, Washington State Sand and Gravel General Permit for Pit 30 Quarry in the 200-East Area. Ecology issued the permit to BNI as owner/operator. The Pit 30 Quarry supports the construction of the WTP, and the primary function is making construction sand and gravel. This permit expired October 1, 2015; however, a renewal application was submitted allowing the permit to remain in effect through the remainder of 2015.

Wildlife Permits

Permit MB60138B-1, Federal Fish and Wildlife Permit, issued by the U.S. Fish and Wildlife Service to DOE-RL, authorizes the collection of migratory birds for ecological monitoring, and danger to human safety and health including control of contamination. This permit expires March 31, 2018.

Table 2.10. Environmental Permits

Permit MB81249A-1, Federal Fish and Wildlife Permit, issued by the U.S. Fish and Wildlife Service to MSA, authorizes the collection of migratory birds for danger to human safety and health and the determination and control of contamination. This permit expired March 31, 2015.

Review Reference Number 13260-2009-I-0121, Federal Fish and Wildlife Section 7 Review, issued to Environmental Assessment Services in July 2009, for the potential of incidental take of salmonids during fishing activities in the Columbia River. This review has no expiration listed.

Review Reference Number 13260-2011-I-0080, Federal Fish and Wildlife Section 7 Review, issued to DOE in July 2011 for the potential of incidental take of bull trout during fishing activities in the Columbia River. This review has no expiration listed.

Permit 15-221a, Scientific Collection Permit issued by WDFW to MSA for May 2015 through May 2016, authorizes food fish, shellfish, game fish, and wildlife collection for research purposes. This permit is renewed annually.

Permit 14-151a, Scientific Collection Permit issued by WDFW to MSA for May 2014 through May 2015, authorizes the collection of food fish, shellfish, game fish, and wildlife for research purposes. This permit is renewed annually.

Agency Contact Information

State of Washington Department of Ecology P.O. Box 47600 Olympia, WA 98504-7600	U.S. Environmental Protection Agency Region 10 1200 Sixth Ave. Seattle, WA 98101	U.S. Department of Energy Richland Operations Office 825 Jadwin Ave. Richland, WA 99352
U.S. Fish and Wildlife Service Migratory Bird Permit Office 911 NE 11th Ave. Portland, OR 97232-4181	Washington State Department of Health P.O. Box 47890 Olympia, WA 98504-7890	

2.9 Environmental Noncompliance

JW Cammann

2.9.1 Regulatory Agencies

During CY 2015, there were 27 regulatory agency compliance actions filed against the DOE and its contractors for alleged violations of regulatory requirements (3 to WDOH, 19 to Ecology, and 5 to EPA Region 10) or other enforceable agreements. Fourteen of the 27 compliance actions resulted from regulatory agency inspections of DOE facilities on the Hanford Site (see Section 2.1.2.2). The compliance actions resulted in 54 concerns and 72 compliance actions that contributed to \$169,722 in fines and penalties during CY 2015. Table 2.11 summarizes the alleged environmental noncompliances by program area. Table 2.12 summarizes the 27 alleged environmental noncompliances filed against the DOE and its contractors during CY 2015 including a description of the alleged noncompliances. Figure 2.1 shows alleged environmental noncompliance concerns, violations, and associated fines.

Table 2.11. Alleged Environmental Noncompliance Summary by Program Area, 2010–2015

Program Area	2010	2011	2012	2013	2014	2015
CAA	3	0	0	4	2	3
CWA	1	0	0	0	0	1
RCRA	3	1	2	4	7	16
CERCLA	0	0	3	1	0	0
Others	4	1	2	1	1	7
Total Notices of Violation	11	2	7	10	10	27

Table 2.12. Summary of Alleged Environmental Noncompliances for CY 2015

Agency	Doc Number	Title	Alleged Noncompliance Description
EPA	2016-06	DISPUTE RESOLUTION REGARDING DISAPPROVAL OF TRI-PARTY AGREEMENT CHANGE CONTROL FORM M-16-15-08	DOE-RL notification to EPA that TPA Milestone M-016-149, "Complete 100-IU-2/6 Interim Response Actions," due March 31, 2016, will be missed.
Ecology	2016-05	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT 241-CX TANK SYSTEM	Incomplete documentation of annual inspections of 241-CX Tank System; using initials rather than full name when signing inspection reports.
Ecology	2016-04	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT HEXONE STORAGE AND TREATMENT FACILITY	Time of annual facility inspection not documented on data sheets; some data sheets missing second page.
Ecology	2016-03	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT 400 AREA WASTE MANAGEMENT UNIT	Revise contingency plan and Fast Flux Test Facility building emergency plan to include location of emergency response and spill control equipment; inspection log deficiencies including times, signatures, and notation of problems/repairs.
Ecology	2016-02	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT SINGLE-SHELL TANK FARMS	Proper posting of signage on tank farm perimeter fencing to indicate hazard, incomplete dangerous waste inspection records, failure to remedy problems on inspection records, dangerous waste training plan deficiencies.
Ecology	2016-01	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT LOW-LEVEL BURIAL GROUND TRENCHES 31/34	Failure to perform dangerous waste inspections weekly; deficiencies in list of job titles in Dangerous Waste Training Plan; less than 90-day accumulation tank labeling deficiencies.
Ecology	2015-23	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT WASTE TREATMENT PLANT MATERIAL HANDLING FACILITY	Improper labeling of dangerous waste containers to indicate their contents and potential hazards.
Ecology	2015-22	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT OPERATION AND MAINTENANCE GROUNDWATER MONITORING WELLS	Operation and maintenance groundwater monitoring well violation of dangerous waste regulations including inspection reporting, groundwater sampling, calculation of critical means, groundwater monitoring plans and records.
WDOH	2015-21	NOTICE OF HIGH PRIORITY VIOLATIONS FOR 291-A-1 (PUREX), 296-B-1 (B-PLANT), AND 296-H-212 (CANISTER STORAGE BUILDING) EXHAUST STACKS	High priority violations associated with emission unit sampling and monitoring system operations.
Ecology	2015-20	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT WASTE RECEIVING AND PROCESSING FACILITY (WRAP)	WRAP Dangerous Waste Training Plan failing to include all personnel who prepare/maintain records, provide training, provide regulatory interpretations, are responsible for notifications, and perform emergency response.
Ecology	2015-19	DANGEROUS WASTE INSPECTION AT LOW-LEVEL BURIAL GROUND GREEN ISLANDS (LLBG-GI) AND NONRADIOACTIVE DANGEROUS WASTE LANDFILL (NRDWL)	NRDWL inspection records dated 1/6/2014, 4/2/2014, 7/8/2014, 10/6/2014, and 1/6/2015 did not include the time of the inspection. LLBG-GI indicated items needing repair; but, no details provided.
Ecology	2015-18	DISPUTE RESOLUTION REGARDING DISAPPROVAL OF TRI-PARTY AGREEMENT CHANGE CONTROL FORM M-45-15-03	Change control form modifies Milestone M-045-82 for submittal of complete permit modification requests for Tiers 1, 2, and 3 currently due September 30, 2015.
Ecology	2015-17	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT T-PLANT	Alleged violations of WAC 173-303 dangerous waste regulations for waste storage, employee training, and container labeling.
Ecology	2015-16	NOTICE OF HIGH PRIORITY VIOLATION FOR THE 222-SE ENGINE AT 222-S LABORATORY	Operation of the 222-SE Engine (located at the 222-S Laboratory) in excess of 100 hours in a calendar year.
WDOH	2015-15	NOTICE OF HIGH PRIORITY VIOLATION FOR THE 291-A-1 PUREX EXHAUST STACK	Operation of PUREX stack 291-A-1 (EU 369) without continuous sampling of stack emissions as required by the Air Operating Permit and Radioactive Air Emissions License (FF-01) due to a break in the sampling line.
Ecology	2015-14	DISPUTE RESOLUTION REGARDING DISAPPROVAL OF TRI-PARTY AGREEMENT CHANGE CONTROL FORM M-45-15-01	Initiation of dispute resolution under the TPA for Ecology's disapproval of TPA Change Form M-045-15-01.

Table 2.12. Summary of Alleged Environmental Noncompliances for CY 2015

Agency	Doc Number	Title	Alleged Noncompliance Description
Ecology	2015-13	NOTICE OF NON-COMPLIANCE WITH DANGEROUS WASTE REGULATIONS AT 207-A SOUTH RETENTION BASIN	Inadequate inspection procedures, incomplete inspection records, insufficient corrective actions to remedy problems discovered during inspections.
WDOH	2015-12	AS LOW AS REASONABLY ACHIEVABLE CONTROL TECHNOLOGY DEMONSTRATION FOR MANAGEMENT OF HEPA FILTERS	HEPA filters in service exceeding 10-year lifetime.
EPA	2015-11	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT THE CENTRAL WASTE COMPLEX, CENTRALIZED CONSOLIDATION/ RECYCLE CENTER, AND MIXED WASTE TRENCHES 31 AND 34	Compliance with dangerous waste permit, dangerous waste generator standards, universal waste management standards, and used oil management standards.
Ecology	2015-10	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT B-PLANT	Inadequate waste designation, improper emergency equipment per building emergency plan, need to update building emergency plan, improper tank labeling, closure plan for 221-B, tank inspections, inaccurate LDR reports.
Ecology	2015-09	NOTICE OF VIOLATION OF WASTEWATER DISCHARGE PERMIT REQUIREMENTS AT MO-234 DURING POTABLE WATER LINE BREAK	Failure to notify Ecology of a noncompliance with ST 4511 permit and failure to identify and report correctly an unauthorized discharge covered by the ST 4511 permit.
Ecology	2015-08	DISPUTE RESOLUTION ON DISAPPROVAL OF TRI-PARTY AGREEMENT CHANGE CONTROL FORM M-62-14-02	Initiation of dispute resolution under the TPA for Ecology's disapproval of TPA Change Form M-62-14-02.
Ecology	2015-07	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT THE 331 BUILDING AND 350 COMPLEX	Hazardous waste manifest deficiencies, dangerous waste training plan deficiencies, container labeling deficiencies, and container inspection deficiencies.
Ecology	2015-06	NOTICE OF VIOLATION OF DANGEROUS WASTE REGULATIONS AT TRENCH 94 AND CENTRAL WASTE COMPLEX OPERATING UNIT GROUP 6	Dangerous Waste Training Plan deficiencies, Contingency Plan not maintained on site, Building Emergency Director not on site.
EPA	2015-05	CONSENT AGREEMENT AND FINAL ORDER FOR DANGEROUS WASTE REGULATION VIOLATIONS AT EFFLUENT TREATMENT FACILITY/LIQUID EFFLUENT TREATMENT FACILITY (ETF/LERF) AND INADEQUATE CLOSURE PLANS	Inadequate closure plan for eight treatment, storage, and disposal (TSD) units per WAC 173-303-610; noncompliant storage of drummed dangerous waste at ETF/LERF.
EPA	2015-04	DISPUTE RESOLUTION ON DISAPPROVAL OF TRI-PARTY AGREEMENT CHANGE CONTROL FORM M-16-14-04	Inability to meet TPA milestone M-016-173, "Select Sludge Treatment and Packaging Technology and Propose New Interim Sludge Treatment and Packaging Milestones" by March 31, 2015 due to funding uncertainties.
EPA	2015-03	DISPUTE RESOLUTION ON DISAPPROVAL OF TRI-PARTY AGREEMENT CHANGE CONTROL FORM M-16-13-04	Inability to meet TPA milestone M-016-149 for remediation of several waste sites by 3/31/2015 due to NHPA Section 106 consultations, discovery of unanticipated materials, and associated safety concerns.

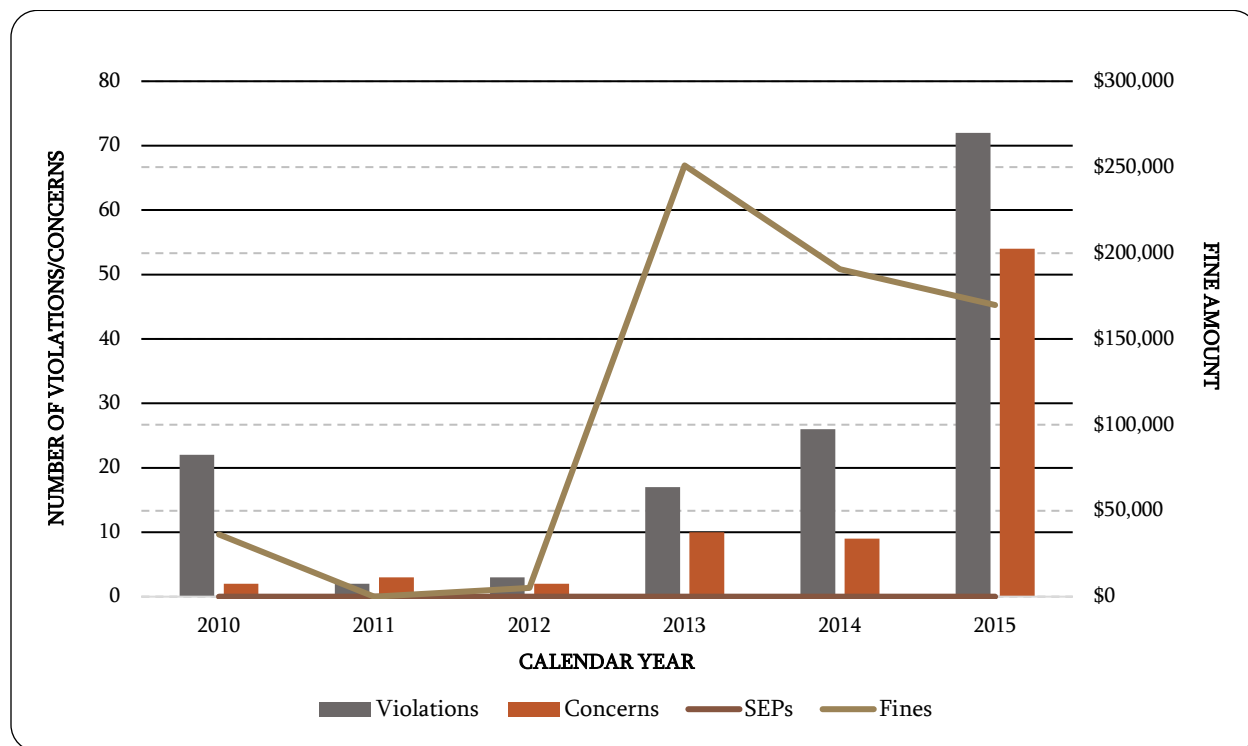


Figure 2.1. Alleged Environmental Noncompliance Violations, Concerns, and Associated Fines Summary

SEPs = Supplemental environmental projects performed to benefit the local community in lieu of a penalty payment

To avoid litigation expense and to settle administrative or judicial claims or causes of action a regulatory agency may have against them, DOE and its contractors, without admitting fault or liability, may enter into Agreed Orders and other negotiated regulatory agreements to resolve regulatory agency allegations asserted therein. Nothing in the agreements or in the execution and implementation of the terms and conditions of the agreements shall be taken as an admission of liability by DOE and its contractors, and DOE and its contractors neither admit nor deny the specific factual allegations contained therein. Regulatory agencies progress through a variety of tools to gain compliance, usually starting with a warning letter or letter of noncompliance. If the warning does not result in compliance, then enforcement actions can escalate to notices, orders, or civil penalties issued by the Washington State Attorney General. Although DOE and its contractors may receive warning letters from regulatory agencies, such letters do not constitute formal enforcement actions represented by notices, orders, or civil penalties issued by the Washington State Attorney General that may be appealed.

2.9.2 Waste Water Permit Deviations

M Kamberg

During CY 2015, 20 wastewater permit deviations were reported as indicated in Table 2.13.

Table 2.13. CY 2015 Wastewater Permit Deviations

Date	Permit Number Deviated	Reported to	Reason(s)
January 11	ST0004502	Ecology	Leaking valve on the TEDF line at manhole TL-2
January 13	ST0004511	Ecology	Water leak in a caisson
January 29	ST0004502	Ecology	Two leaking valves on the TEDF line at manholes TL-1 and TL-6
January 29	ST0004500	Ecology	Leak on the SALDS line at manhole ETF-06
February 6	ST0004511	Ecology	Water leak caused by a stuck flushing valve
April 7	ST0004511	Ecology	Failing to follow applicable best management practices identified in permit condition S4.A.2 for a potable water tank leak at MO-098
April 8	ST0004502	Ecology	Minor leaks from the air vacuum relief valves
April 13	ST0004511	Ecology	Water leak near Building 2220E
April 16	ST0004502	Ecology	Leak from a blind flange connection
April 23	ST0004511	Ecology	Water overflow at the 283-WD facility
May 7	ST0004511	Ecology	Nine (9) permit deviations via letter for water line leaks that occurred during CYs 2013 and 2014
May 13	ST0004511	Ecology	Failing to follow applicable best management practices identified in permit conditions S4.A.2 and S4.A.4 for a chiller flush discharge at 222-S
July 11	ST0004511	Ecology	Water line leak near the 300 Area fire station
July 13	300 Area Combined Sewer Permit CR-IU010	City of Richland	Low pH not sampled within required time frame
August 18	ST0004502	Ecology	Chloroform effluent limit exceedance
September 23	ST0004511	Ecology	Water discharges from mobile car wash
October 14	HAN071	WDOH	Release of sewage to the ground at lift station 2607-E6
October 30	HAN049	WDOH	Release of sewage to the ground at lift station 2607-W1
November 10	HAN047	WDOH	Release of sewage to the ground at lift station 2607-W1
December 3	ST0004511	Ecology	Failing to follow applicable best management practices identified in permit condition S4.A.2 for leak from a break in chiller potable water feed line at 222-S
December 15	ST0004511	Ecology	Discharging water within 300 feet of a Waste Information Data System site

3.0 Environmental Management System

SL Vaughn

DOE requires Hanford Site contractors to develop and operate under an Integrated Safety Management System (ISMS). In accordance with contract obligations, contractors maintain an EMS that is consistent with ISO 14001 standard. In 2015, all but one Hanford Site contractor established ISMS as mandated by their contracts with 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. DOE verified that Hanford Site entities incorporated appropriate environmental program elements within their ISMS under the authority of [DOE M 450.4-1](#), *Integrated Safety Management System Manual*. The dates that DOE approved the Hanford Site contractor's ISMS are provided in Table 3.1. Table 3.2 lists applicable DOE orders and their approval dates.

Table 3.1. DOE Contract Actions and Contractor Implementation

Actions, Implementation	Richland Operations Office				Office of River Protection		
	HPMC	CHPRC	MSA	WCH	ATL	BNI	WRPS
Contractor Start Date	Oct 1, 2012	Oct 1, 2008	Aug 24, 2009	Aug 27, 2005	May 5, 2005	Dec 11, 2000	Oct 1, 2008
DOE Approval of Contractor ISMS	NA	Nov 2009	Jan 2011	Nov 2007	Mar 2006	Feb 2003	Sept 2009
Direction to Implement DOE EO 13423	Oct 2012	Oct 2008	Aug 2009	June 2009	NA	NA	Oct 2008
Direction to Implement DOE EO 13514	NA	June 2012	May 2011	Oct 2012	NA	NA	Mar 2011
Direction to Implement DOE O 430.2B	NA	June 2009	Aug 2009	June 2009	NA	NA	Oct 2008
Direction to Cancel DOE O 430.2B	NA	July 2012	July 2012	Oct 2012	NA	NA	Sept 2014
Direction to Implement DOE O 450.1A	Oct 2012	June 2009	Aug 2009	June 2009	Nov 2009	NA	Oct 2009
Direction to Cancel DOE O 450.1A	Oct 2012	July 2012	Dec 2012	Oct 2012	Sept 2013	NA	Sept 2014
Direction to Implement DOE O 436.1	NA	July 2012	July 2012	Oct 2012	NA	NA	Oct 2013
Contractor EMS Established	Oct 2012	Nov 2009	Dec 2009	Sept 2009	NA	NA	Sept 2009
ISO 14001 Certification	NA	Jul 2012/2015	Sept 2011/2014	NA	NA	NA	NA
DOE Declared DOE O 450.1A Conformance	NA	Dec 2009	Dec 2009	Nov 2009	NA	NA	Sept 2009
Most Recent Declaration of Conformance	NA	Jul 2015	Sept 2014	Sept 2015	NA	NA	Sept 2015
Contractor EMS Scorecard Rating	Red	Green	Green	Green	Red	Red	Green
EMS Scorecard for 2014	Green				Yellow		

ATL=Advanced Technologies and Laboratories, Inc., BNI=Bechtel National, Inc., CHPRC=CH2M Plateau Remediation Company, EMS=Environmental Management System, HPMC=HPMC Occupational Medical Services, MSA=Mission Support Alliance, LLC, WCH=Washington Closure Hanford, LLC, WRPS=Washington River Protection Solutions, LLC

Table 3.2. DOE Order and Executive Order Issuance

Order	Approval Date
DOE Order 450.1	January 15, 2003
Executive Order 13423	January 26, 2007
DOE Order 430.2B	February 27, 2008
DOE Order 450.1A	June 4, 2008
Executive Order 13514	October 8, 2009
DOE Order 436.1	May 2, 2011
Executive Order 13693	March 25, 2015

Performance related to EMS must be reported annually to DOE Headquarters (HQ). Each contractor is given an overall ranking of red, yellow, or green based on the previous fiscal year's performance. Rankings for Hanford Site contractors are provided in Table 3.1 along with rankings for both RL and ORP.

As the services and infrastructure contractor for the Hanford Site, MSA developed a sustainability plan for the Hanford Site in 2015 with input from site contractors. The plan describes the energy management program and identifies planned energy efficiency, water conservation, transportation fleet management, and sustainable buildings activities, as required by [DOE O 436.1](#). Environmental objectives developed in 2010 were maintained in 2015, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship.

Several contractors have made their environmental policy and environmental aspects available to the public through company Internet websites (Table 3.3). An EMS is a systematic approach to environmental performance ensuring planned activities lead to continual improvement and demonstrating to stakeholders a commitment to the environment.

Table 3.3. Hanford Site Environmental Management System Internet Links

Contractor	Website	Category
CHPRC	http://chprc.hanford.gov/files.cfm/prc-pol-sh-5053.pdf	Policy
MSA	http://msa.hanford.gov/files.cfm/ems.pdf	Policy, Aspects
WCH	http://www.washingtonclosure.com/about_us/environmental_stewardship	Policy, Aspects
WRPS	http://wrpstoc.com/tank-operations/environmental-management/	Policy, Aspects

3.1 Environmental Performance Measures

In consultation with DOE and other Hanford Site prime contractors, MSA developed and maintains environmental performance measures for the Hanford Site. Performance measures address the goals of [DOE O 436.1](#), [Executive Order 13423](#), and [Executive Order 13514](#). The measures developed in response to these executive and DOE orders include regulated waste reduction; toxic and hazardous material reduction; sustainable acquisition; compliance with electronic product environmental assessment tool standards; sanitary waste diversion; construction waste diversion; electricity use; facility fuel use; water use; vehicle fuel use; numbers of alternative fuel vehicles; on-time environmental deliverables; environmental inspections; environmental non-compliances; and greenhouse gas reduction. Baseline data were obtained in accordance with guidance in the orders.

Where no guidance was available, data from 2009 or 2010 were used to establish performance baselines. Performance measurement data are used as a tool to ensure environmental goals within the DOE Orders are appropriately managed. Performance related to EMS must be reported annually to HQ.

Fleet Management. The acquisition target for alternative fuel vehicles was not met in 2015 (Figure 3.1). DOE requires that a minimum of 100% of all non-mission critical light-duty vehicles purchased during FY 2015 be alternative fuel vehicles ([DOE O 436.1](#)).

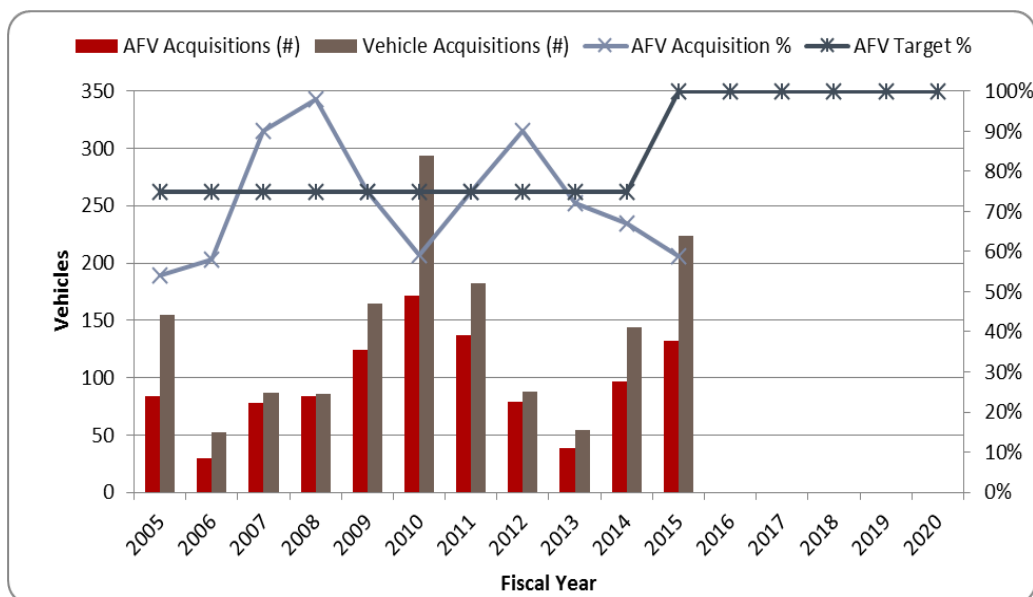


Figure 3.1. Fleet Management – Acquisitions FYs 2005–2020

AFV = alternative fuel vehicle

Alternative Fuel Use. The alternative fuel use target was surpassed for FY 2015, as was the target for petroleum-based fuel use (Figure 3.2). The requirement specifies that Hanford Site contractors fleets operate alternative fuel vehicles exclusively on alternative fuels to the maximum extent possible to reduce the amount of petroleum-based fuels used by 2% annually through FY 2020, relative to a FY 2005 baseline and to increase the amount of alternative fuels used by 10% annually through to FY 2015 relative to a FY 2005 baseline ([Executive Order 13514](#) [74 FR 52117]).

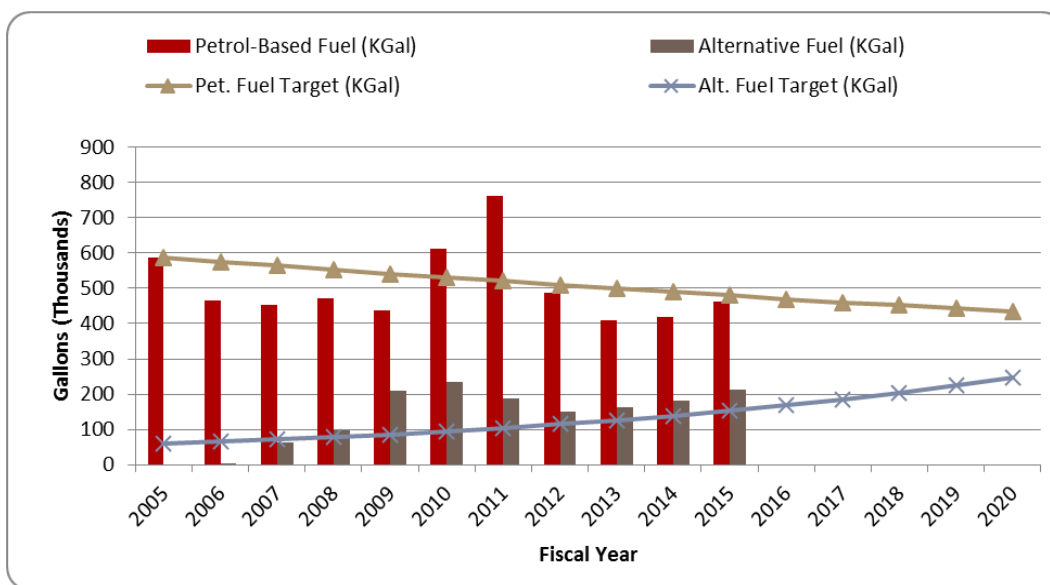


Figure 3.2. Vehicle Fuel Use – FYs 2005–2015 with Target Objectives through 2020

Potable and Non-potable Water Use. The target objectives for potable and non-potable were met in FY 2015 (Figure 3.3). As specified by [Executive Order 13514](#) (74 FR 52117), water use requirements stipulate the reduction of potable water consumption intensity by 2% annually through FY 2020 or 26% by the end of FY 2020, relative to a baseline of water consumption in FY 2007. Correspondingly, there is a requirement to reduce non-potable water use by 2% annually through the end of FY 2020 or 20% by the end of FY 2020 relative to a FY 2010 baseline.

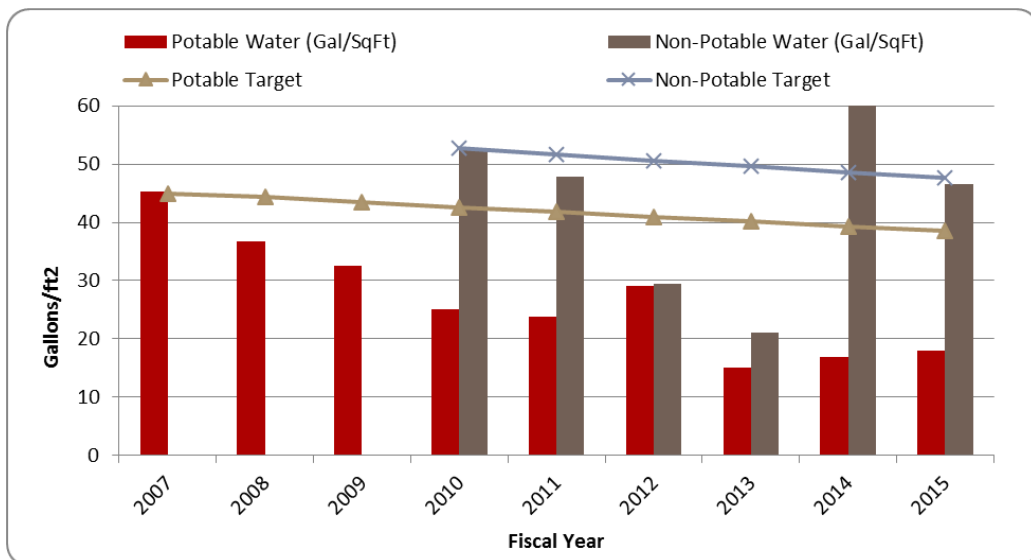


Figure 3.3. Water Use – FYs 2007–2015 with Target Objectives through 2015

Electricity Use. The target objective for green electricity was met; however, the target objective for standard electricity was not met in FY 2015 (Figure 3.4). Targets and objectives for electricity use designate improvements to increase energy efficiency and energy management. Requirements call for the reduction of standard electricity use by 3% annually or 45% through the end of FY 2020 relative to the FY 2003 baseline, and an increase in renewable energy consumption (green electricity) equivalent to 7.5% of the annual electricity and thermal consumption total by FY 2010.

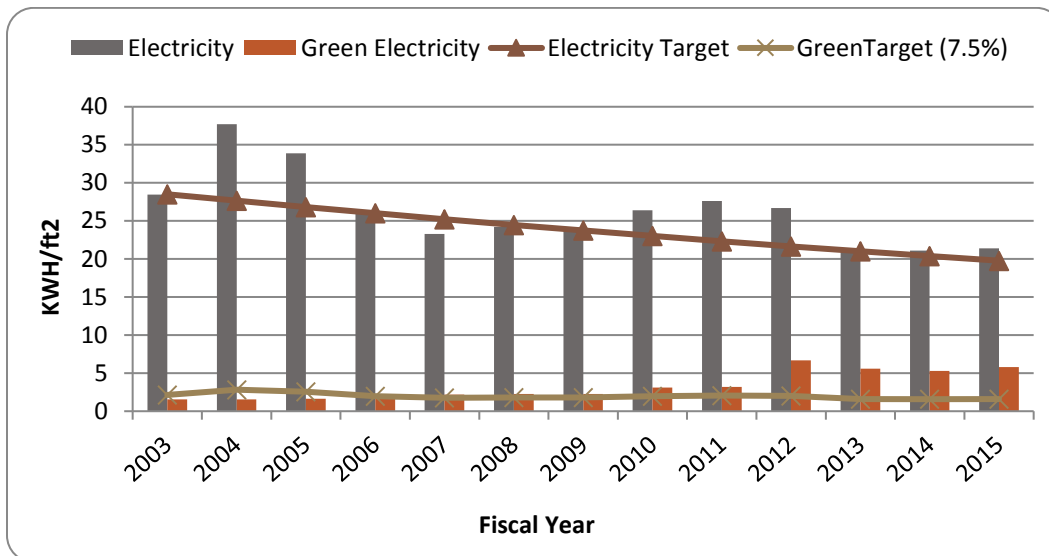


Figure 3.4. Electricity Use – FYs 2003–2015 with Target Objectives through 2015

Facility Fuel Use. The target objectives for facility fuel use were met in FY 2015 (Figure 3.5). Objectives were established to demonstrate improvements in energy efficiency and effective management of energy use. The target requirements include reducing energy use by 3% annually (or 45% through the end of FY 2020) relative to the FY 2003 baseline.

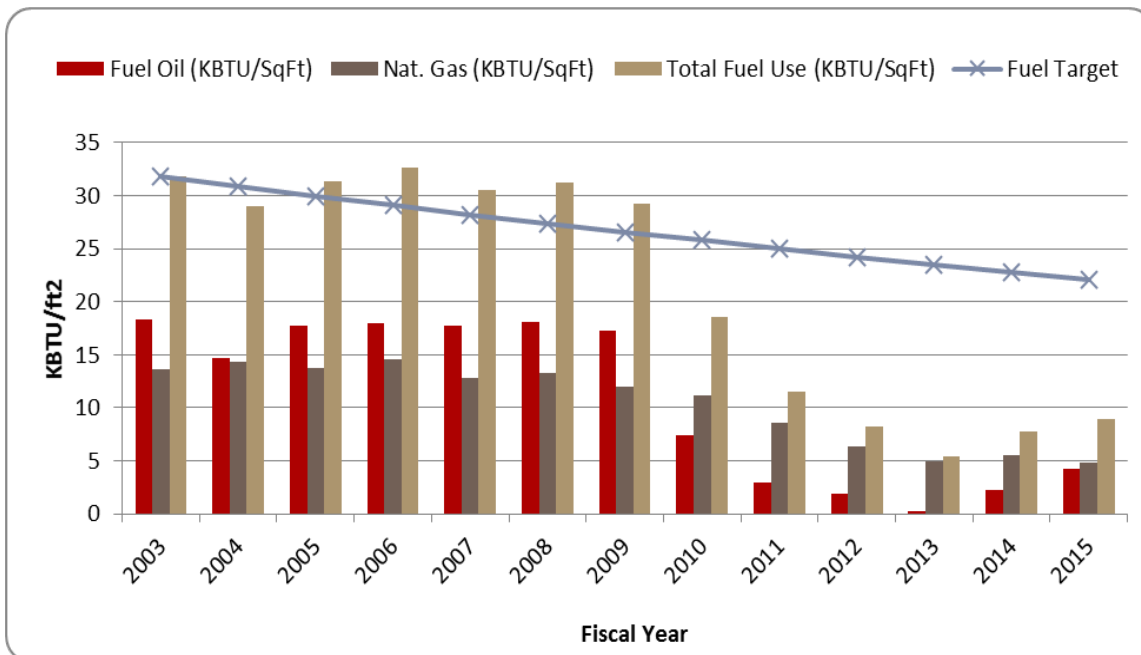


Figure 3.5. Facility Fuel Use – FYs 2003–2015 with Target Objectives through 2015

KBTU=one thousand British thermal units

Facility Energy Use. The target objective for facility energy use was met in FY 2015 (Figure 3.6). Requirements call for the reduction of energy use, a combination of electricity, fuel oil, and natural gas use by 3% annually or 45% through the end of FY 2020 relative to the FY 2003 baseline.

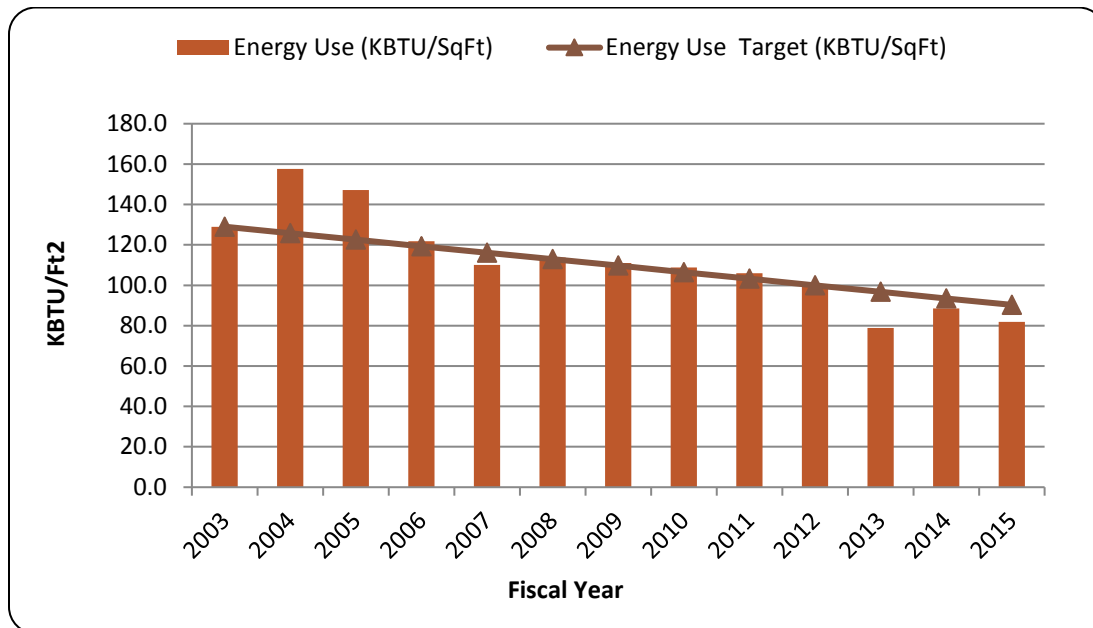


Figure 3.6. Facility Energy Use – FYs 2003–2015 with Target Objectives through 2015

Electronic Product Environmental Assessment Tool. The target objectives for the electronic product environmental assessment tool were exceeded in FY 2015, with 99% of the purchases meeting the requirements (Figure 3.7). [Executive Order 13514](#) (74 FR 52117) specifies 95% of procured electronic assets (notebooks, computers, and monitors) must comply with the electronic product environmental assessment tool standard in an effort to reduce or eliminate the environmental impacts of electronic assets by incorporating electronic stewardship practices.

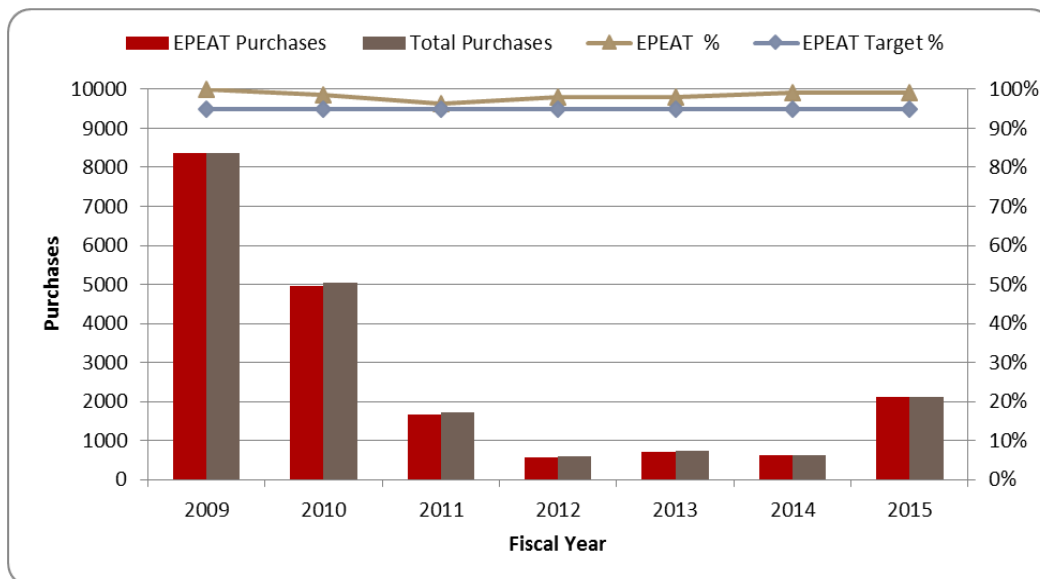


Figure 3.7. Electronic Product Environmental Assessment Tool Standards Compliance – FYs 2009–2015 with Target Objectives through 2015

Sanitary Waste Reduction. The target objective for sanitary waste reduction requires the diversion of post-consumer materials suitable for reuse and recycling from landfills by 10% per year based on a FY 2010 baseline (Figure 3.8). More Hanford Site sanitary waste was recycled than was sent to landfills in FY 2015.

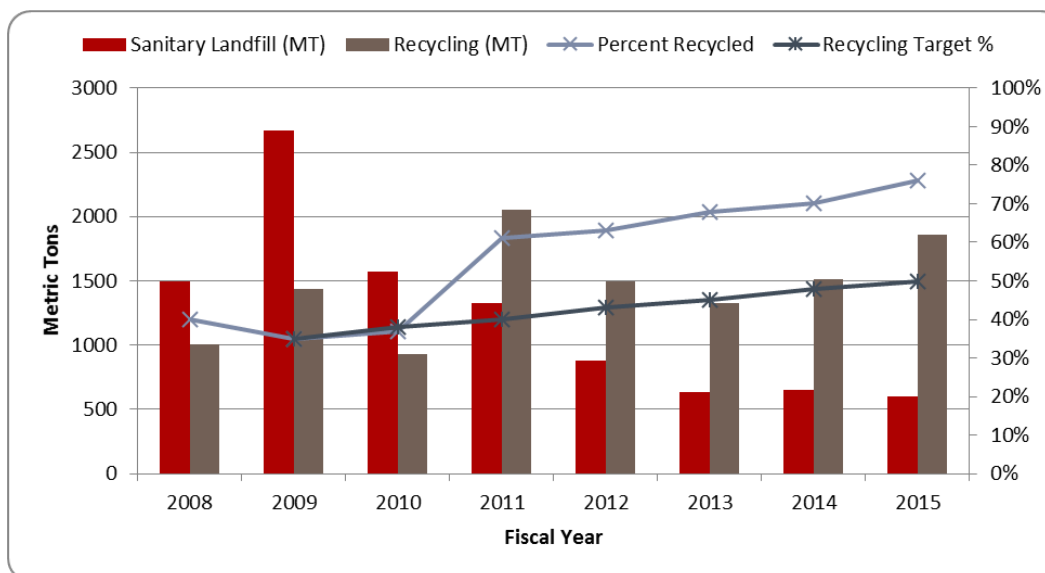


Figure 3.8. Sanitary Waste Reduction – FYs 2008–2015 with Target Objectives through 2015

Regulated Waste Reduction. The target objective for regulated waste reduction was met in FY 2015 (Figure 3.9). Objectives for regulated waste reduction on the Hanford Site include eliminating or minimizing waste generation 5% annually (based on FY 2009 generation) through source reduction, including segregation, substitution, and reuse that would otherwise require storage, treatment, and long-term monitoring and surveillance. Regulated waste includes waste such as hazardous, universal, special, and state-regulated industrial and radioactive waste not suitable for disposal in sanitary or construction and demolition landfills. Regulated waste from Hanford's ERDF is not included in Figure 3.9. Waste to this facility decreased in FY 2015 (Figure 3.10).

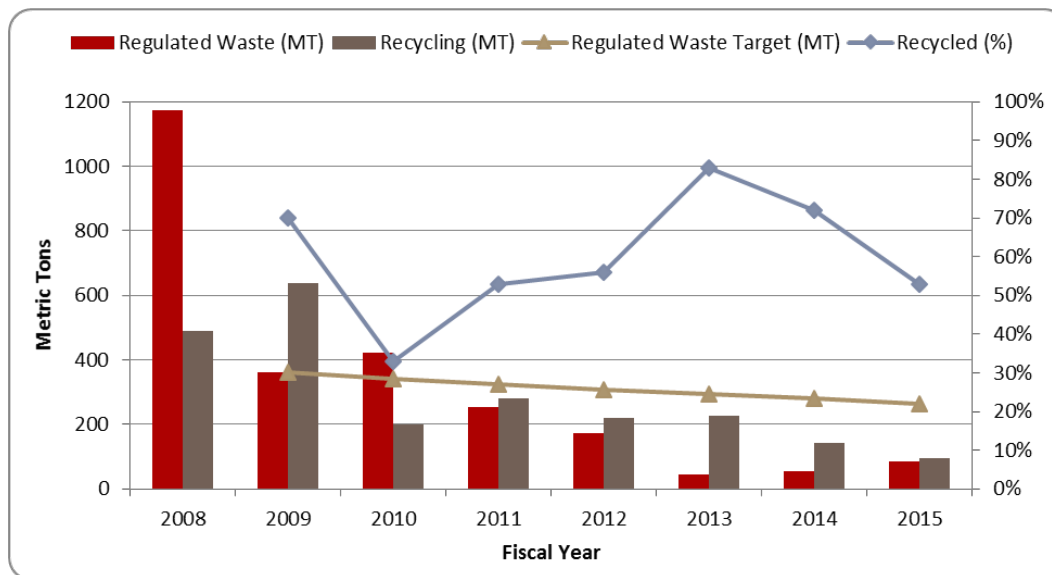


Figure 3.9. Regulated Waste Reduction – FYs 2008–2015 with Target Objectives through 2015

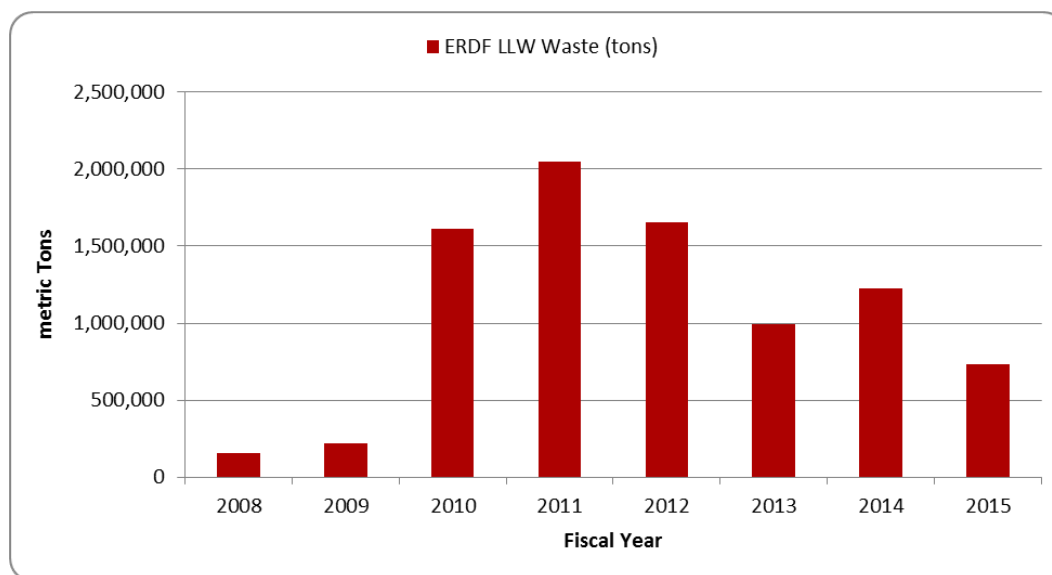


Figure 3.10. On-site Waste Disposal – FYs 2008–2015 at the Environmental Restoration Disposal Facility

In addition to these metrics, each contractor has established company-specific performance measures within their EMS.

3.2 Hanford Site Awards and Recognition

SW Davis

3.2.1 HPMC Occupational Medical Services

HPMC OMS self-declared conformance to ISO 14001:2004 on March 17, 2016. DOE-RL conducted the external audit on March 21, 2016. This contract requirement due April 30, 2016 was completed ahead of schedule.

3.2.2 CH2M Plateau Remediation Company

The Environmental Compliance & Quality Assurance Organization conducted an independent assessment to review implementation of CHPRC's environmental management system (EMS) as described in PRC-MP-EP-40182, *EMS Manual*, and its conformance with ISO 14001:2004. Employee awareness of CHPRC's Environmental Policy and environmental roles and responsibilities was assessed, and an effectiveness review of FY 2015 EMS audit corrective actions was conducted. CHPRC's internal audit was followed up by a required surveillance audit. NSF-International Strategic Registrations, Ltd., an American National Standards Institute National Accreditation Board-accredited certification body for the international standard ISO 14001, conducted its annual surveillance audit of the CHPRC EMS June 20–23, 2016. Two auditors reviewed CHPRC documents, visited four CHPRC Projects, interviewed CHPRC workers to discuss CHPRC implementation of the ISO core elements, and met with CHPRC senior staff members to gauge management commitment. No non-conformances and two opportunities for improvement were issued, and no Corrective and Preventative Action Plan was necessary. The auditors concluded that CHPRC remains compliant with the ISO 14001 standard and recommended continuation of ISO 14001 certification for another year.

3.2.3 Mission Support Alliance, LLC

MSA completed its required surveillance audit for 2015 to maintain its ISO 14001:2004 registration with a follow up surveillance audit in 2016 and a reassessment in 2017. MSA's EMS coordinator, also presented the Environmental Leadership Award 2015. The award was established to recognize outstanding environmental performance by employees. This year's winner is the MSA Zero Waste Company Picnic Team.

MSA's increased efforts on accessing utility incentives available through the BPA to offset the cost of project implementation. Integration of this activity into not only projects but routine maintenance began to yield positive results toward the end of FY 2015 with incentives issued for efficiency upgrades at two facilities that netted a cost avoidance of \$9,124.

3.2.4 Washington Closure Hanford, LLC

At the Project Management Institute's Global Congress 2015–North America conference held in October 2015, WCH was one of three finalists for the international Project of the Year Award. WCH placed second but was recognized at the conference for its tremendous progress. In addition, WCH won the 21st Annual Project of the Year award from the Project Management Institute Columbia River Basin Chapter in March 2015. The award recognizes, honors, and publicizes our team for superior performance and execution of exemplary project management.

4.0 Radiological Protection and Doses

This section provides information on the Hanford Site radiological program and doses as well as cleanup activities as DOE progresses toward site closure and the likely transfer of property to other entities. Additional information on radiation, dose rates, and dose terminology can be found in Appendix A, Helpful Information and Appendix B, Glossary.

4.1 External Radiation Monitoring

CJ Perkins

External radiation is defined as radiation originating from a source external to the human body. External radiation was monitored at the Hanford Site in relative proximity to known 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 activities; atmospheric fallout from historical nuclear weapons testing; and natural sources such as cosmic radiation. During any given year, external radiation levels can vary from 15–25% at any location because of changes in soil moisture and snow cover (NCRP 1975).

The HarshawTM* thermoluminescent dosimeter (TLD) system is used to measure external radiation on 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. Data obtained from the two TLD-700 chips were used to determine the average total environmental dose at each location. The two TLD-200 chips were included to determine doses in the event of a radiological emergency and were not used in calculating average total environmental dose. 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 (mrem/day) at each location were converted to annual dose equivalent rates (mrem/yr) by averaging the daily dose rates and multiplying by 365 days/yr. The TLDs were positioned approximately 3.3 ft (1 m) above 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 included underground radioactive material areas, contamination areas, soil contamination areas, high-contamination areas, roads, and fence lines.

4.1.1 External Radiation Measurements

External radiation fields were monitored in 2015 at 115 locations (Table 4.1) near Hanford Site facilities and operations. The TLD results were used individually or averaged to determine dose rates in a given area for a specific sampling period. Individual TLD results and detailed maps of monitoring locations are available upon request.

* Harshaw is a trademark of Thermo Fisher Scientific, Inc., Waltham, MA.

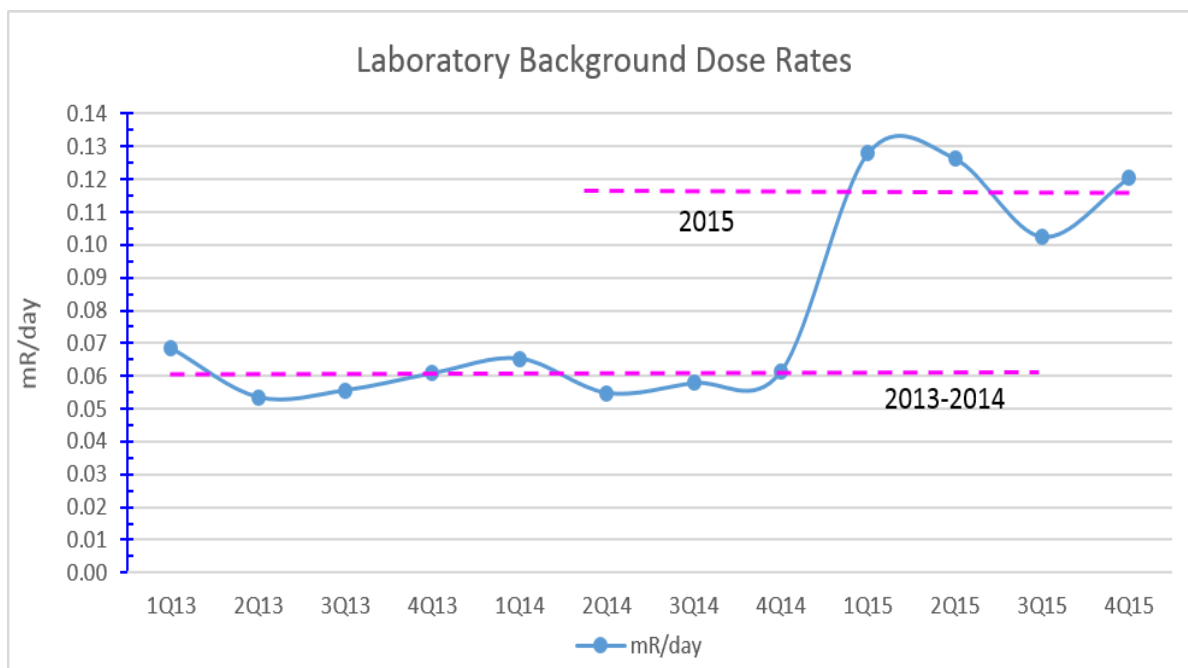
Table 4.1. Thermoluminescent Dosimeter Locations, 2015

Location	No. of Dosimeters
100-K Area	14
100-N Area	1
200 East Area	42
200 West Area	24
200 North Area	1
300 Area	8
300 TEDF	6
400 Area	7
618-10 Burial Ground	4
CVDF	4
ERDF	3
IDF	1
Total	115

CVDF=Cold Vacuum Drying Facility (100 K Area), ERDF=Environmental Restoration Disposal Facility (200 West Area), IDF=Integrated Disposal Facility (200 East Area), TEDF=300 Area Treated Effluent Disposal Facility

In early 2015, the Hanford External Dosimetry Program's (HEDP) laboratory was relocated from its long-time location near the 300 Area and to a location between the 200 East and 200 West Areas. This relocation introduced two substantial variances within the 2015 data set.

One significant difference was the higher background dose rate levels (approximately 50% higher) attributable to elevated radon levels inherent within the new HEDP facility (Figure 4.1). These background values are subtracted from the ambient dose rate levels measured in the environs to determine site-specific dose rate levels above background. This simple calculation produced artificially decreased dose rate values for 2015 when compared to previous years' values.

**Figure 4.1. Background Dose Rates at the Hanford External Dosimetry Program Laboratory**

The second significant difference that occurred during 2015 was the material used for shielding the dosimeters during their residency in the HEDP facility. Prior to 2015, the shielding material used was lead which is substantially better than the steel shielding used in 2015. The effect of this change was to expose the dosimeters to the significantly higher background levels discussed in the previous paragraphs and ultimately cause a higher dose rate reading.

Due to the complexities and uncertainties imparted on the 2015 TLD data by these changes at the HEDP facility, annual data comparisons are impractical and are not being reported. Comparative data reporting will resume once the HEDP laboratory background and shielding values are stable.

100-K Area. As in years past, the 2015 dose rate levels near the load-out area of the 105-KW (reactor) building where radioactive contaminated sludge and debris from the cleanout of the 100-K West Basin was transported were noticeably higher than other TLD locations at 100-K.

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 accessing the river. Cleanup activities at the retired 116-N-1 and 116-N-3 Trenches (located near the Columbia River) have decreased dose rates notably over the past few years.

200-East Area. Dose rate levels measured during 2015 near the “A” and “C” Tank Farms were higher than other 200 East area locations.

200-West Area. Dose rate levels measured during 2015 near the “S” and “T” Tank Farms and at the Solid Waste Operations Complex were higher than other 200 West area locations.

200-North. Dose rates measured in 2015 were low, and all four quarterly measurements were similar.

300 Area. Dose rate levels measured during the second quarter of 2015 near the North Process Trench were slightly higher than any other period or at other 300 Area locations.

400 Area. Dose rates measured in 2015 at all seven monitoring locations were low and similar.

ERDF. Dose rates measured in 2015 at all three monitoring locations were low and similar.

618-10 Burial Ground. Dose rates measured in 2015 at all four monitoring locations were low and similar.

Integrated Disposal Facility. Dose rates measured in 2015 were low, and all four quarterly measurements were similar.

4.1.2 Waste Disposal Sites Radiological Surveys

JW Wilde

During 2015, 886 environmental radiological surveys were reported as performed at active and inactive waste disposal sites and the surrounding terrain to detect and characterize radioactive surface contamination. 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 included underground radioactive material areas, contamination areas, soil contamination areas, high-contamination areas, roads, and fence lines. Vehicles equipped with radiation detection devices, and Global Positioning Systems (GPS) were used to measure accurately the extent of contamination. Area measurements were entered into the Hanford Geographical Information System, a computer database maintained by MSA. 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 Hanford Site operational areas. These sites were posted as underground radioactive material areas, contamination areas, and soil contamination areas. The external dose rate at 80% of the outdoor contamination areas was estimated to be less than 1 mrem (0.01 mSv) per hour, although direct dose-rate readings from isolated radioactive specks could have been higher.

Underground radioactive material areas are regions where radioactive materials occur below the soil surface. These areas are typically stabilized cribs, burial grounds, covered ponds, trenches, and ditches. Barriers have been placed over the contamination sources to inhibit radionuclide transport to the surface. These areas are surveyed at least annually to assess the effectiveness of the barriers.

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 0.25 in. [0.6 cm]). 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. In addition, onsite paved roadways on which radioactive materials are transported to ERDF are surveyed annually.

4.2 Potential Radiological Doses

R Perona, RT Rytí

Potential radiological doses to the public and biota from Hanford Site operations in 2015 were evaluated to determine compliance with pertinent regulations and limits. Potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, contaminated groundwater seeping into the Columbia River, and fugitive emissions from areas of contaminated soil and operating facilities. A summary of the methods and results of the public and biota dose assessments is provided here. Details of the methods used to calculate radiological doses are provided in Appendix D.

The radiological impacts of Hanford Site operations were assessed in terms of the following:

- Dose to a hypothetical, maximally exposed individual (MEI) at an off-site location, evaluated by using a multimedia pathway assessment [DOE O 458.1](#) (Section 4.2.1)
- Collective dose to the population residing within 50 mi (80 km) of Hanford Site operation areas (Section 4.2.2)
- Doses for air pathways calculated using regulation-specified EPA methods for comparison to the *Clean Air Act* standards in [40 CFR 61, Subpart H](#) (Section 4.2.3)
- Doses from recreational activities, including hunting and fishing (Section 4.2.4.1)
- Dose to a worker consuming drinking water on the Hanford Site (Section 4.2.4.2)
- Dose to a visitor of the Manhattan Project National Historical Park (Section 4.2.4.3)
- Doses from non-DOE industrial sources on and near the Hanford Site (Section 4.2.5)

- Absorbed dose received by biota exposed to radionuclide releases to the Columbia River and to radionuclides in on-site surface water bodies (Section 4.2.6).

Radiological dose assessments related to environmental releases are ideally based on direct measurements of radionuclide concentrations in specific exposure media; however, amounts of many radioactive materials released to the Columbia River or the atmosphere from Hanford Site sources are too small to be measured in environmental media after they are dispersed in the offsite environment. For the radionuclides present in measurable amounts, it can be difficult to distinguish the small contribution of Hanford Site sources from contributions caused by fallout from historical nuclear weapons testing and naturally occurring radionuclides such as uranium and its decay products. As a result, computer models are employed to calculate offsite radionuclide concentrations based on measured and estimated releases. In specific instances, such as ambient air measurements of tritium at on- and off-site locations near the 300 Area, radionuclide concentrations may be distinguishable from background levels, and these measurements are used to support the dose assessment.

Calculations of radiation dose require the use of biological and radiological models of the behavior of radioactive material in the human body. Scientific understanding of these processes has improved over time. In the 1960s, the annual environmental reporting at the Hanford Site used the recommendations and methodologies of the ICRP Publication 2 (*Permissible Dose for Internal Radiation* [[ICRP 1959](#)]). In the 1970s, the annual reports began to follow the newer recommendations in ICRP Publication 26 ([ICRP 1977](#)) and Publication 30 (*Limits for Intakes of Radionuclides by Workers*, Part 1 and Supplement to Part 1 [ICRP 1979a and 1979b, respectively]) incorporated in the dose factors from the EPA in Federal Guidance Reports 11 and 12 ([EPA 1988](#) and [EPA 1993](#), respectively). The GENII Version 1 computer code at the Hanford Site beginning in 1988 used ICRP Publications 26 and 30 as well as EPA dose factors. The GENII Version 2 computer code for the annual report dose calculations beginning in 2009 uses ICRP Publication 60 methods (ICRP 1991) and updated EPA dose factors ([EPA 1999](#)).

Off-site dose for a MEI (Section 4.2.1) and collective dose for population residing within 50 mi (80 km) of Hanford Site operation areas (Section 4.2.2) are calculated separately for liquid releases to the Columbia River and stack air emissions. Radiological doses from the water pathways are calculated based on differences in radionuclide concentrations between upstream and downstream sampling points on the Columbia River. Although the downstream minus upstream radionuclide concentrations potentially include groundwater-related contributions from other operating areas, they have been assigned to the 200 Area for tabulation of radiological dose. No direct discharge of radioactive materials from the 100 or 300 areas to the Columbia River was reported during 2015. Radiological doses from the air pathways are calculated based on stack emissions measurements from approximately 60 emission points in Hanford Site operation areas.

Columbia River shoreline spring and seep water-containing radionuclides is known to enter the river along the portion of the Hanford Site shoreline extending from the 100-BC Area downstream to the 300 Area. Tritium and uranium isotopes were measured in the Columbia River downstream of the Hanford Site (Richland Pumphouse station, HRM 46.4) in 2015 at concentrations statistically greater than upstream (Priest Rapids Dam station) levels (Appendix D). Radioactive air emissions are discussed in Section 6.1 and summarized in Table 6.1. For the GENII Version 2.10 ([PNNL-14583, Rev 3](#)) calculations supporting this dose assessment, ingrowth of short-lived radioactive progeny during environmental transport was calculated to develop a complete set of radionuclide release estimates. Details on the development of air pathway and water pathway radioactive release estimates are provided in Appendix D.

4.2.1 Maximally Exposed Individual Dose (Off-site Resident)

The MEI is a hypothetical person whose location and lifestyle are such that it is unlikely any actual member of the public would have received a higher radiological dose from Hanford Site releases during 2015. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides in Hanford Site liquid effluents and air emissions using a multimedia pathway assessment ([DOE O 458.1](#), Section 4.e). In reality, such a combination of maximized exposures to radioactive materials is highly unlikely to apply to any single person. The individual pathway dose calculations themselves also incorporate conservative assumptions intended to ensure that modeled concentrations of radionuclides in exposure media and resulting doses are protective. For these reasons, the dose assessment results for the MEI represent a hypothetical upper bound of potential individual dose rather than an anticipated dose to an actual individual.

The location of the hypothetical MEI varies depending on the relative contributions of radioactive air emissions and liquid effluent releases from Hanford Site operational areas. Four off-site locations were evaluated to determine the location of the MEI (Figure 4.2). The Ringold location receives maximal air pathway impacts from the 200 Area. Depending on annual differences in the prevailing wind direction, either the Sagemoor or Horn Rapids Road location may receive maximal air pathway impacts from the 300 Area. A small population of West Pasco residents obtains their drinking water from the Riverview location via a community water system, and the domestic drinking water pathway is applied to that location. Residences in the vicinity of Horn Rapids Road receive drinking water from the City of Richland, which has an intake downstream of the Hanford Site, so the domestic drinking water pathway is also applied here. Both Riverview and Horn Rapids Road are locations where Columbia River water is withdrawn for irrigation.

Dose calculations for 2015 releases indicate that the MEI is located at the PNNL Physical Sciences Facility, an off-site business just to the south of the Hanford Site 300 Area at 638 Horn Rapids Road. For the Horn Rapids Road receptor dose calculations, the following exposure routes were evaluated:

- Inhalation and external radiation exposure related to airborne radionuclides
- External radiation exposure and inadvertent soil ingestion for radionuclides deposited on the ground
- Ingestion of domestic drinking water from the Columbia River
- Ingestion of locally grown food products irrigated with Columbia River water and/or containing radionuclides deposited from the air
- External radiation exposure to radionuclides in Columbia River water and sediments near the Hanford Site during recreational activities (i.e., fishing, boating) and inadvertent ingestion of water while swimming
- Consumption of locally caught Columbia River fish.

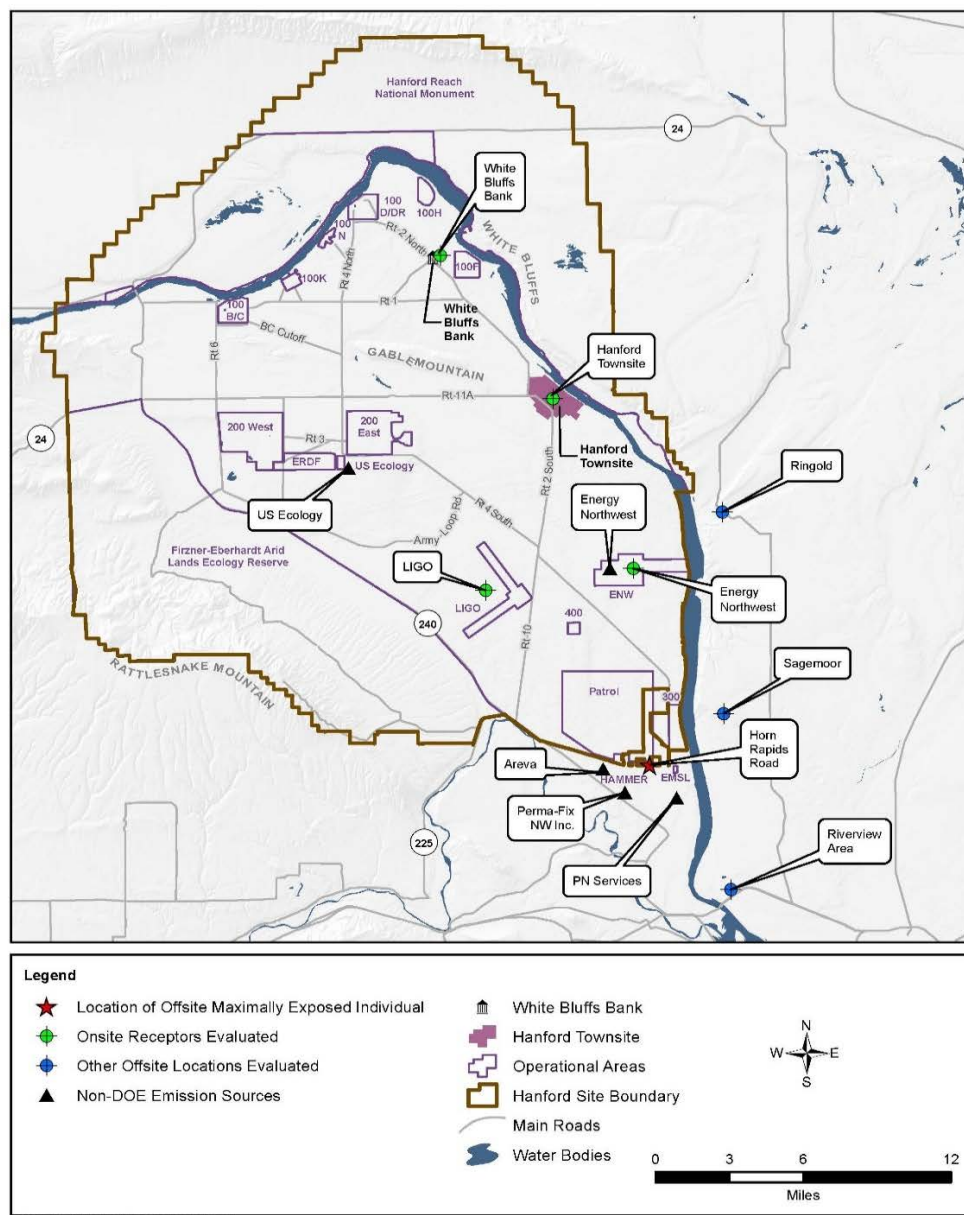


Figure 4.2. On-Site Receptors Evaluated

A graphical depiction of the conceptual site model showing all potentially complete exposure pathways for the Horn Rapids Road MEI evaluated using GENII Version 2.10 ([PNNL-14583, Rev 3](#)) is provided in Figure 4.3. Additional information related to selection of the MEI location for releases is included in Appendix D. Exposure variable input values related to residency and recreational exposure times, intake rates for water, foods, other media, and agricultural pathway assumptions for the MEI are provided in Appendix D.

The total dose to the MEI at Horn Rapids Road in 2015 was calculated to be 0.21 mrem (2.1 mSv)/yr (Table 4.2; Figure 4.4). This dose is 0.21% of the 100 mrem (1000 mSv) per year public dose limit specified in [DOE O 458.1](#) and 0.84% of the 25-mrem (250-mSv)/yr threshold where a supplemental assessment of dose to the lens of the eye, skin, and extremities is required. Air pathway contributions from sources in the 300 Area contributed approximately 70% of the total dose of 0.21 mrem (2.1 mSv)/yr, with the remaining dose related to water pathway exposures.

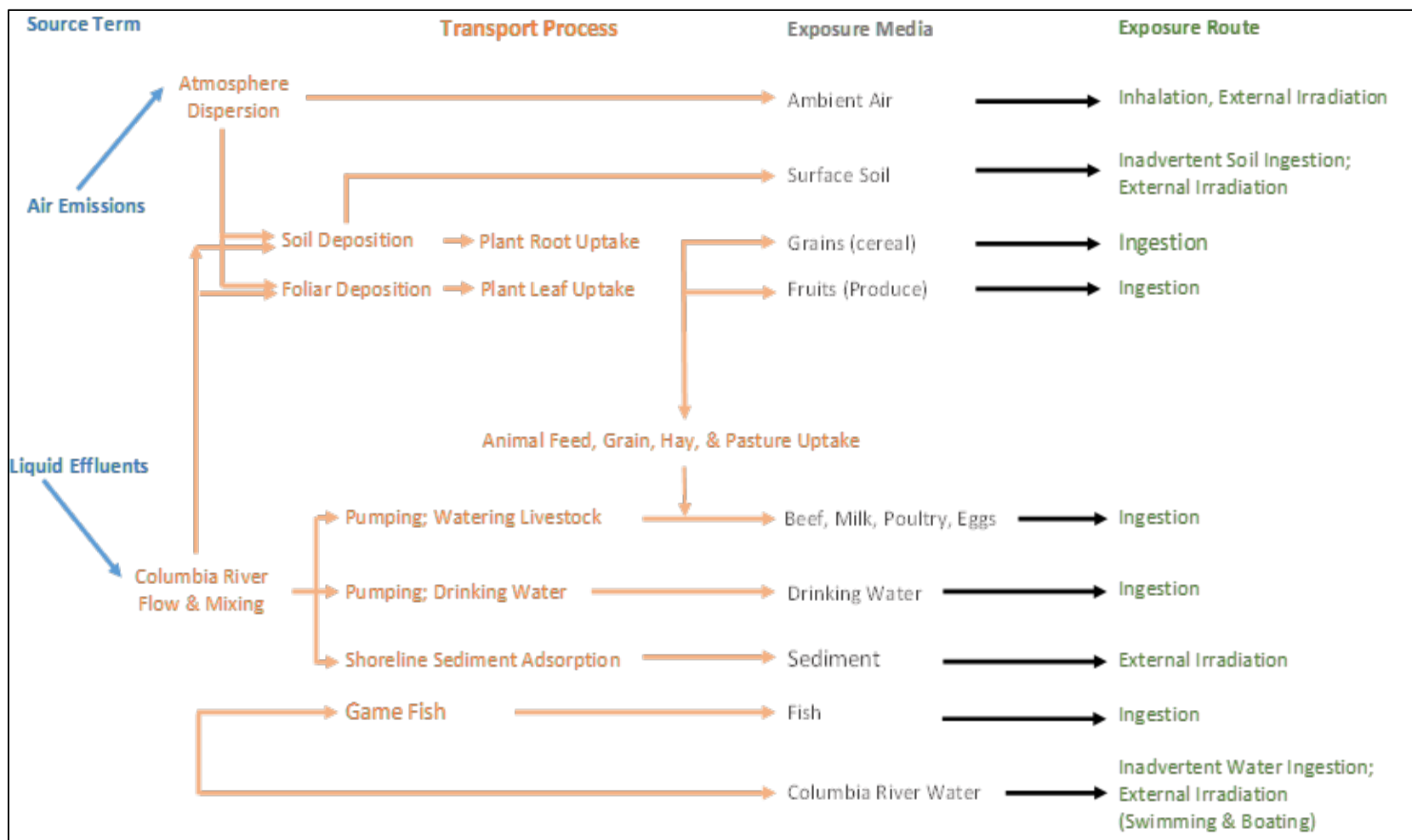


Figure 4.3. Conceptual Site Model of Exposure Pathways Evaluated in Dose Calculations (Horn Rapids Road MEI)

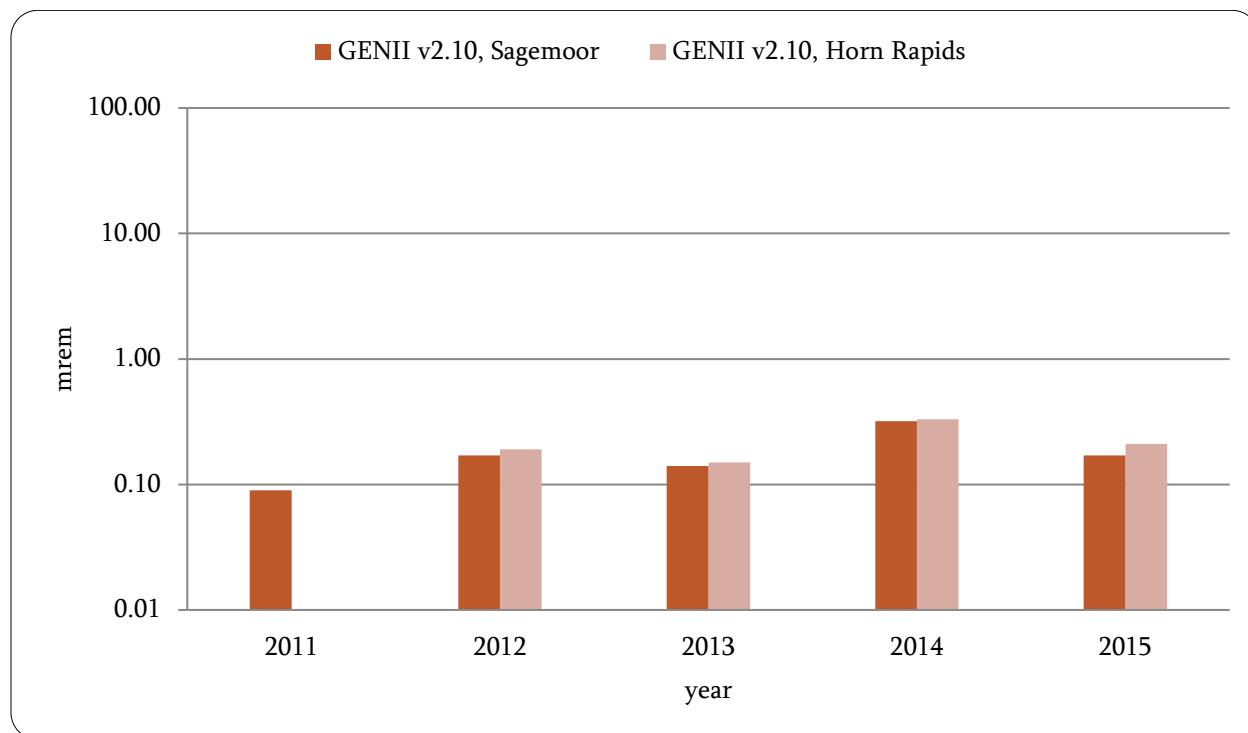


Figure 4.4. Total Dose for the Hypothetical MEI Over Time

Table 4.2. Pathway Doses for the Hypothetical MEI Residing at Horn Rapids Road

Release Type	Exposure Pathway	Dose Contributions from Operational Areas (mrem)*				Pathway Total
		100 Areas	200 Areas†	300 Area	400 Area	
Air	Food Ingestion	6.1E-07	4.8E-05	0.094	2.8E-07	0.094
	Inhalation	5.7E-06	8.4E-05	0.059	1.0E-06	0.059
	External, Soil Ingestion	5.4E-09	1.0E-06	0.0010	6.7E-09	0.0010
	Subtotal Air	6.3E-06	1.3E-04	0.15	1.3E-06	0.15
Water	Irrigation (food and soil ingestion; external)	NA‡	0.015	NA	NA	0.015
	Drinking Water Ingestion	NA‡	0.0053	NA	NA	0.0053
	Recreation (river water, sediments; external, ingestion)	NA‡	2.7E-04	NA	NA	2.7E-04
	Fish Ingestion	NA‡	0.032	NA	NA	0.032
	Subtotal Water	NA	0.052	NA	NA	0.052
Air + Water Total		6.3E-06	0.052	0.15	1.3E-06	0.21

*To convert mrem to International System dose units (mSv), multiply by 10.
†Integrates releases from all operational areas based on difference between down and upstream Columbia River radionuclide concentrations.
‡No measured releases; the last 100 Area NPDES-permitted outfall (1908-K Outfall) ceased releases in March 2011.
NA=Not applicable. All liquid discharges reflected in the difference between upstream and downstream radionuclide concentrations are assigned to the 200 Area.

The primary radionuclides and exposure pathways contributing to the MEI dose are as follows:

Air Releases. Consumption of food products containing tritium released from the 300 Area contributed approximately 61% of the total air pathways dose of 0.15 mrem (1.5 mSv)/yr. Inhalation of the radioactivity progeny of radon-220 released from the 300 Area contributed approximately another 33% of the total air pathways dose.

Water Releases. Consumption of fish from the Columbia River contributed 0.032 mrem (0.32 mSv) or 61% of the total water pathways dose of 0.052 mrem (0.52 mSv)/yr. Consumption of food grown using Columbia River water withdrawn downstream from the Hanford Site contributed approximately another

29% of the total water pathways dose, and drinking water ingestion contributed the remaining 10%. Isotopes of uranium and their progeny, particularly uranium-234 and uranium-238, contribute approximately 60% of the total water pathways dose of 0.052 mrem (0.52 mSv)/yr. Most of the remaining 40% of the water pathways dose is related to strontium-90 and cesium-134, two radionuclides that were protectively included in dose calculations based on comparing downstream and upstream concentrations but not detected at concentrations above sample quantitation limits (Appendix D).

The MEI dose in 2015 of 0.21 mrem (2.1 mSv) is below the 0.33 mrem (3.3 mSv) MEI dose calculated in 2014 ([DOE/RL-2014-52](#), *Hanford Site Environmental Report for Calendar Year 2014*). The difference between the 2015 and 2014 dose estimates is mostly attributable to the inclusion of naturally occurring potassium-40 in the 2014 water pathways dose calculations. Potassium-40 was included in the 2014 dose calculations for water releases because average downstream river concentrations were statistically greater than upstream concentrations, even though potassium-40 is a naturally-occurring radionuclide not of Hanford origin. In 2013 and 2015, downstream potassium-40 concentrations were not statistically different from those measured upstream.

The MEI dose estimate incorporates a number of conservative assumptions to ensure that pathway doses are protective and therefore calculated doses are likely to be overestimated. In the air pathways calculations, gross alpha and gross beta radiation measurements in stack emissions from the 100, 200, and 300 areas were protectively added to the measured emissions of plutonium-239/-240 (an alpha-emitting radionuclide related to Hanford operations) and cesium-137 (a beta-emitting radionuclide related to Hanford operations), respectively. The actual measured total air releases of plutonium-239/-240 and cesium-137 are a small fraction (35 and 14%, respectively) of assumed releases that include the contribution of gross radioactivity values. Although gross alpha and gross beta levels in stack emissions are similar to ambient air background levels, the addition of these values ensures that possible contributions from any unmeasured operations-related radionuclides are protectively incorporated in the estimated doses.

In the irrigation pathways calculations, all produce eaten by the MEI was protectively assumed to be locally grown and originate from areas irrigated with Columbia River water. For the fish consumption pathway, near-shore water samples were protectively used to represent Columbia River water generally, and it was assumed that all fish consumed by the MEI are resident species rather than anadromous fish, such as salmon or steelhead. Because anadromous fish spend most of their lives in the ocean they would have a much lesser exposure to contaminants associated with the Hanford Reach compared to species that spend their entire lives in the Hanford Reach, such as sturgeon.

Because releases of tritium from the 300 Area are the major source of calculated Hanford-related radiological dose for the hypothetical MEI, modeled annual-average tritium concentrations at locations near the 300 Area were compared to concentrations based on air monitoring station samples. Figure 4.5 shows the 2015 modeled annual average air concentrations of tritiated water vapor (HTO) at the Horn Rapids Road MEI location and 2015 annual averages based on measured values at two off-site locations south and east of the 300 Area (Battelle Complex and Byers Landing) and two on-site locations near the southern border of the 300 Area northeast of the Horn Rapids Road MEI location. Measured monthly tritium concentrations vary substantially at each monitoring location. The 95% upper and lower confidence intervals of the annual average values are shown on Figure 4.5 in addition to the annual average.

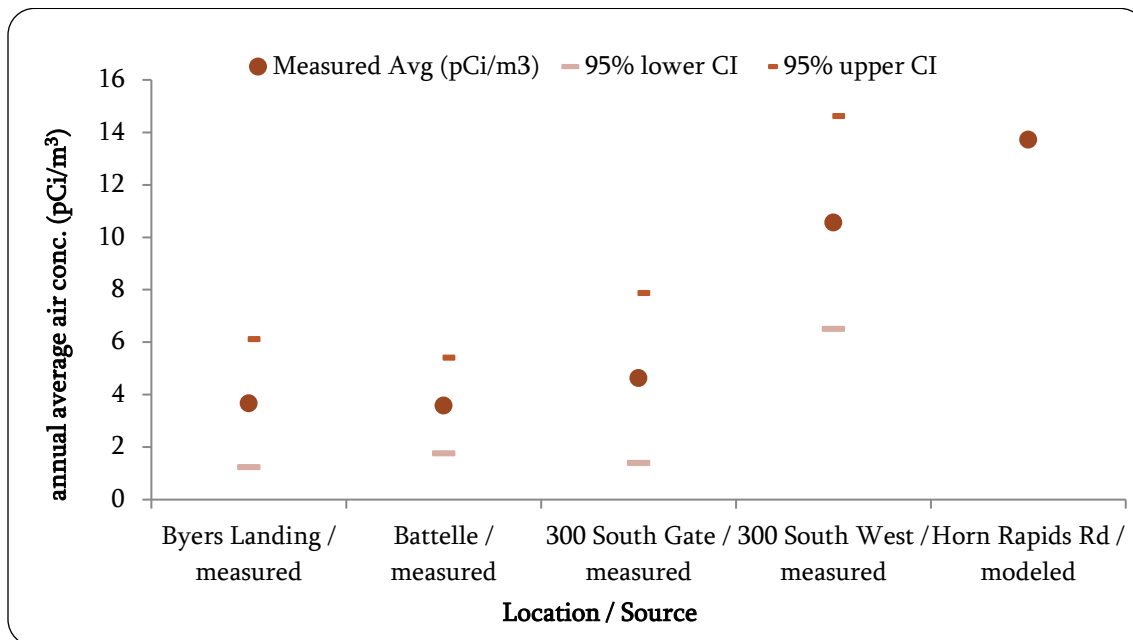


Figure 4.5. Comparison of Measured and Modeled Tritium Air Concentrations Near the 300 Area
Error bars are 95% confidence intervals of the mean

The modeled annual-average tritium concentration at the Horn Rapids Road MEI location is above the range of the 95% upper and lower confidence interval of the mean of the measured values at the two nearby off-site monitoring locations and the 300 South Gate on-site location. The Horn Rapids Road modeled annual-average tritium concentration is within the 95% upper and lower confidence interval of the mean of the measured values at the 300 South West monitoring station. A relationship between 300 Area monthly tritium air emissions and on-site 300 Area ambient air concentrations in 2006 was shown by Barfuss (2007), but there was little correlation of monthly emissions and air concentrations for a combined group of four nearby off-site monitoring locations. Figure 4.5 shows that the modeled MEI tritium air concentration is higher than the upper 95% confidence interval annual-average tritium concentrations measured at Battelle Complex (near the Horn Rapids Road MEI Location) and Byers Landing (near the Sagemoor MEI location) stations. This suggests that modeled tritium air concentrations may overestimate actual annual-average levels at these off-site locations.

Note that exact correspondence between modeled and measured annual average values would not be expected because the episodic nature of HTO releases is not captured in the GENII air dispersion modeling, which assumes a constant rate of HTO emissions. However, the modeled tritium values do not account for regional background levels of tritium, which would add between 1.5 and 4 pCi/m³ to the modeled values (Figure 11 in Barfuss 2007) and exacerbate the difference between modeled and measured tritium values at off-site locations near the 300 Area.

Samples of locally raised foodstuffs were collected in 2015 from four locations including the Sagemoor, Riverview, Sunnyside, and East Wahluke areas. Sampled foodstuffs included fruits (apples, cherries, melons, and tomatoes), leafy vegetables, potatoes, corn, milk, and wine. Gamma-emitting radionuclides and strontium-90 were measured in all foodstuffs, and tritium was also measured in tomatoes, milk and wine. Measured concentrations of the Hanford-related radionuclides strontium-90, cesium-137, and tritium in foods were compared to modeled concentrations calculated for the MEI receptor using the

GENII computer code. These comparisons encompassed fruits, leafy vegetables, grain (corn), root vegetables (potatoes), and milk. Modeled concentrations of tritium and cesium-137 are related primarily to air emissions, whereas modeled concentrations of strontium-90 are related to irrigation with Columbia River water. The following observations are drawn from the comparisons:

- Cesium-137 was not detected in any food sample. Analytical detection limits were approximately a factor of 1,000 to 10,000 times larger than the worst-case modeled concentrations but comparable to or below environmental surveillance project dose-based reporting limits ([DOE/RL-91-50](#)) calculated using a 1 mrem (10 μ Sv)/yr threshold. Cesium-137 routine air releases are far below levels of detection or radiological concern in foodstuffs.
- Strontium-90 was detected only in leafy vegetable samples from the Sagemoor, Sunnyside, and East Wahluke areas. Strontium-90 concentrations of approximately 0.006 pCi/g in the samples were approximately 30 times larger than the worst-case modeled concentration (0.0002 pCi/g) and also larger than the detection limit of the sample collected in the Riverview area (0.0004 pCi/g). However, low levels of strontium-90 in the environment are widespread to past above-ground weapons testing, and measured concentrations in leafy vegetables from the Sagemoor, Sunnyside, and East Wahluke areas are consistent with trends based on observations in off-site vegetation samples ([PNNL-20577, Radionuclide Concentrations in Terrestrial Vegetation and Soil Samples On and Around the Hanford Site, 1971 Through 2008](#)). Detected concentrations of approximately 0.006 pCi/g in leafy vegetables are almost 100 times below the environmental surveillance project dose-based reporting limit ([DOE/RL-91-50](#)).
- Tritium was measured in samples of tomatoes from the Sunnyside and Riverview areas but was not detected at either location, with analytical detection limits of approximately 0.08 and 0.03 pCi/g, respectively. Tritium was also detected in samples of milk at average concentrations of approximately 19 pCi/L (Sunnyside), 28 pCi/L (East Wahluke), and 35 pCi/L (Sagemoor). The relative tritium concentrations in milk from these three locations is consistent with expectations for air dispersion from releases in the 300 Area. However, these concentrations are well below the modeled worst-case tritium concentration in milk for cows grazing at the MEI location of Horn Rapids Road (approximately 600 pCi/L) and far less than the environmental surveillance project dose-based reporting limit of 17,000 pCi/L ([DOE/RL-91-50](#)).

4.2.2 Collective Dose

Collective dose is defined as the sum of doses to all individual members of the public within a defined distance of a specific release location. The regional collective dose from 2015 Hanford Site operations was estimated by calculating the radiological dose to the population residing within a 50-mi (80-km) radius of on-site operating areas ([DOE O 458.1](#); Section 4.e(d)). The collective doses reported are based on regional population data from the 2010 census, as described in Appendix D.

The conceptual site model of potentially complete exposure pathways for the Horn Rapids Road MEI shown in Figure 4.3 is also applicable to the collective dose calculations. Like the Horn Rapids Road MEI, the collective dose calculation also incorporates the drinking water exposure pathway because the cities of Richland and Pasco obtain all or part of their municipal water directly from the Columbia River downstream from the Hanford Site, and the City of Kennewick obtains its municipal water indirectly from wells adjacent to the river. A primary distinction between the MEI and collective dose calculations is the

use of population-average values for certain exposure variables in place of reasonable upper bound values. Exposure variable input values related to residency and recreational exposure times, intake rates for foods and other media, and agricultural pathway assumptions for the collective dose calculations are provided in Appendix D. The air pathways collective dose calculations employ population data from the 2010 census broken out according to direction and distance to coincide with air dispersion and deposition modeling conducted within the GENII Version 2.10 computer code ([PNNL-14583, Rev 3](#)).

The annual collective dose is reported in units of person-rem (person-sievert), which is the sum of doses to all individual members of the exposed population. The total collective dose calculated for this population in 2015 was 1.7 person-rem (0.017 person-Sv)/yr (Table 4.3), below the collective dose calculated in 2014 and approximately equal to that calculated in 2013 (Figure 4.6). Air pathway contributions from releases in the 300 Area contributed approximately 65%, and water pathway contributions assigned to the 200 Area contributed approximately 35% to the total collective dose of 1.7 person-rem (0.017 person-Sv) in 2015.

Table 4.3. Collective Pathway Doses within a 50-mi (80-km) Radius

Release Type	Exposure Pathway	Dose Contributions from Operational Areas, person-rem*				Pathway Total
		100 Areas	200 Areas	300 Area	400 Area	
Air	Food Ingestion	1.0E-04	0.0045	0.64	1.1E-05	0.64
	Inhalation	0.0018	0.014	0.39	6.0E-05	0.41
	External, Soil Ingestion	1.1E-06	4.0E-05	0.0061	2.6E-07	0.0062
	Subtotal Air	0.0019	0.019	1.0	7.1E-05	1.1
Water	Irrigation (food and soil ingestion; external)	NA†	0.016‡	NA	NA	0.016
	Drinking Water Ingestion	NA†	0.0020‡	NA	NA	0.0020
	Recreation (river water, sediments; external, ingestion)	NA†	0.012‡	NA	NA	0.012
	Fish Ingestion	NA†	0.58‡	NA	NA	0.58
	Subtotal Water	NA	0.61	NA	NA	0.61
Air + Water Total		0.0019	0.63	1.0	7.1E-05	1.7

NA=not applicable. All liquid discharges reflected in difference between up- and downstream radionuclide concentrations assigned to 200 Area.
 *To convert person-rem to International System dose units (person-Sv), divide by 100.
 †No measured releases; the last 100 Areas NPDES-permitted outfall (1908-K Outfall) ceased releases in March 2011.
 ‡Integrates releases from all operational areas based on difference between down- and upstream Columbia River radionuclide concentrations.

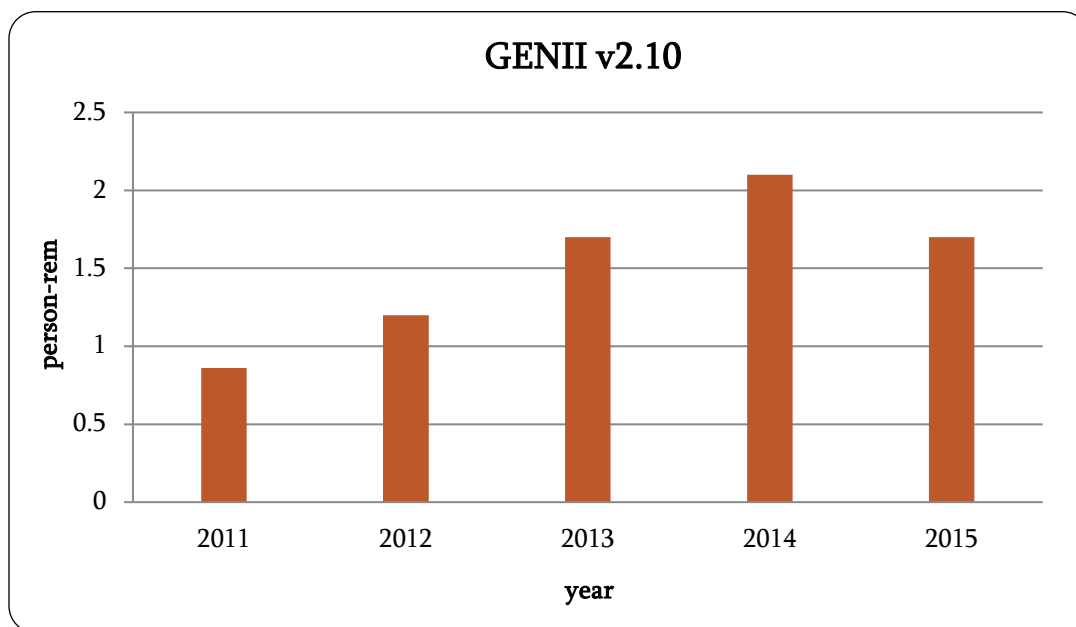


Figure 4.6. Collective Total Dose within a 50-mi (80-km) Radius

The primary radionuclides and exposure pathways contributing to the collective dose are as follows.

Air Releases. Consumption of food products grown downwind of the 300 Area contributed approximately 60% of the of the air pathways collective dose of 1.1 person-rem (0.011 person-Sv). The remaining air pathways collective dose is primarily related to inhalation. About 70% of these food and inhalation air pathways doses are due to releases of tritium from the 300 Area. Approximately another 25% of the total air pathways collective dose is associated with inhalation of the radioactive progeny of radon-220 released from the 300 Area. Air releases from the 100, 200, and 400 areas had negligible contributions to the air pathways collective dose.

Water Releases. Consumption of drinking water drawn from the Columbia River downstream of the Hanford Site contributed approximately 95% of the total water pathways collective dose of 0.61 person-rem (0.0061 person-Sv). Naturally occurring isotopes of uranium (-234 and -238) and their progeny from releases assigned to the 200 Area were the largest contributors (approximately 80%) to the drinking water collective dose.

The collective dose in 2015 of 1.7 person-rem (0.017 person-Sv) is below the 2.1 person-rem (0.021 person-Sv) collective dose calculated in 2014 ([DOE/RL-2014-52](#)) and approximately equal to the 2013 collective dose. There is no specific collective dose metric analogous to the 100 mrem (1,000 mSv) per year public dose limit for individual exposures described in Section 4.2.

4.2.3 Compliance with *Clean Air Act* Standards

Historically at the Hanford Site, there has been one primary expression of radiological risk to an off-site individual, the MEI dose; however, it is currently calculated by two different methods in response to two different requirements. One MEI dose computation is required by [DOE O 458.1](#) and is calculated using the GENII computer code as described in Section 4.2.1 of this report. This calculation considers all potential environmental exposure pathways (e.g., from releases to both air and water) that maximize a hypothetical off-site individual's exposure to the Hanford Site's radiological liquid effluents and air emissions. A second estimate of MEI air pathways dose is required by the *Clean Air Act* and must be calculated using an EPA air dispersion and dose modeling computer code (CAP-88; [EPA 2000](#)) or other methods accepted by the EPA under the *Clean Air Act* to demonstrate compliance with [40 CFR 61, Subpart H](#) requirements. This regulation specifies that no member of the public shall receive a dose greater than 10 mrem (100 mSv)/yr from exposure to airborne radionuclide emissions (other than radon) released at DOE facilities. The Hanford Site stack emissions and emissions from diffuse and unmonitored sources (e.g., windblown dust) are considered in the off-site dose for the *Clean Air Act* and are based solely on an airborne radionuclide emissions pathway.

The assumptions embodied in the CAP-88 computer code differ slightly from standard air pathways assumptions used with the GENII computer code; therefore, air-pathway doses calculated by the two codes may differ somewhat. In principle, the MEI for air pathways assessed under [40 CFR 61, Subpart H](#) may be evaluated at a different location from the all-pathways MEI if dose from the water pathways exceeds that from air pathways (Appendix D).

The *Clean Air Act* regulation also requires that an annual report for each DOE facility be submitted to EPA that supplies information about atmospheric emissions for the preceding year and any potential contributions to off-site dose. For more detailed information about 2015 air emissions at the Hanford Site, refer to DOE's report to EPA ([DOE/RL-2016-10](#)).

4.2.3.1 Dose from Stack Emissions to an Off-site Maximally Exposed Individual

Using CAP-88, the maximally exposed off-site individual for air pathways in 2015 was at PNNL's Laboratory Supply Warehouse, an offsite business located in north Richland, Benton County, WA directly south of the Hanford Site 300 Area and proximal to the Horn Rapids Road MEI location (Figure 4.2). The potential air pathway dose from stack emissions to a MEI at that location calculated using the CAP-88 computer code was determined to be 0.067 mrem (0.67 mSv)/yr, less than 1% of the EPA standard of 10 mrem (100 mSv)/yr. The CAP-88 result is approximately one-half of the air pathway dose of 0.15 mrem (1.5 mSv) for stack emissions calculated with GENII (Table 4.2).

Dose related to radon-220 is not included in the dose calculated for EPA compliance in [40 CFR 61, Subpart H](#) but is regulated by the 10-mrem (100-mSv)/yr standard established in [WAC 246-247](#). A release of 385 curies of radon-220 was calculated from engineering estimates for stack emissions from Building 325 in the 300 Area. A radon-220 dose of 0.064 mrem (0.64 mSv)/yr was calculated using the CAP-88 computer code for the Laboratory Supply Warehouse MEI, far below the [WAC 246-247](#) standard. The sum of MEI dose for radon-220 and dose calculated for compliance with [40 CFR 61, Subpart H](#) using the CAP-88 computer code is approximately 0.13 mrem (1.3 mSv), practically equivalent to the Horn Rapids Road air pathways MEI dose of 0.15 mrem (1.5 mSv) calculated using the GENII computer code.

4.2.3.2 Dose from Diffuse and Fugitive Radionuclide Emissions to an Off-site Maximally Exposed Individual

The December 15, 1989, revisions to [40 CFR 61, Subpart H](#) required DOE facilities to estimate the dose to a member of the public for radionuclides released from all potential sources of airborne radionuclides. DOE and EPA interpreted the regulation to include diffuse and fugitive (nonpoint source) emissions, as well as emissions from monitored point sources (i.e., stacks) described in Section 4.2.3.1. EPA has not specified or approved standardized methods to estimate diffuse airborne 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-2016-10](#)). Modeled contributions from monitored stack emissions and contributions from background levels of radionuclides are subtracted from perimeter ambient air concentrations measured for each radionuclide and positive differences are attributed to a virtual fugitive source located near the center of the Hanford Site.

The Laboratory Supply Warehouse location immediately south of the 300 Area was chosen for purposes of demonstrating compliance with the MEI dose standard for diffuse and fugitive emissions ([DOE/RL-2016-10](#)). The estimated dose from diffuse emissions to a MEI was calculated using the CAP-88 computer code to be 0.022 mrem (0.22 mSv)/yr. Therefore, the potential combined dose from stack emissions, radon-220 emissions, and diffuse emissions (excluding radon) during 2015 at the Laboratory Supply Warehouse location was 0.15 mrem (1.5 mSv)/yr, far below the 10 mrem (100 mSv) per year federal and state standards described above.

4.2.3.3 Maximum Dose to Non-U.S. Department of Energy Workers at the Hanford Site

DOE has recently allowed private businesses to locate their activities and personnel on some regions of the Hanford Site. The EPA Region 10 Office and the WDOH provided guidance to DOE-RL that, when demonstrating compliance with [40 CFR 61](#) standards, it should evaluate potential doses to non-DOE

employees who work at facilities within the Hanford Site but who are not under direct DOE control. This situation has created the need to calculate a maximum dose for an on-site individual employed by a non-DOE business who works within the boundary of the Hanford Site.

Doses to members of the public employed at non-DOE facilities at locations outside access-controlled areas on the Hanford Site (those requiring DOE-access authorization for entry) were evaluated in the 2015 EPA air emissions report ([DOE/RL-2016-10](#)) as possible MEI locations included the Columbia Generating Station operated by Energy Northwest and Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California (Figure 4.2). The non-DOE worker dose due to stack emissions at these facilities was calculated using the CAP-88 computer code assuming full-time occupancy because EPA guidance does not allow for adjustment of such doses to account for less than full-time occupancy. The highest estimated dose to a member of the public from fugitive emissions was at LIGO. The total dose attributable to 2015 stack emissions, fugitive source emissions, and radon-220 at LIGO was calculated using CAP-88 to be 0.075 mrem (0.75 mSv; [DOE/RL-2016-10](#)). Even assuming that a LIGO employee is continuously present, the estimated total dose to non-DOE on-site workers in 2015 was lower than the 0.15 mrem (1.5 mSv)/yr total dose calculated with CAP-88 to an off-site MEI at the Laboratory Supply Warehouse.

4.2.4 Special Case Dose Estimates

The exposure assumptions used to calculate the dose to the MEI were selected to provide a scenario yielding a reasonable upper bound dose estimate. The MEI dose calculations are based on measurements of radionuclide releases from stack emissions (air pathways) and differences between downstream and upstream radionuclide concentrations in the Columbia River (water pathways), followed by modeling of environmental transport related to a number of different exposure pathways (Figure 4.3). Exposure pathways using other radionuclide measurements also exist that could have resulted in radiological exposures. Three such scenarios include an outdoor recreationalist who consumed meat from contaminated wildlife that migrated from the Hanford Site; an individual who drank water from one of four DOE-owned water treatment facilities at the Hanford Site; and a visitor to the Manhattan Project National Historical Park. The potential doses resulting from these scenarios are examined in the following sections.

4.2.4.1 Outdoor Recreationalist Dose

Wildlife has access to Hanford Site areas that are contaminated with radioactive materials and have the potential to acquire radioactive contamination and migrate off site. Wildlife sampling was conducted at the Hanford Site to estimate radionuclide tissue concentrations in animals from the site that could potentially have been hunted off site. An outdoor recreationalist is also potentially exposed to contaminated soil and sediment along the river corridor if they access this area from the Columbia River. However, concentrations of radionuclides measured in soil (cesium-137, plutonium-238, plutonium-239/-240, and strontium-90) at far field sampling locations are not readily distinguishable from background levels, and soil concentrations are less susceptible to yearly variation than sediment and wildlife. An evaluation of radionuclide soil concentrations and trends over time is provided in [PNNL-20577](#). Review of the 2015 sediment data indicates that concentrations of key radionuclides frequently detected in sediment (including cesium-137, plutonium-239/-240, and uranium isotopes) have approximately equal concentrations at upstream (Priest Rapids Dam) and downstream (McNary Dam) locations. Also, sediment concentrations at the dam locations are generally as large as or larger than concentrations at locations along the Hanford Site in the 100 Area and at Hanford Townsite. The 2015 sediment data do not indicate the presence of a Hanford contribution to sediment

radionuclide concentrations. Therefore, the screening assessment of outdoor recreationalist dose will focus on wildlife samples obtained in 2015.

Gamma-emitting radionuclides were analyzed in muscle tissue samples collected in 2015 from Canada goose and cottontail rabbit. In addition to muscle tissue, bone samples were collected from these animals and analyzed for strontium-90, a radionuclide that accumulates in bone tissue. For estimating dose from ingestion of game meat, radionuclide concentrations in muscle tissue are most applicable. Ten muscle tissue samples were collected and analyzed in 2015 for Canada goose, and four for cottontail rabbit. The only radionuclide detected in the muscle tissue of either animal was potassium-40, a naturally occurring primordial radioisotope not of Hanford Site origin.

Four fillet tissue samples and four carcass samples were obtained from sturgeon in the Hanford Reach in 2015. Five fillet tissue samples and four carcass samples were obtained from whitefish in the 100 Area region of the Columbia River. Additionally, five fillet tissue samples and three carcass samples were obtained from whitefish in an upstream reference area. Fillet samples were analyzed for gamma-emitting radionuclides, tritium, strontium-90, and isotopes of plutonium and uranium. Carcass samples were only analyzed for strontium-90. Detected radionuclides in fillet samples were limited to cesium-137, potassium-40, uranium-234, uranium-235, and uranium-238. Potassium-40 is a naturally occurring radionuclide that is not of Hanford Site origin. However, cesium-137 and uranium isotopes are associated with Hanford Site operations.

Cesium-137 was detected in three of the four sturgeon fillet samples from the Hanford Reach. Uranium-234, -235, and -238 were detected in one white fish fillet sample from the 100 Area and two fillet samples from the reference area. However, isotopic uranium concentrations detected in the reference area whitefish fillet samples were all higher than the values detected in the 100 Area fillet sample. These uranium isotope results for whitefish are in contrast to sampling results for uranium isotopes in carp fillet samples collected in 2014, where concentrations of uranium-234 and uranium-238 were observed to increase in carp fillet samples with downstream distance from an upstream reference area to the 100 Area to the 300 Area. Differences in sampling locations and species may explain these differences between 2014 carp and 2015 whitefish fish fillet results; Hanford Site uranium releases to the Columbia River estimated from downstream and upstream river concentrations were approximately equivalent in these 2 years.

The potential radiation dose received from consumption of fish fillets with cesium-137 concentrations similar to those measured in sturgeon in 2015 would be negligible. Assuming annual fish consumption of 88 lbs (40 kg) for an MEI (Table D.4), the annual radiation dose related to fish ingestion for fish that contains 0.0065 pCi/g [2.4×10^{-4} Bq/g] of cesium-137 is estimated to be 0.012 mrem (0.12 mSv)/yr.

The dose estimate was derived using a cesium-137 ingestion dose factor of 4.8×10^{-5} mrem/pCi (1.3×10^{-2} mSv/Bq) from ICRP Publication 72 (ICRP 1995) in the following manner:

$$0.0065 \text{ pCi cesium-137/g} \times 40 \text{ kg} \times 1,000 \text{ g/kg} \times 4.8 \times 10^{-5} \text{ mrem/pCi} = 0.012 \text{ mrem (0.12 mSv)/yr}$$

4.2.4.2 Hanford Site Drinking Water Dose

Drinking water was sampled and analyzed for tritium, strontium-90, gross alpha radiation, and gross beta radiation during 2015 in accordance with applicable regulations ([40 CFR 141](#)); water samples were collected from the 100-K Area, 200-West Area, and two sources in the 400 Area. The water supply for the

100-K and 200-West Areas is the Columbia River, whereas the primary and backup water supplies for the 400 Area are groundwater wells (see Section 7.1).

A comparison of analytical results for the 100-K, 200 Area, and 400 Area drinking water samples to state and federal standards is provided in Section 7.1. Tritium and strontium-90 are both man-made soluble beta radiation emitters; there are also naturally occurring beta emitters in the uranium, actinium, and thorium decay series. Potential on-site drinking water dose from Hanford-related beta-emitting radionuclides is addressed in this section by evaluating drinking water data for tritium and strontium-90.

Strontium-90 was analyzed in one sample from each of the four drinking water sources in 2015 and was not identified above its analytical detection limit in any drinking water sample. Tritium was analyzed in one sample from both the 100-K and 200-West Areas and was not detected above its analytical detection limit in either sample. Tritium was detected in all four drinking water samples collected from the primary drinking water sources for the 400 Area (well P-16) and also in the single sample from backup well P-14. Based on the four quarterly samples from the primary well, the annual average 400 Area drinking water tritium concentration was 1,275 pCi/L (47 Bq/L). Assuming a consumption rate of 0.26 gal (1 L)/day for 250 working days at the FFTF in the 400 Area, the potential annual worker dose in 2015 would be approximately 0.21 mrem (0.21 mSv). A single tritium sample was also collected from Well P-14 in the 400 Area, where a value of 13,000 pCi/L was reported. Based on this single measurement, an annual worker drinking water dose for water obtained exclusively from this backup supply well would be 0.22 mrem (2.2 mSv). These estimates are well below EPA's drinking water dose limit of 4 mrem (40 mSv)/yr for beta-emitting radionuclides in public drinking water supplies.

The dose estimates were derived using a tritium ingestion dose factor of 6.7×10^{-8} mrem/pCi (1.8×10^{-5} mSv/Bq) from ICRP Publication 72 (ICRP 1995) in the following manner:

$$1,275 \text{ pCi tritium/L} \times 1 \text{ L/day} \times 250 \text{ d/year} \times 6.7 \times 10^{-8} \text{ mrem/pCi} = 0.021 \text{ mrem/yr}$$

4.2.4.3 Manhattan Project National Historical Park Visitor Dose

The Manhattan Project National Historical Park at Hanford includes guided tours of the B Reactor as well as access to several pre-Manhattan Project locations, two of which (Hanford Townsite and White Bluffs Bank) are situated to the east of 100-K and the 200 Area. These historical locations are geographically closer to these air emissions sources than the off-site MEI locations evaluated in Section 4.2.1. However, unlike an off-site residential MEI receptor, visitors to these locations would not be exposed from agricultural and drinking water exposure pathways, nor would they be continually exposed over the course of a year, as might be anticipated for some residents. For these reasons, potential doses at these locations are likely to be considerably below those calculated for the hypothetical off-site MEI.

Inhalation dose related to 100-K and 200 Area stack emissions was calculated for a hypothetical individual at the Hanford Townsite and White Bluffs Bank locations using the GENII Version 2 computer code.

Although Historical Park visitors would be present only briefly and on a single occasion at these locations, individuals conducting tours could be present for greater lengths of time. Additionally, these locations are adjacent to the Columbia River where recreationalists might be exposed while boating, fishing, or engaged in other activities. For this screening calculation, continuous exposure at the Hanford Townsite and White Bluffs Bank locations was assumed. The results of these dose calculations are presented in Table 4.4.

Table 4.4. Annual Doses for a Hypothetical Individual at the Hanford Townsite and White Bluffs Bank Locations (2015)

Release Type	Exposure Pathway	Location	Dose Contributions from Operational Areas, mrem*		
			100 Areas	200 Areas	Pathway Total
Air	Inhalation	Hanford Townsite	4.2E-05	1.7E-04	2.1E-04
		White Bluffs Bank	2.0E-04	1.4E-04	3.4E-04

*To convert mrem to International System dose units (mSv), multiply by 10.

Radiological doses assuming continuous inhalation exposure at either the Hanford Townsite or White Bluffs Bank locations are far below the hypothetical off-site MEI air pathways dose of 0.15 mrem (1.5 mSv; Table 4.2) at Horn Rapids Road.

4.2.5 Doses from Non-U.S. Department of Energy Sources

Doses from non-DOE sources were not quantified in 2015 because the MEI dose of 0.33 mrem (3.3 mSv)/yr from DOE-related sources (section 4.2.1) was far below the threshold of 25 mrem (250 mSv)/yr at which the contribution of non-DOE sources must be included. [DOE O 458.1](#) paragraph 4.e.(1)(c) states that dose evaluations to demonstrate compliance with the public dose limit must include:

[t]he dose to members of the public from DOE-related exposure sources only, if the projected DOE-related dose to the representative person or MEI is 25 mrem (250 mSv) in a year or less. If the DOE-related dose is greater than 25 mrem (250 mSv) in a year, the dose to members of the public must include major non-DOE sources of exposure and dose from DOE-related sources.

Before it was superseded by the release of [DOE O 458.1](#) in 2011, DOE O 5400.5 provided the applicable requirements for radiation protection of members of the public. Chapter II, Paragraph 7 of DOE O 5400.5, Chg 2 has a reporting requirement for a combined dose due to DOE and other manmade sources.

Therefore, Hanford Site environmental reports prior to 2011 routinely evaluated dose contributions from various non-DOE industrial sources of radiation exposure on or near the Hanford Site. These included a commercial, low-level radioactive waste burial ground at the Hanford Site operated by 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, Inc.; a commercial, low-level radioactive waste treatment facility operated near the site by Perma-Fix Northwest, Inc.; and a commercial decontamination facility operated near the site by PN Services (Figure 4.2). The total individual dose from non-DOE source activities in 2010 was conservatively estimated at about 0.004 mrem (0.04 mSv)/yr ([PNNL-20548](#)).

4.2.6 Dose to Non-Human Biota

Dose assessments for non-human biota evaluate the potential for exposures from Columbia River sediment and water, soils (near facilities and off site), and exposures associated with West Lake. Upper estimates of the radiological dose to aquatic organisms were made in accordance with the [DOE O 458.1](#) interim requirement for management and control of liquid discharges and air emissions. The current dose limit for aquatic animal organisms is 1 rad (10 milligray [mGy]) per day. Rad is a unit of absorbed dose of ionizing radiation equal to an energy of 100 ergs/g of irradiated material. In addition to the dose limit for aquatic organisms there is a dose limit for riparian or terrestrial wildlife of 0.1 rad (1 mGy)/day.

Concentration guides for assessing doses to biota are very different from the DOE-derived concentration standards used to assess radiological doses to humans. A tiered approach is used to estimate radiological

doses to aquatic and terrestrial biota. This method uses the RESidual RADioactive (RESRAD)-BIOTA computer code ([DOE/EH-0676](#), *User's Guide, Version 1, RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation*; [DOE-STD-1153-2002](#), *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*) to compare radionuclide concentrations measured by routine monitoring programs to a set of biota concentration guides.

Biota concentration guides are the soil, water, or sediment concentrations of a radionuclide that would produce 1 rad (10 mGy)/day for aquatic biota or terrestrial plants or 0.1 rad (1 mGy)/day for riparian or terrestrial wildlife. 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 limit. If the sum of fractions exceeds 1.0, then the dose limit has been exceeded. If the initial estimated screening value (Tier 1) exceeds the guideline (sum of fractions more than 1.0), additional screening calculations are performed (Tier 2 or Tier 3) to evaluate more accurately 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 2015 from on and around the Hanford Site.

Researchers used the RESRAD-BIOTA computer code to evaluate potential effects on biota from the maximum concentrations of radionuclides measured in Columbia River sediment and water as tabulated in Appendix C. The detected radionuclides evaluated across all locations in the Columbia River sediment and water biota dose assessment are carbon-14, cobalt-60, cesium-137, plutonium-238, plutonium-239/-240, strontium-90, technetium-99, tritium, uranium-234, uranium-235, and uranium-238. Potassium-40 was also detected in sediments upstream, on site, and downstream of the Hanford Site. Potassium-40 is a naturally occurring radionuclide and is not associated with releases from the reactors or any groundwater plumes entering the Columbia River. Therefore, dose associated with potassium-40 is not included in the biota dose assessment. Most of the locations located on the Columbia River had samples collected from riverbank springs or seeps that carry groundwater contaminants into the Columbia River. Concentrations in springs or seeps are greater than those observed in the river water; therefore, the dose assessment results for these discrete areas of elevated concentrations are protective relative to the potential for impacts on populations of biota in the Columbia River. For an initial screen of ecological populations, the sediment and water data were split into five subareas: upstream, 100 Areas, Hanford Townsite, 300 Area, and downstream and the maxima concentrations evaluated in these locations. If risks to biota were identified in the initial screen, then further assessments using average concentration over smaller spatial units would be evaluated. The results of the screening calculations listed in Table 4.5 show the concentrations in all Columbia River sediment and water samples passed the Tier 1 screen and indicate that the calculated doses were below dose limits (sum of fractions less than one). Most of the estimated dose in the 100 Areas is from carbon-14 (89%) and strontium-90 (9%) and dose in the 300 Area is basically entirely associated with uranium isotopes. Biota doses upstream at the Hanford Townsite and downstream were all similar and likely related to background concentrations in water and sediment. Further documentation of the Columbia River biota dose calculations is provided in Appendix D.

Table 4.5. Estimated Doses to Biota Associated with Columbia River Sediment and Water*

Location	Media Sampled for Key Radionuclides†	Tier 1 Screen Sum of Fractions‡	Pass or Fail
Upstream	Sediment, Water	0.015	Pass
100 Areas	Sediment, Water	0.64	Pass
Hanford Townsite	Sediment, Water	0.016	Pass
300 Area	Water	0.30	Pass
Downstream	Sediment, Water	0.016	Pass

*Using RESRAD-BIOTA computer code, a screening method to estimate radiological doses to aquatic and riparian biota.

†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 or 3) is required. The sum of fractions has been rounded to two figures with a maximum of three decimal points. Maximum concentrations and the Biota Concentration Guides are presented in Appendix D.

‡The biota dose assessment requires concentration data for both sediment and water. If one of these media is not measured then it is estimated by using the default water to sediment partition coefficient. If water was measured, then sediment was estimated from water and if sediment was measured then water was estimated from sediment. In some cases where both sediment and water were measured a radionuclide was only measured in one medium (e.g., tritium in water), and the concentration for that radionuclide in the other medium was estimated. See Appendix D for details on what was measured.

Biota dose calculations also were completed for West Lake, located on the Central Plateau of the Hanford Site. West Lake is a vernal pool or ephemeral wetland that fills with water during the winter and generally becomes smaller or dries up entirely in other seasons. West Lake is part of the 200 Area Unplanned Release Waste Group Operable Unit (200-UR-1 Operable Unit), and is planned for supplemental characterization ([DOE/RL-2009-121](#), *Sampling and Analysis Plan for the West Lake Site*). The results of these planned investigations will be presented in the appropriate CERCLA remedial action document for the 216-N-8 waste site. In parallel with these planned CERCLA studies, this program has been collecting sediment data annually. In addition, other media (water and biota) have been collected from West Lake on a less regular schedule. Both sediment and water samples were collected in 2015 and data tabulated (Appendix C, Tables C.2, C.3, and C.4).

The results of the 2015 screening calculations listed in Table 4.6 show the West Lake sediment and water concentrations failed the Tier 1 and 2 screens. The Tier 1 screen was based on the maximum concentration, and the Tier 2 screen was based on the average concentrations of five water and three sediment samples. The estimated biota dose for Tiers 1 and 2 was almost entirely due to the measured concentration of uranium in water and the assumed potential for uptake from water to aquatic biota using a default bioaccumulation factor.

Table 4.6. Estimated Doses to Biota Associated with West Lake*

Tier	Exposure Assumptions	Sum of Fractions†		Pass or Fail
		2014	2015	
1	Maximum Sediment, Water Concentration and Default Bioaccumulation	62	16	Fail
2	Average Sediment, Water Concentration and Default Bioaccumulation	31	3.7	Fail
3	Average Sediment, Water Concentration and Site-specific Bioaccumulation	0.34	0.05	Pass

*Using RESRAD-BIOTA computer code, a screening method to estimate radiological doses to aquatic and riparian biota.

†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 or 3) is required.

The RESRAD-BIOTA default bioaccumulation factor for uranium isotopes from water to aquatic biota is 1,000. This means that the concentration in tissues would be 1,000 times that measured in water. Site-specific data from West Lake support a much lower uranium bioaccumulation factor. Aquatic biota

(only brine flies have been sampled, and they are also the most relevant organisms) and water were sampled concurrently in 2000 and 2007 ([PNNL-13487](#), *Hanford Site Environmental Report for Calendar Year 2000*; [DOE/RL-2007-50](#), *Central Plateau Ecological Risk Assessment Data Package Report*). The maximum concentration of any of the uranium isotopes in brine flies was 0.77 pCi/g for uranium-233/-234 in 2007. The minimum uranium-233/234 water concentration was 940 pCi/L in 2007. The bioaccumulation factor is calculated by dividing the biota concentration (in pCi/g) by the water concentration (in pCi/ml); therefore, the maximum bioaccumulation factor for uranium would be less than one. A bioaccumulation factor of one was used for the Tier 3 biota dose calculation as a somewhat protective measure of site-specific uranium uptake into the food chain. The Tier 3 biota dose calculations resulted in sum of fractions less than one, indicating that the calculated doses were below dose limits related to the biota concentration guides. This result was similar to those calculated for 2012, but the 2014 doses were about 10 times greater than those calculated for 2013 (Table 4.6). The reason is that the maximum concentrations in West Lake pond water samples varied quite widely, and isotopic uranium is typically detected in West Lake pond water. The last 3 years of concentrations were 2013 (uranium-234 at 256 pCi/L, uranium-235 at 13.8 pCi/L, uranium-238 at 250 pCi/L); 2014 (uranium-234 at 6,580 pCi/L, uranium-235 at 248 pCi/L, uranium-238 at 6,380 pCi/L); and 2015 (uranium-234 at 1,650 pCi/L, uranium-235 at 87.1 pCi/L, uranium-238 at 1,570 pCi/L). The maximum concentration measured in 2014 was about 25 times greater than that measured in 2013. Further documentation of the West Lake biota dose calculations, including the Tier 3 Biota Concentration Guides, is provided in Appendix D.

Biota dose calculations were implemented for terrestrial biota based on exposures to soils collected on and distant to the Hanford Site. The RESRAD-BIOTA computer code evaluates potential effects on biota from the maximum concentrations of radionuclides measured in near field and far field soil samples as tabulated in Appendix C. The radionuclides evaluated in soil are cesium-137, plutonium-238, plutonium-239/-240, and strontium-90. The results of 2015 screening calculations listed in Table 4.7 show the near- and far-field soil concentrations passed the Tier 1 screen, based on the maximum concentration. Basically, the entire estimated dose for near-field locations is from cesium-137 (94%) and strontium-90 (6%). Biota doses at far field locations are likely related to background concentrations in soil. For a long-term trend in soil concentrations and associated biota doses on and off the Hanford Site, see [PNNL-20577](#).

Table 4.7. Estimated Doses to Terrestrial Biota Associated with On- and Off-site Soil*

Location	Tier 1 Screen Sum of Fractions†	Pass or Fail
Near field	0.72	Pass
Far field	0.024	Pass

*Using RESRAD-BIOTA computer code, a screening method to estimate radiological doses to aquatic and riparian biota.
†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 or 3) is required. The sum of fractions has been rounded to two figures with a maximum of three decimal points. Maximum concentrations and the Biota Concentration Guides are presented in Appendix D.

In addition to the dose assessments related to soils, sediments, and water, there are also fish and wildlife collected from the Hanford Site and reference locations. Although none of the biota dose assessments (except for West Lake) required any additional tiers of analyses, these supplemental calculations characterize more realistic doses based on measured concentrations. Dose to aquatic animals based on the maximum concentrations of carbon-14 (192 pCi/g), cesium-137 (7.48 pCi/g), and strontium-90 (0.835 pCi/g) in clams was 0.0009 rad/day. Dose to aquatic animals based on the maximum concentrations of cesium-137 (0.0145

pCi/g), uranium-234 (0.00055 pCi/g), uranium-235 (0.000272 pCi/g), and uranium-238 (0.000422 pCi/g), in fish was 0.00003 rad/day. Internal dose to terrestrial plants based on the maximum concentrations of cesium-137 (0.12 pCi/g), plutonium-238 (0.0014 pCi/g), plutonium-239 (0.0033 pCi/g), and strontium-90 (1.4 pCi/g) in plants was 0.0001 rad/day. Dose to terrestrial animals based on the maximum concentrations of strontium-90 (0.169 pCi/g) in rabbit bone was 0.00007 rad/day. Using the measured tissue data leads to lower doses than using the default bioaccumulation information assumed in the Tier 1 RESRAD-Biota calculations.

4.2.7 Radiological Dose in Perspective

The dose for the MEI in 2015 was 0.21 mrem (2.1 mSv; section 4.2.1). The average individual dose from Hanford Site operations in 2015, based on the 50-mi (80-km) radius population exposed to air emissions and the Tri-Cities populations exposed to water pathways releases to the Columbia River, was approximately 0.0058 mrem (0.058 mSv). To place the MEI and average individual estimated doses into perspective, the estimated doses may be compared with doses received from other routinely encountered sources of radiation. The NCRP issued a report in March 2009 estimating that the overall average exposure to ionizing radiation for the average American is 620 mrem (6,200 mSv) per year ([NCRP 2009](#)). Approximately 50% of the 620 mrem (6,200 mSv)/yr average annual dose is related to natural sources, with the remaining 50% attributable primarily to medical procedures.

The most relevant radiation sources for comparison to doses received from environmental media include natural terrestrial and cosmic background radiation, and inhalation of naturally occurring radon (Figure 4.7). Average annual individual background dose related to terrestrial radiation (19 mrem [190 mSv]), cosmic background radiation (30 mrem [300 mSv]), and radon (radon-222) and thoron (radon-220) gases (230 mrem [2,300 mSv]) are shown relative to Hanford Site operational doses in Figure 4.8. The calculated radiological doses from Hanford Site operations in 2015 were a small percentage of national average annual doses from these natural background sources. Note that annual dose is shown on a linear scale in Figure 4.8, and Hanford-related doses are too small to be observed. For example, the national annual average radiation dose from natural terrestrial sources (approximately 19 mrem [190 mSv]) is approximately 90 times larger than the 2015 Hanford Operations dose to the MEI receptor (0.21 mrem [2.1 mSv]).

Scientific studies (*Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII Phase 2* [[National Research Council 2006](#)]) have been performed to estimate the possible risk from exposure to low levels of radiation. These studies provide information to government and scientific organizations for use in recommending radiological dose limits and standards for public and occupational safety.

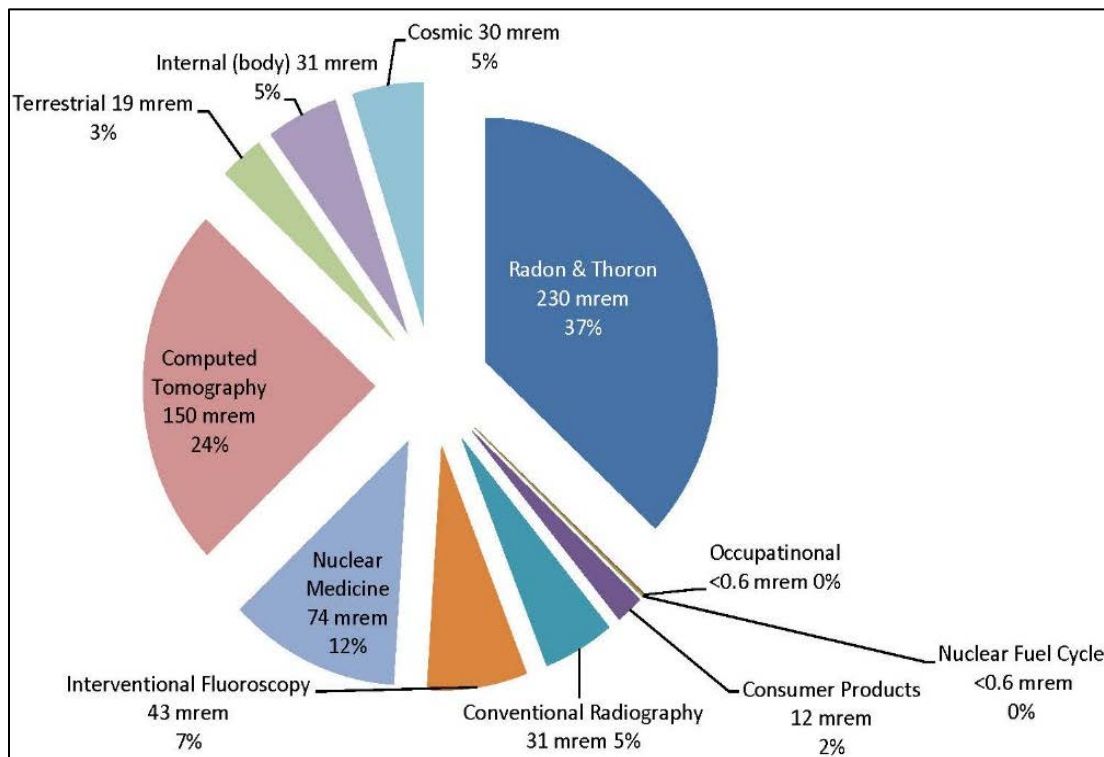


Figure 4.7. U.S. Annual Average Radiological Doses from Various Sources (2009 National Council on Radiation Protection and Measurements)

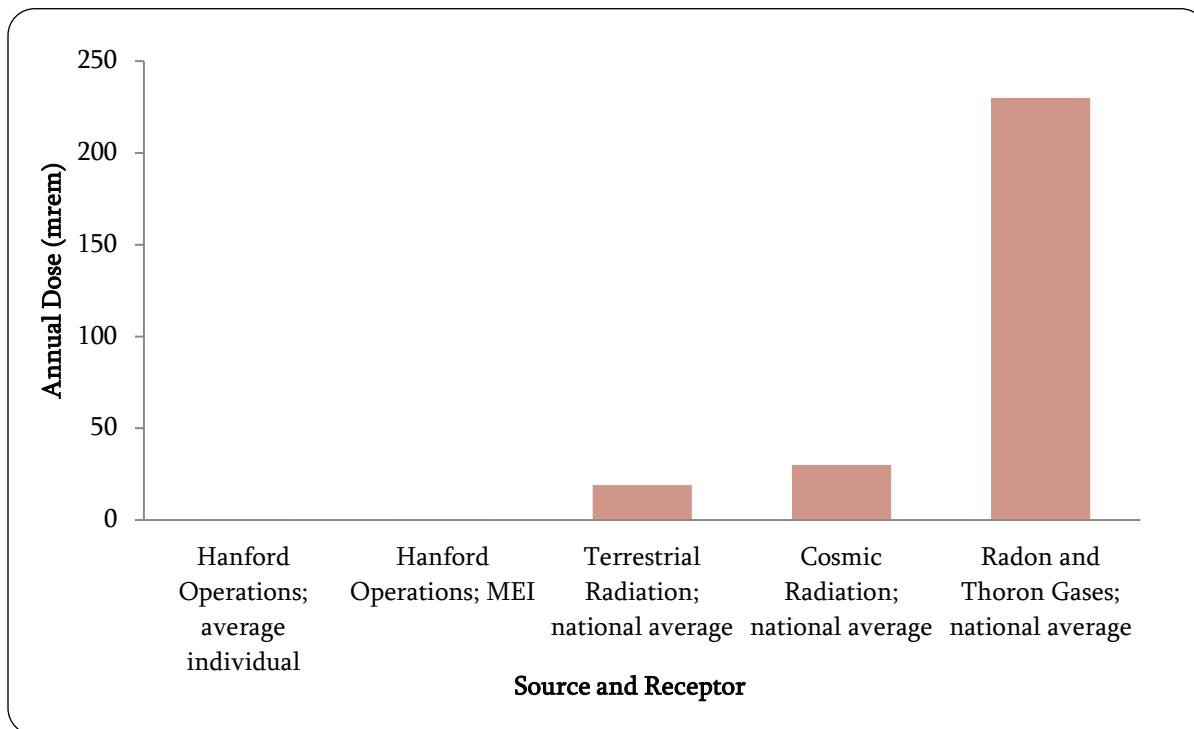


Figure 4.8. Radiological Doses from Hanford Site Operations Compared to Annual Average from Natural Sources

Although no increase in the incidence of health effects from low doses of radiation actually has 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, historically, painters of radium dials). This concept is known as the “linear no-threshold” hypothesis. Under these assumptions, public exposure to radiation from current Hanford Site releases, exposure to natural background radiation (which is hundreds of times greater), and exposure to very high levels of radiation each increases an individual’s probability or chance of developing a detrimental health effect (primarily cancer) proportional to the dose received.

Scientists do not fully agree on how to translate the available epidemiological data on health effects from high radiological doses into the numerical probability (risk) of detrimental effects from low radiological doses ([UNSCLEAR 2012](#), *Biological Mechanisms of Radiation Actions at Low Doses*). Some scientific studies have indicated that low radiological doses may result in beneficial rather than adverse effects (Calabrese 2009). Because cancer is a common disease in the general population and may be attributable to many other causes besides radiation (e.g., genetic defects, natural and man-made chemicals, natural biochemical body reactions), some scientists doubt that the risk from low-level radiation exposure can be proven conclusively. In developing *Clean Air Act* regulations, EPA used a probability of approximately 4 per 10 million (4×10^{-7}) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (10 mSv; [EPA 1989](#)). Additional data support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time ([National Research Council 2006](#)). Guidance from the Interagency Steering Committee on Radiation Standards (ISCORS; *A Method for Estimating Radiation Risk from TEDE* [[ISCORS 2002](#)]) recommends that agencies assign a risk factor of 6 per 10 million (6×10^{-7}) for developing a fatal cancer after receiving a dose of 1 mrem (10 mSv).

One approach for providing perspective on calculated risks related to low-dose radiation exposures is to compare them to risks involved in other typical activities. Table 4.8 compares the estimated risks from various radiological doses to the risks of some activities encountered in everyday life.

Table 4.8. Estimated Risk from Various Activities and Exposures

Activity or Exposure Per Year	Risk of Fatality
Home accidents	100×10^{-6} *
Firearms (sporting accidents)	10×10^{-6} *
Flying as an airline passenger (cross-country roundtrip – accidents)	8×10^{-6} *
Recreational boating (accidents)	6×10^{-6} *
Riding or driving 300 mi (483 km) in a passenger vehicle	2×10^{-6} *
Dose of 1 mrem (10 mSv) for 70 yrs	0 to 0.6×10^{-6} †
Natural background radiological dose (310 mrem [3,100 μ Sv]) for 70 yrs	0 to 200×10^{-6} †
Dose to hypothetical MEI (2015 rate) of 0.21 mrem (2.1 mSv)/yr living near Hanford Site for 70 yrs	0 to 0.1×10^{-6} †

*Real actuarial values.
†Upper bound calculated using 6×10^{-7} risk of developing a fatal cancer after receiving a 1 mrem (10 mSv) dose ([ISCORS 2002](#)).

4.3 Radiological Clearance of Hanford Site Property

JW DeMers

Principal requirements for the control and clearance of DOE property containing residual radioactivity are found in [DOE O 458.1](#). These requirements are designed to ensure the following:

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

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

In the process of performing environmental remediation or related support activities, Hanford Site contractors encounter a wide variety of contaminated personal property, including consumables, office items, tools and equipment, and debris. Over 19,000 items of personal property were cleared from radiological areas on the Hanford Site; however, the majority of the items did not leave the Hanford Site. The personal property items primarily consisted of small items such as flashlights, hard hats, radios, cameras, pens, pencils, respiratory protection, radiological control instruments, and industrial hygiene instruments. All of these items met [DOE O 458.1](#) clearance criteria and therefore did not require additional radiological controls post-survey. In January 2000, DOE issued a moratorium prohibiting the release of volume-contaminated metals, and subsequently suspended the release of metals for recycling purposes from DOE radiological areas in July 2000. As a result, no volume of contaminated metals or metals for recycling purposes were released from Hanford in 2015.

Final disposition of potentially contaminated personal property with hard-to-detect radionuclides depends on whether the property is considered radiologically contaminated, and whether the disposal of such property is subject to CERCLA requirements. Radiologically contaminated property is disposed at ERDF if subject to CERCLA requirements, and if not, at the CWC in the 200-West Area. Personal property that has contamination levels below approved DOE control and clearance guidelines ([DOE O 458.1](#)) are considered for release if the property can be reused. Hanford Site contractors routinely encounter 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 during work activities. The control and release criteria ([DOE O 458.1](#)) 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 O 458.1](#).

Accordingly, a request to DOE in May 2006 was submitted by WCH (DOE contractor for the River Corridor Closure Contract) to increase the release criteria (authorized limits) for hard-to-detect radionuclides. The requested authorized limits would apply only to beta-gamma surface contamination on potentially contaminated equipment and materials, and exclude 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 these authorized limits would be protective of human health and the environment. Based on these analyses, the authorized limits would result in a dose of less than 1 mrem (10 mSv) in any year to the MEI and a collective dose of less than 10 person-rem (0.1 person-Sv) to any exposed population. These authorized limits (Table 4.9) were reviewed by RL and HQ personnel and approved for use by WCH in May 2007. In 2008, RL provided conditional approval to CHPRC and Fluor Hanford, Inc. to use these hard-to-detect authorized limits. In addition to this request, in 2013 CHPRC requested and was approved an authorized limit to apply the general beta-gamma limits to the low energy beta emitter, plutonium-241 (1,000 dpm/100 cm² removable limit and 5,000 dpm/100 cm² total contamination limit). In June 2009, WRPS submitted a request to ORP for approval to use these hard-to-detect authorized limits. ORP provided conditional approval for this request in June 2009. MSA submitted a request to RL in October 2009 for approval to use these hard-to-detect authorized limits. RL provided conditional approval for this request in November 2009.

Table 4.9. Approved Release Criteria (Authorized Limits) for Select Hard-to-Detect Radionuclides* for Residual Beta-Gamma Surface Contamination

Average	Maximum	Removable
50,000 dpm/100 cm ²	150,000 dpm/100 cm ²	10,000 dpm/100 cm ²

*Carbon-14, iron-55, nickel-59, nickel-63, selenium-79, technetium-99, palladium-107, and europium-155

4.3.2 Granular Activated Carbon for Offsite Shipment and Regeneration Radiological Clearance

Carbon tetrachloride was found in the unconfined aquifer beneath the 200 West Area in the mid-1980s. Groundwater monitoring indicated the carbon tetrachloride plume was widespread, and concentrations were increasing. An expedited response action was initiated in 1992 to extract carbon tetrachloride from the vadose zone in the 200-ZP-2 Operable Unit, currently designated as the 200-PW-1 Operable Unit, in the 200 West Area. The 200-PW-1 Operable Unit soil-vapor extraction system includes vapor-phase granular activated carbon canisters to remove carbon tetrachloride from the extracted vapors prior to discharge. This facility was in full operation by 1995.

Workers installed a groundwater pump-and-treat system in 1996 in a second operable unit (200-ZP-1 Operable Unit) to treat contaminated groundwater in the unconfined aquifer. The system includes an air-stripping unit that volatilizes carbon tetrachloride in the groundwater and then discharges the carbon tetrachloride vapors through granular activated carbon canisters that are identical to the large, carbon-steel granular activated carbon canisters in the 200-PW-1 Operable Unit soil-vapor extraction system.

Each of these systems uses granular activated carbon canisters to capture the volatile organic compounds removed during the extraction process. When a granular activated carbon canister has reached volatile organic compound saturation, it is removed from the system, and the granular activated carbon is prepared for shipment to an off-site facility for regeneration and reuse. Regeneration of the granular activated carbon requires heating it in a hearth furnace to remove the captured volatile organic compounds.

Based on past Hanford Site activities, and the results of characterization sampling, this granular activated carbon could contain residual radioactivity. Characterization sampling results were used to determine specific radionuclides of concern for this residual radioactivity. For any potential residual radioactivity, [DOE O 458.1](#) requires that the residual radioactivity not exceed established guidelines or that radiological release criteria (i.e., authorized limits) be developed and submitted to the applicable DOE field office.

Following review by RL and HQ personnel in October 2008, approved authorized limits for offsite shipment and regeneration of granular activated carbon was approved for use by CHPRC.

In anticipation of placing the new 200-West Area Pump and Treat facility online, increasing the volume of spent granular activated carbon being sent off site, a request to modify the authorized limits was made by CHPRC and approved by DOE in October 2010 (Table 4.10). This modification to the authorized limits does not change the expected dose to the public.

Table 4.10. Approved Modified Authorized Limits for Off-site Shipment and Regeneration of Granular Activated Carbon

Radionuclide	Authorized Limit (pCi/g)
Americium-241	29
Carbon-14	3,000
Cesium-137	80
Cobalt-60	21
Europium-152	40
Europium-154	40
Europium-155	700
Iodine-129	50
Neptunium-237	50
Nickel-63	100
Plutonium-238	26
Plutonium-239	24
Plutonium-240	24
Protactinium-231	10
Selenium-79	2,000
Strontium-90	100
Technetium-99	500
Thorium-232 plus progeny	6
Tritium	300,000
Uranium-234	100
Uranium-235	100
Uranium-238 plus short-lived progeny	100

Approximately 150,000 lbs (68,000 kg) of granular activated carbon was shipped off site in 2015 for regeneration under these approved modified authorized limits.

4.3.3 Tri-Cities Development Council (TRIDEC) Land Conveyance

The [DOE O 458.1](#) authorized limits for radiological release of proposed land conveyance to TRIDEC were approved in December 2013. In 2015, field work was completed, and sample and survey results determined that authorized limits were met. Independent verification contractor Oak Ridge Associated Universities completed verification field and close-out activities. In 2015, approximately 1,640 ac (664 ha) were cleared and transferred to the local community reuse organization for development.

5.0 Environmental Restoration and Waste Management

Environmental restoration and waste management activities continued on the Hanford Site during 2015. The following sections describe ongoing Hanford Site River Corridor closure, cleanup, remediation, facility decommissioning, waste management operations, underground waste storage tank status, construction of the WTP and its associated facilities, and research activities related to waste cleanup.

5.1 Cleanup and Remediation Activities

The following sections describe ongoing cleanup and remediation activities at the Hanford Site.

5.1.1 River Corridor Closure

JA Lerch

The 220-mi² River Corridor includes the Hanford Site 100 and 300 areas that border the Columbia River. The River Corridor includes nine deactivated plutonium-production reactors, numerous support facilities, and liquid- and solid-waste disposal sites. DOE's focus is to complete source cleanup actions in the 100 and 300 Areas with the following principal goals:

- Deactivation, decommissioning, decontamination, and demolition (D4) of 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 current cleanup criteria in protecting human health and the environment
- Prepare the River Corridor for transition to the DOE-RL long-term stewardship program (surveillance and maintenance).

In 1991, the TPA agencies agreed to a strategy to apply available funding to actual cleanup rather than spending available resources on extensive characterization and risk assessment activities. Waste site cleanup under interim action RODs were initiated in the 100 and 300 areas during the mid-1990s and continue today within the River Corridor. As the interim actions are completed, associated geographical areas are transitioned into the RL long-term stewardship program. Through 2015, transitions have been completed for 190 of the 220 mi² of the River Corridor.

In parallel with continued cleanup activities, the remedial investigation/feasibility study process is being implemented for six decision areas of the River Corridor (100-B/C, 100-K, 100-N, 100-D/H, 100-F/IU-2/IU-6, and 300 Area) to integrate the interim actions and establish final cleanup decisions for source and groundwater operable units. Final action RODs were issued in November 2013 ([DOE/EPA 2013](#)) for the 300 decision area and in September 2014 ([DOE/EPA 2014](#)) for the 100-F/IU-2/IU-6 decision area. Completion of RI/FS reports, public review of proposed actions, and development of RODs for the remaining four decision areas are anticipated to be completed between 2016 and 2017.

5.1.2 100 Area

This section describes ongoing cleanup and remediation activities in the 100 Area.

5.1.2.1 100-B/C, 100-D, 100-F, 100-K, 100-H, and 100-N Areas Waste Sites

JA Lerch

The 100 Area waste sites vary in complexity and waste type. Typical waste sites include waste burial grounds, liquid effluent waste sites, burn pits, retired septic systems, piping systems, and miscellaneous waste sites. Full-scale remediation of waste sites in the 100 Areas began in 1996. In 2015, remediation activities were conducted in the 100-B/C, 100-D, 100-H, 100-N, and IU-2/6 Areas. Waste generated from the cleanup of waste sites is disposed at ERDF in the 200 Area. This centralized disposal facility is the primary disposal pathway, but other disposal options are available if the material does not meet the waste acceptance criteria for the facility.

A total of 100,860 tons (91,499 MT) of contaminated soil and debris from 100 Area remediation activities were disposed at ERDF in 2015. Quantities and respective locations are as follows:

- 18,728 tons (16,990 MT) from the 100-B/C Area
- 31,465 tons (28,545 MT) from the 100-D Area
- 40,732 tons (36,951 MT) from 100-H Area
- 5633 tons (5110 MT) from the 100-N Area
- 4303 tons (3904 MT) from the IU-2/6 Area.

5.1.2.2 100-K Basins

BM Barnes

The 100-K Area remediation activities included facility demolition, waste site remediation, cleanout of the 100-K West Basin, and groundwater pump-and-treat operations. The K West Basin is the only remaining operating nuclear facility. The K West Basin is undergoing cleanout that involves removing radioactive contaminated sludge and debris as a precursor to facility deactivation and demolition. For nearly 30 years, the basins stored 2,300 tons (2,100 MT) of N Reactor spent fuel and a small quantity of slightly irradiated single-pass reactor fuel from other Hanford Site reactors. In October 2004, the major cleanup effort to remove the fuel from the K East and K West Basins was completed.

This fuel corroded during storage and the fuel washing and packaging process left behind approximately 989 ft³ (28 m³) of sludge. Currently, the sludge is stored in underwater containers in the K West Basin for subsequent removal and disposition. The project's CERCLA remedial design documentation will describe the means of sludge treatment and location of the national repository for sludge disposal. The sludge for subsequent removal and disposition includes the K West Basin knock-out-pot sludge, K West Basin settler tube sludge, and K East Basin floor and pit sludge. The K West Basin fuel cleaning system transferred sludge generated from the cleaning of fuel to either knock-out-pots or settler tanks. Knock-out-pots collect particles greater than 0.02 in. (500 µm) in size by using either a downstream strainer or an internal screen. A series of horizontal tubes downstream of the knock-out-pots, settler tanks allow particles less than 0.02 in. (500 µm) to settle and not be recirculated. The basin floor and pit sludge is a non-homogenous mixture of debris that includes windblown sand and environmental particulates; concrete fragments from the basin walls; corrosion products from fuel canisters and fuel racks; fuel cladding pieces;

tiny pieces of corroded uranium (uranium oxides, hydrates, and hydrides); ion-exchange resin beads; PCBs; and fission products. Sludge has been defined as any material that is less than or equal to 0.25 in. (0.64 cm) in size.

5.1.2.2.1 100-K Area Remediation Progress and Accomplishments (2015)

- Continued 105-KE Reactor Building interim safe storage activities, engineering for reactor penetration sealing, and the safe storage enclosure.
- Continued construction activities on the 100-K Annex in support of sludge removal operations.
- Continued groundwater pump-and-treat operations.
- Continued testing systems and components to be used to remove K Basins sludge at the Maintenance and Storage Facility located in the 400 Area prior to deployment to the K West Basin and its radiological environment.

5.1.2.2.2 K Basins Progress on Defense Nuclear Facilities Safety Board Recommendations

ET Glossbrenner, RA Quintero

In a Staff Issue Report to the Assistant Secretary for Environmental Management under the subject “Review of the Sludge Treatment Project Preliminary Documented Safety Analysis Hydrogen Hazards” dated August 21, 2015 ([Defense Nuclear Facilities Safety Board \[DNFSB\] 2015a](#)), the DNFSB identified technical deficiencies in the methodology used to determine the uranium metal concentration in Engineered Container SCS-CON-230 and a hydrogen accident scenario not identified in the Preliminary Documented Safety Analysis (PDSA). This letter was sent for DOE’s consideration.

In a Staff Issue Report to the Assistant Secretary for Environmental Management titled “Hanford Site Boundary Definition and the Associated Impact on Phase 1 of the Sludge Treatment Project” dated August 21, 2015 ([DNFSB 2015b](#)), the DNFSB expressed concern about a Specific Administrative Control (SAC) being removed from the preliminary design of Phase 1 of the Hanford Sludge Treatment Project (STP), also known as the Engineered Container Retrieval and Transfer System (ECRTS). The DNFSB requested a report within 45 days of receipt of the letter describing DOE’s position on controlling river access and the technical basis for the position. In a letter enclosure to the DNFSB Chairman titled “Information Associated with Defense Nuclear Facilities Safety Board (DNFSB) Letter Dated August 21, 2015, on Sludge Treatment Project Site Boundary” dated November 18, 2015 ([DNFSB 2015c](#)), the Assistant Secretary for Environmental Management concurred with DOE-RL and provided the technical basis for the position.

By issuing the *Defense Nuclear Facilities Safety Board 25th Annual Report to Congress* in March 2015 ([DNFSB 2015d](#)), the DNFSB resolved all previously identified issues for the Hanford Site K-Basin Closure Sludge Treatment Project. The issues were specified in a letter dated April 23, 2014 to the DOE-RL manager in which the DNFSDB closed the remaining issue concerning the preliminary design and safety basis for Phase I of the STP ([DNFSB 2014a](#)) and also in a letter enclosure to the DOE-RL manager titled “Summary of Sludge Treatment Project Final Design and Safety Basis” dated May 2, 2014 ([DNFSB 2014b](#)).

5.1.3 200 Area – Central Plateau

PA Burke

The Central Plateau is a 75 mi² (194 km²) region near the center of the Hanford Site, which includes the area designated in [DOE/EIS-0222-F](#) and ROD ([64 FR 61615](#)) as the Industrial-Exclusive Area, a rectangular area of about 20 mi² (52 km²) in the center of the Central Plateau. The Industrial-Exclusive Area contains the 200-East and 200-West Areas, used primarily for Hanford Site nuclear fuel processing and waste management and disposal activities. The Central Plateau also encompasses the CERCLA 200 Area NPL site. The Central Plateau has a large physical inventory of chemical processing and support facilities, tank systems, liquid- and solid-waste disposal and storage facilities, utility systems, administrative facilities, and groundwater monitoring wells.

The *Hanford Site Cleanup Completion Framework* ([DOE/RL-2009-10](#)) defines the path forward for cleanup at the Hanford Site. The framework document defines the main components of cleanup in two main geographic areas—the River Corridor and Central Plateau. As a result of the goals established in [DOE/RL-2009-10](#), the TPA agencies developed changes to the TPA that reflect the path forward for Central Plateau cleanup. The Central Plateau includes two principal cleanup locations, the Inner and Outer Areas, which are described below.

5.1.3.1 Inner Area

The Inner Area is the projected final footprint region of the Hanford Site. Dedicated to waste management and residual contamination containment, it will remain under federal ownership and control as long as potential hazards exist. Operable units within the Inner Area include those described in the sections below.

5.1.3.1.1 200-PW-1, 200-PW-3, 200-PW-6, and 200-CW-5 Operable Units

This operable unit group includes 22 waste sites located in the 200 East and 200 West Areas that are contaminated with plutonium or cesium from processing activities at PFP and the Plutonium Uranium Extraction (PUREX) Plant. Specific sites are listed in Appendix C of the *Hanford Federal Facility Agreement and Consent Order Action Plan* ([Ecology/EPA/DOE 1989c](#)). At EPA's request, the TPA agencies agreed to retain the 200-PW-1, 200-PW-3, 200-PW-6 Operable Unit group and the 200-CW-5 Operable Unit and consolidate them into a single decision (Table 5.1).

The *Record of Decision: Hanford 200 Area Superfund Site 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* ([DOE/EPA/Ecology 2011](#)) was issued in September 2011. The selected remedy in the ROD addresses soils and subsurface disposal structures contaminated primarily with plutonium and cesium, two settling tanks, and associated pipelines. The remove, treat, and dispose approach for contaminated soil and debris will be used to address plutonium contaminated soils and subsurface structures, and consists of removing a portion of contaminated soil, structures, settling tanks, and associated debris; treating these removed wastes as required to meet disposal requirements at ERDF (Section 5.4.3.7) or waste acceptance criteria for off-site disposal at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, NM; and disposing at ERDF or WIPP. The 200-CW-5 Operable Unit (also known as the Z-Ditches) will use the remove, treat, and dispose approach to excavate contaminated soils and dispose at ERDF or the WIPP, as appropriate.

Table 5.1. Central Plateau Operable Unit Structure

New Operable Unit Group	Description	Predecessor Operable Units		Lead Regulatory Agency
Inner Area				
200-PW-1/3/6	Plutonium-contaminated soil sites located near the PFP and cesium-contaminated sites near the Plutonium	No change		EPA
200-CW-5	Uranium Extraction Plant (PUREX)			
200-WA-1 200-BC-1	Soil waste sites located in the 200 West Inner Area not included in the 200-SW-2, 200-CR-1, 200-PW-1, 200-PW-6, 200-CW-5, and 200-IS-1 Operable Units; Soil waste sites in the BC Cribs and Trenches	200-BC-1 200-LW-1/2 200-MG-1/2 200-MW-1 200-PW-2/4	200-SC-1 200-TW-1/2 200-UR-1 200-UW-1	EPA
200-EA-1	200-East Inner Area not included in the 200-SW-2, 200-CB-1, 200-CP-1, and 200-PW-3 Operable Units	200-CS-1 200-IS-1 200-LW-1/2 200-MG-1/2	200-MW-1 200-PW-2/4 200-SC-1 200-TW-1/2 200-UR-1	Ecology
200-IS-1	Selected pipelines, diversion boxes, etc. in the Inner Area			Ecology
200-SW-2	Solid waste burial grounds and waste sites in the footprint of the burial grounds	200-CW-1 200-MG-1/2	200-SW-2	Ecology
200-DV-1	Selected soil waste sites in the Inner Area with deep vadose zone contamination	200-TW-1/2	200-PW-5	Ecology
200-CB-1	B Plant Canyon; associated waste sites	200-IS-1 200-MG-1/2 200-MW-1	200-PW-2/4 200-UR-1	Ecology
200-CP-1	PUREX Canyon; associated waste sites	200-IS-1 200-MG-1/2	200-MW-1 200-UR-1	Ecology
200-CR-1	REDOX Canyon; associated waste sites	200-IS-1 200-MG-1/2	200-UR-1	EPA
Outer Area				
200-OA-1 200-CW-1 200-CW-3	Sites located in the Outer Area	200-CS-1 200-CW-1 200-CW-3 200-IS-1 200-MG-1/2	200-MW-1 200-SW-2 200-UR-1 200-UW-1	EPA

Also known as the High-Salt Waste Group, three of the six 200-PW-1 waste sites will use the remove, treat, and dispose approach to excavate the highest concentrations of contaminated soils located up to 2 ft (0.6 m) below the bottom of the structure, and dispose at ERDF or the WIPP, as appropriate. An evapotranspiration barrier will be constructed over the remaining waste in these waste sites.

200-PW-3 Operable Unit. Also known as the Cesium-137 Waste Group, this operable unit will require additional backfill for three of the five waste sites to achieve coverage of at least 15 ft (4.57 m) depth. Contamination at the other two waste sites is deeper than 15 ft (4.57 m) from the ground surface and will not require additional backfill.

200-PW-6 Operable Unit. This operable unit and three of the six 200-PW-1 waste sites, also known as the Low-Salt Waste Group, will use the remove, treat, and dispose approach to excavate a significant portion (~90%) of the contaminated soils to a depth of 33 ft (10 m) below ground surface and dispose at ERDF or WIPP, as appropriate. An evapotranspiration barrier will be constructed over the remaining waste at these

sites. A soil vapor extraction system is being used to remove and treat carbon tetrachloride contamination at waste sites in the High-Salt Waste Group and will continue to be used until vadose zone cleanup levels are met. Soil covers will be used to provide coverage to a depth of at least 15 ft (4.57 m) over cesium-contaminated soils, which consists of maintaining or enhancing existing soil cover with additional backfill.

Institutional controls and long-term monitoring will be required for waste sites in the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units where waste is left in place and unrestricted land use is precluded.

5.1.3.1.2 200-WA-1/200-BC-1 Operable Unit (200-West Inner Area)

This operable unit group includes soil waste sites located in the BC Cribs and Trenches and soil waste sites in the Inner Area portion of the 200-West Area not included in the 200-CR-1, 200-CW-5, 200-IS-1, 200-PW-1, 200-PW-6, and 200-SW-2 Operable Units. Specific sites are listed in Appendix C of the TPA Action Plan ([Ecology/EPA/DOE 1989c](#)); additional sites may be added to the 200-WA-1/200-BC-1, Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). The *Remedial Investigation/Feasibility Study Work Plan 200-WA-1 and 200-BC-1 Operable Units* ([DOE/RL-2010-49](#)) was issued in December 2011. In addition, DOE obtained approval of the *216-U-8 Crib and 216-U-12 Crib Vadose Zone Characterization Sampling and Analysis Plan* ([DOE/RL-2009-94](#)), which supports the 200-WA-1 Operable Unit remedial investigation.

5.1.3.1.3 200-EA-1 Operable Unit (200-East Inner Area)

This operable unit consolidates the remaining Inner Area sites in the 200-East Area except for the environmental media underlying tank farm waste management areas (WMA), landfills in the 200-SW-2 Operable Unit, PUREX, B Plant Canyon, and several waste sites with deep vadose zone contamination that are adjacent to WMA environmental media sites. Specific sites are listed in Appendix C of the TPA Action Plan ([Ecology/EPA/DOE 1989c](#)); additional sites may be added to the 200-EA-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). The 200-EA-1 Operable Unit will use a comprehensive application of the technical cleanup principles for the Inner Area developed for the 200-WA-1 Operable Unit.

Analysis for the 200-EA-1 Operable Unit will follow the same pattern as the 200-WA-1 Operable Unit and will utilize the same technical basis documents and comprehensive alternatives evaluation to clearly demonstrate how selected remedies for each fit within the framework of impacts from the entire Inner Area. The 200-EA-1 work plan has not been initiated.

5.1.3.1.4 200-IS-1 Operable Unit

This operable unit includes select inactive waste transfer pipelines and pipeline components in the 200-IS-1 Operable Unit and soil waste sites in the Inner Area portion of the 200-East Area that are not included in the canyon area operable units or in the tank farm WMAs. Specific sites are listed in Appendix C of the TPA Action Plan ([Ecology/EPA/DOE 1989c](#)).

The TPA agencies agreed to use a coordinated CERCLA remedial action and RCRA corrective action process for cleanup decisions in the pipelines operable unit group. The *200-IS-1 Operable Unit Pipeline System Waste Sites RFI/CMS/RI/FS Work Plan* ([DOE/RL-2010-114](#)) was issued in September 2011.

5.1.3.1.5 200-SW-2 Operable Unit (Burial Grounds)

This operable unit includes 24 landfills located in the 200-East and 200-West Areas. Three soil waste sites located within the boundary of one of the burial grounds were added to the 200-SW-2 Operable Unit during restructuring. Specific sites are listed in Appendix C of the TPA Action Plan ([Ecology/EPA/DOE 1989c](#)). Portions of the burial grounds listed in the RCRA Permit (WA7890008967) include TSD facilities. DOE is working with Ecology to remove unused areas from the permit scope.

The TPA agencies agreed to use a coordinated CERCLA remedial action and RCRA corrective action process for cleanup decisions in the 200-SW-2 Operable Unit. [DOE/RL-2004-60](#) (2011), *200-SW-2 Radioactive Landfills Group Operable Unit RCRA Facility Investigation/Corrective Measures Study/Remedial Investigation/Feasibility Study Work Plan*, was issued in March 2015.

5.1.3.1.6 200-DV-1 Operable Unit (Deep Vadose Zone)

This operable unit includes 43 soil waste sites located in the Inner Area that were previously located in the 200-TW-1/2 and 200-PW-5 Operable Units. Specific sites are listed in Appendix C of the TPA Action Plan ([Ecology/EPA/DOE 1989c](#)). The *Remedial Investigation/Feasibility Study and RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-DV-1 Operable Unit* ([DOE/RL-2011-102](#)) was submitted to Ecology for review on March 18, 2015. The *Long-Range Deep Vadose Zone Program Plan* ([DOE/RL-2010-89](#)), issued in October 2010, summarizes the state of knowledge about contaminant cleanup challenges faced by the deep vadose zone beneath the Central Plateau and the approach to solving those challenges.

5.1.3.1.7 200-CB-1 Operable Unit (B Plant Canyon)

This operable unit includes the B Plant Canyon Building (221-B) and the Waste Encapsulation Storage Facility (WESF), along with exterior ventilation system components for each structure (e.g., HEPA filters and sand filter) and 17 soil waste sites within the vicinity. Specific sites are listed in Appendix C of the TPA Action Plan ([Ecology/EPA/DOE 1989c](#)); additional sites may be added to the 200-CB-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). Sites near the B Plant Canyon currently assigned to the 200-IS-1 Operable Unit may be reassigned to the 200-CB-1 Operable Unit, pending the outcome of discussions among the TPA agencies. Cesium and strontium capsules located in the WESF are not included in the scope of the 200-CB-1 Operable Unit.

5.1.3.1.8 200-CU-1 Operable Unit (U Plant Canyon)

This operable unit includes the U Plant Canyon Building (221-U) and other structures included in the ROD for the U Plant Canyon ([DOE/EPA/Ecology 2005](#)). The U Plant Canyon Disposition Initiative is a pilot project for disposition of the five canyon buildings in the 200-East and -West areas. Implementation of the selected remedial action (close in place – partially demolished structure) began in 2009.

5.1.3.1.9 200-CP-1 Operable Unit (PUREX Canyon)

This operable unit includes the PUREX Canyon Building (202-A), PUREX Storage Tunnels (218-E-15 and 218-E-16), exterior components of the ventilation system for each structure (e.g., deep bed filters), and 20 soil waste sites in the vicinity. Specific sites are listed in Appendix C of the TPA Action Plan ([Ecology/EPA/DOE 1989c](#)); additional sites may be added to the 200-CP-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil determined to require additional evaluation

or remediation following demolition of a structure). Sites near the PUREX Canyon currently assigned to the 200-IS-1 Operable Unit may be reassigned to the 200-CP-1 Operable Unit, pending the outcome of discussions among the TPA agencies. The 200-CP-1 work plan has not been initiated.

5.1.3.1.10 200-CR-1 Operable Unit (REDOX Canyon)

This operable unit includes the REDOX Canyon Building (202-S), exterior components of the ventilation system (e.g., filters), and 12 soil waste sites located in the vicinity. Specific sites are listed in Appendix C of the TPA Action Plan ([Ecology/EPA/DOE 1989c](#)); additional sites may be added to the 200-CR-1 Operable Unit as new waste sites in the geographic area are discovered or created (e.g., soil that is determined to require additional evaluation or remediation following demolition of a structure). Sites near the REDOX Canyon Building currently assigned to the 200-IS-1 Operable Unit may be reassigned to the 200-CR-1 Operable Unit, pending the outcome of discussions among the TPA agencies. The 200-CR-1 work plan has not been initiated.

5.1.3.2 Outer Area

The Outer Area is defined as all areas of the Central Plateau beyond the boundary of the Inner Area. The Outer Area covers approximately 65 mi² (168 km²) and contains more than 90 waste sites and structures scattered throughout the largely undisturbed sagebrush-steppe habitat. Most of the waste sites in the Outer Area are small near-surface sites that will be removed for treatment as needed for onsite disposal or sampled to confirm that no additional action is required, apart from implementing appropriate institutional controls. The largest components of Outer Area remediation are ponds where cooling water and chemical sewer effluents were discharged and the BC Control Area where surface contamination was spread through animal intrusion.

5.1.3.2.1 200-CW-1, 200-CW-3, and 200-OA-1 Operable Units (Outer Area)

Soil waste sites in the Outer Area requiring cleanup are assigned to one of the following three operable units.

200-CW-1 Operable Unit – Contains ponds used for discharging large volumes of cooling water and other effluents with low levels of contamination or that were only potentially contaminated. There are 14 sites in the 200-CW-1 Operable Unit, including eight ponds and associated sewer lines, control structures, and unplanned releases.

200-CW-3 Operable Unit – Contains 16 sites that were associated with operating the 200 North Area, a small complex initially used for temporary storage of spent nuclear fuel and later for storing miscellaneous materials and rail cars. The soil waste sites (trenches, small ponds, septic tanks, and sewer lines) were cleaned up as part of interim actions conducted from 2005–2010.

200-OA-1, Operable Unit – Incorporates soil waste sites from several previous operable units.

The *200-CW-3 Operable Unit Interim Remedial Action Report* ([DOE/RL-2011-58](#)) was issued in September 2011. The summary of waste site remediation activities, cleanup processes, and cost information will support developing a final remedial action for the Outer Area of the Hanford 200 Area NPL site.

5.1.3.2.2 Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill (NRDWL)

The NRDWL and SWL are located in the Outer Area and are not included in the operable units described above. The NRDWL is a RCRA-permitted disposal facility for dangerous waste generated at the Hanford Site that was not contaminated with radioactive materials. The NRDWL received dangerous waste from

1975–1985, asbestos waste through 1988, and sanitary solid waste in 1976. The SWL is a non-RCRA solid waste landfill south of the NRDWL. The SWL received non-dangerous and -radioactive solid waste, including paper, construction debris, asbestos, and lunchroom waste from 1973 to early 1996. The SWL also received up to 1.3 million gal (5 million L) of sewage and 100,000 gal (380,000 L) of garage wash water. Because the NRDWL is a RCRA-permitted TSD site, closure is being managed in accordance with [WAC 173-303](#); the Solid Waste Landfill is regulated under [WAC 173-350](#).

5.1.4 300 Area

JA Lerch

In 2015, remediation of 300-FF-2 Operable Unit waste sites continued. Waste generated from the cleanup of waste sites in the 300-F-2 Operable Unit was disposed at the ERDF, located on the Central Plateau, and other EPA-approved disposal facilities. In 2015, approximately 530,114 tons (480,911 MT) of contaminated soil from the 300-FF-2 Operable Unit were disposed at the ERDF.



Figure 5.1. 618-10 Burial Ground

As part of 300 Area activities, remediation of the 618-10 Burial Ground (Figure 5.1) continued in 2015, with a focus on trench excavation and vertical pipe unit (VPU) augering, with these actions to serve as future cleanup activities.

5.2 Facility Decommissioning Activities

This section provides information regarding the transition of Hanford Site facilities from stabilization to surveillance and maintenance and eventual decommissioning. Decommissioning activities include the interim safe storage of plutonium production reactors and deactivation and decommissioning of facilities in the 100, 200, 300, and 400 areas, and ancillary reactor facilities.

5.2.1 100 Area

As of 2015, all D4 activities in the 100 Area have been completed.

5.2.2 200 Area – Central Plateau

JA Lerch

Central Plateau facilities include buildings and waste sites in the 200 East, 200 West, and 200 North areas and those on the adjoining Rattlesnake Unit (ALE Reserve). The transition toward decommissioning encompasses surveillance, maintenance, and deactivation activities.

5.2.2.1 Plutonium Finishing Plant Decommissioning Progress

WG Cox

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

All special nuclear materials and stored fuel elements have been removed from the plant, and security was downgraded by the end of 2009. The removal and disposal of process equipment, chemicals, glove boxes, and hoods from the buildings began in 2009 and continued through 2015. The following sections describe the significant accomplishments at PFP during 2015 (Figure 5.2).



Figure 5.2. Plutonium Finishing Plant

5.2.2.1.1 Plutonium Finishing Plant Complex

In 2015, 243Z (Low-level Waste Treatment Facility), 296Z015 Stack, 243ZA (Low-level Waste Sump Facility), and 243ZB (Closed Loop Cooling System) were demolished and removed from the complex.

5.2.2.1.2 234-5Z, Plutonium Finishing Plant

Removal of plutonium-contaminated process equipment continued with a specific focus on removing gloveboxes, associated piping, and ductwork. The following was completed in 2015:

- Removed nine gloveboxes – 98% of all PFP gloveboxes and hoods
- Removed 4,295 linear feet (LFT) of asbestos for a total of 22,366 ft (77% complete)
- Removed 3,988 LFT of E4 ducting in 234-5Z duct level for a total of 5,467 ft (55% complete).

5.2.2.1.3 236-Z, Plutonium Reclamation Facility (PRF)

At the PRF, workers completed size reduction and seal out of the remaining 236Z Pencil Tanks.

5.2.2.2 Canyon Disposition Initiative

BJ Dixon

The Canyon Disposition Initiative was created to investigate the potential for using the five former chemical separations facilities (B Plant, T Plant, U Plant, PUREX Plant, and REDOX Plant) in the 200 Areas as disposal facilities for Hanford Site remediation waste rather than demolishing these canyon buildings. The U Plant was selected as a pilot project for the Canyon Disposition Initiative. The remaining canyon buildings are to be addressed individually, building on previous canyon disposition work.

Planning and sampling activities to support preparation of a CERCLA feasibility study for implementing the Canyon Disposition Initiative at U Plant began in the mid-1990s. In fall 2005, EPA issued an ROD ([DOE/EPA/Ecology 2005](#)), with a remedy that calls for the process equipment already in U Plant to be consolidated into the belowground plant process cells, and for the cells, two lower galleries, and other void spaces to be filled with grout. The exterior walls and roof would then be collapsed in place, and the site would be covered with an engineered barrier.

Implementation of the selected alternative began in 2009 for the 221-U Facility. By October 2011, the equipment consolidation phase had been completed, and facility voids below the canyon deck level (process cells, hot pipe trench, piping and electrical galleries, drain header, process sewer, and ventilation tunnel and ducts) were filled with grout in accordance with the *Remedial Design/Remedial Action Work Plan for the 221-U Facility* ([DOE/RL-2006-21](#)).

5.2.3 300 Area

JA Lerch

D4 activities in the 300 Area (Figure 5.3) continued in 2015 with completion of the 309 SP-100, MO-391, and MO-868 facilities. Future activities in the 300 Area will address the 324 facility and underlying 300-296 waste site.



Figure 5.3. 300 Area

5.2.4 400 Area

LC Tuott

This section provides information on the Fast Flux Test Facility.

5.2.4.1 Fast Flux Test Facility

FFTF is a formerly operating 400 megawatt (thermal) liquid-metal cooled (sodium) research and test reactor located in the 400 Area (Figure 5.4). Built in the late 1970s, the original mission of the facility was



Figure 5.4. Fast Flux Test Facility

to develop and test advanced fuels and materials, and to serve as a prototype facility for future Liquid Metal Fast Breeder Reactor Programs. Other missions were also pursued. FFTF 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 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, all of which was completed in June 2009. FFTF remains in long-term surveillance and maintenance, and routine surveillances are performed annually.

The FFTF decommissioning was included in [DOE/EIS-0391](#) issued on November 12, 2012 and the supplement analysis, [DOE/EIS-0391D-SA-01](#) issued in February 2012, concluded that there were no substantial changes. DOE issued the final Record of Decision on FFTF decommissioning on December 13, 2013 ([78 FR 75913](#)). The decision established that DOE will implement entombment, which would remove all above-grade structures, including the reactor building. The below-grade structures, the reactor vessel, piping, and other components would remain in place and be filled with grout to immobilize the remaining radioactive and hazardous constituents. Waste generated from these activities would be disposed at IDF, with an engineered modified RCRA Subtitle C barrier constructed over the filled area. Remote-handled special components would be processed at Idaho National Laboratory and returned to Hanford. Bulk sodium inventories would be processed at Hanford for use in the WTP.

5.3 Waste Management Activities

This section provides information regarding Hanford Site liquid and solid waste management.

5.3.1 Waste Classifications

WE Toebe

Hanford Site cleanup operations result in the generation of solid wastes that must be evaluated for proper management. Solid wastes are reviewed against procedures in [WAC 173-303-070](#)(3), “Designation of Dangerous Waste,” and are considered dangerous when the criteria for this classification are met. The radionuclides in solid waste are exempt from evaluation under [WAC 173-303-070](#)(3) but are subject to evaluation and categorization as transuranic, HLW, or LLW under the AEA ([42 U.S.C. 2011 et seq.](#)). Wastes that contain constituents regulated under both [WAC 173-303](#) and the AEA are classified as mixed wastes.

Radioactive and/or mixed wastes are managed in several ways. HLW is stored in large underground single-shell and double-shell tanks. LLW typically is stored in tanks or containers. The method used to store LLW depends on the source, composition, and waste concentration. Transuranic waste is stored in vaults, in storage buildings, on aboveground storage pads, and underground pending future retrieval. The DOE *Hanford Site Annual Dangerous Waste Report* lists the dangerous and mixed wastes that are generated, treated, and disposed of on site or shipped off site. Dangerous and mixed wastes are treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous waste generated at the site is shipped off site for treatment and/or disposal. Some types of dangerous waste, such as used lead–acid batteries and aerosol products (e.g., spray paint), are shipped off site for recycling.

Waste that does not contain hazardous or radioactive substances is non-regulated waste. Historically, non-regulated waste generated at the Hanford Site was disposed on site. Beginning in 1999, non-regulated waste (e.g., refuse and drummed nonhazardous 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-regulated waste originates at several 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 include 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 (i.e., oxalates). Non-regulated demolition waste from 100 Area decommissioning projects was buried in situ (in place) or in designated disposal locations on the Hanford Site.

5.3.2 Solid Waste Inventories

JF Berger, DE Nester

The Solid Waste Information and Tracking System is a computer database used to track a portion of mixed and radioactive waste at the Hanford Site, primarily non-CERCLA containerized waste managed by CHPRC, MSA, and WRPS. The database does not include all waste from WCH, ERDF, or any PNNL wastes. The database also does not include high-level radioactive waste volumes managed at Hanford Site tank farms.

Quantities for both mixed and radioactive wastes generated on site or received from off-site sources and disposed at the Hanford Site as tracked by the Solid Waste Information and Tracking System database are shown in Tables 5.2 and 5.3. Quantities of dangerous waste shipped off site as tracked by the database are shown in Table 5.4. Hanford Site solid waste management is discussed in Section 5.3.3.

Table 5.2. Solid Waste* Quantities Generated on the Hanford Site

Waste Category		2010	2011	2012	2013	2014	2015
Mixed	Tons	286	522	305	206	140	657
	Metric tons	260	474	277	187	127	596
Radioactive	Tons	725	4,022	343	513	572	1550
	Metric tons	658	3,649	311	465	519	1408

*Solid waste includes containerized liquid waste.

Table 5.3. Solid Waste* Quantities Received on the Hanford Site from Off-site Sources

Waste Category†		2010	2011	2012	2013	2014	2015
Mixed	Tons	152	320	66	36.5	38.4	97.9
	Metric tons	138	290	60	33	35	88.9
Radioactive	Tons	388	257	82	62.8	57	91.4
	Metric tons	352	233	74	60	52	82.9

*Solid waste includes containerized liquid waste. Solid waste quantities do not include U.S. Navy reactor compartments.

†Total includes Hanford Site-generated waste treated by an off-site contractor and returned as newly generated waste. Includes both low-level radioactive and transuranic waste.

Table 5.4. Dangerous Waste* Quantities Shipped Off the Hanford Site

Waste Category		2010	2011	2012	2013	2014	2015
Containerized (DW Only)	Tons	55	53	18	65.4	103	76.8
	Metric tons	49.9†	48†	16.3†	59.3†	93.4†	69.7†
Containerized (MW Only)	Tons	37	43	91	50.6	33.7	65.7
	Metric tons	33.6‡	39‡	82.5‡	45.9‡	30.6‡	59.6‡
Bulk Solids (DW Only)	Tons	20	26	3	—	22.1	—
	Metric tons	18.1	23.6	2.7	—	20.1	—
Bulk Solids (Non-Rad/Non-DW)	Tons	210	120	17	—	—	—
	Metric tons	191	108.9	15.4	—	—	—
Bulk Liquids (DW Only)	Tons	—	—	—	—	22	—
	Metric tons	—	—	—	—	20	—
Bulk Liquids (Non-Rad/Non-DW)	Tons	—	—	—	—	—	—
	Metric tons	—	—	—	—	—	—
Totals	Tons	322	242	129	116	181	142
	Metric tons	292	219	117	105	164	129

*Does not include Toxic Substances Control Act waste; †Dangerous waste (DW) only; ‡Mixed waste (radioactive and dangerous).

5.3.3 Solid Waste Management

LC Petersen

Solid waste management includes treatment, storage, and disposal of solid waste produced during Hanford Site operations or received from off-site sources authorized by DOE to ship waste to the site. These facilities are operated and maintained in accordance with state and federal regulations and facility permits. The following sections describe specific waste management locations at the Hanford Site.

5.3.3.1 Central Waste Complex

LC Petersen

A solid waste storage facility located in the 200 West Area (Figure 5.5), the CWC operates under interim status standards specified in the RCRA Permit (WA7890008967), CWC Part A Form. CWC receives waste



Figure 5.1. Central Waste Complex

from the Hanford Site and off-site sources authorized by DOE to ship waste to the site for treatment, storage, and disposal; however, the majority of waste received at the CWC is generated from ongoing cleanup, research, and development activities at the Hanford Site. Waste types include low-level, mixed low-level, transuranic, and PCB radioactive. The CWC can store as much as 735,000 cubic feet (ft³; 20,800 cubic meters [m³]) of waste, which is an adequate capacity to store the projected volumes of generated waste from the activities identified above,

assuming on-schedule treatment and disposal of the stored waste. An outside storage area was constructed in 2007 to store large containers of suspect transuranic waste from waste retrieval operations. The volume of waste currently stored in the CWC Outside Storage Areas is approximately 176,900 ft³ (5,010 m³), and the volume of waste currently stored at CWC is approximately 388,500 ft³ (11,000 m³).

5.3.3.2 Waste Receiving and Processing (WRAP) Facility

LC Petersen

The WRAP Facility (Figure 5.6) began operating in 1997 with the mission to analyze, characterize, and prepare drums and boxes of low-level, mixed, and transuranic wastes for disposal. The 52,000 ft² (4,800 m²) facility, along with two 21,500 ft² (2,000 m²) storage buildings, are located north of the CWC in the 200 West Area. The WRAP Facility is operating under interim status standards specified in the RCRA Permit (WA7890008967), WRAP Facility Part A Form.



Figure 5.2. Waste Receiving and Processing Facility

Waste destined for the WRAP Facility includes stored and newly generated waste from current Hanford Site cleanup activities consisting of primarily contaminated cloth, paper, rubber, metal, and plastic

(i.e., debris). Processed materials that qualify as low-level radioactive waste and meet disposal requirements are buried at the Hanford Site. Low-level radioactive waste not meeting burial requirements is processed at the WRAP Facility for on-site burial or prepared for future treatment at other TSD facilities. Waste determined to be transuranic is certified and packaged for shipment to the WIPP for disposal.

In response to budget constraints, actions were taken in late 2011 and 2012 to place the WRAP Facility into a layup status until future funding is available to restart the facility. The layup actions during the interim period maintain facility safety, environmental compliance, and operational viability to enhance the transition to operational status at the end of the layup period.

5.3.3.3 T Plant Complex

LC Petersen

The T Plant Complex (Figure 5.7) is located in the 200 West Area and provides solid waste treatment, storage, and decontamination services for the Hanford Site and off-site facilities. The T Plant Complex is operating under interim status standards specified in the RCRA Permit (WA7890008967), T Plant Complex Part A Form, and is preparing to receive K-basin sludge for storage.

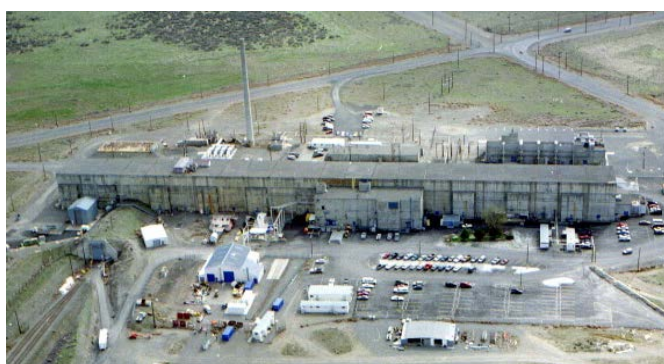


Figure 5.3. T Plant Complex

5.3.3.4 Canister Storage Building (CSB)

DJ Watson

The CSB (Figure 5.8) is a large 42,000-ft² (3,902-m²) facility located in the 200-East Area. The facility stores approximately 2,300 tons (2,086 MT) of spent nuclear fuel packaged in about 400 multi-canister overpacks from the 100-K Basins, 100-N Reactor, and T Plant. The multi-canister overpacks are stored in 220 carbon steel tubes in a below-grade concrete vault. The irradiated fuel was cleaned, packaged, dried, and relocated to the CSB beginning in 2004 to provide safe interim storage in a consolidated location, allowing for cleanup of older facilities, which reduces the cleanup footprint of the Hanford Site and risk. The CSB has a design life of 40 years and will safely store the multi-canister overpacks until they are permanently placed in a National Repository.



Figure 5.4. Canister Storage Building, Interim Storage Area

Adjacent to the CSB is the Interim Storage Area, which also contains spent nuclear fuel packaged in various containers. This spent nuclear fuel will be subsequently repackaged and sent to a National Repository.

5.3.3.5 Low-level Burial Grounds (LLBG)

LC Petersen, JF Berger

The low-level burial grounds consist of eight separate burial areas regulated under the AEA: two are located in the 200 East Area and six are located in the 200 West Area. Two of the burial grounds are used for disposal of LLW and mixed waste (i.e., low-level radioactive waste with a dangerous waste component regulated by [WAC 173-303](#)). Located in the 200 West Area, the 218-W-5 Burial Ground contains Trenches 31 and 34; in the 200 East Area, the 218-E-12B Burial Ground contains Trench 94, which is dedicated for disposal of defueled U.S. Navy reactor compartments. Trenches that contain mixed LLW are regulated under RCRA. Five burial grounds in the 200 West Area were used to dispose of LLW and/or retrievable storage of transuranic waste, as were portions of the 218-E-12B Burial Ground. The 218-W-6 Burial Ground has never received waste. The LLBGs are operating under interim status standards specified in the RCRA Permit (WA7890008967), Low-Level Burial Grounds Part A Form. In addition, the LLBGs are included in [DOE/RL-2004-60](#) (2004), *200-SW-1 Nonradioactive Landfills and Dumps Group and 200-SW-2 Radioactive Landfills and Dumps Group Operable Unit Remedial Investigation/Feasibility Study Work Plan*.

5.3.3.5.1 Low-level Waste Burial Ground 218-W-5, Trenches 31 and 34

Trenches 31 and 34 (Figure 5.9) are rectangular landfills with approximate base dimensions of 250 by 100 ft (76 by 30 m), with a variable depth of 30 to 40 ft (9 to 12 m). The trenches comply with [WAC 173-303](#) requirements for double liners and leachate removal/collection systems. These lined disposal units were originally designated for mixed LLW; however, disposal of LLW in the unlined trenches ceased June 23, 2004. Since that date, Trenches 31 and 34 have accepted LLW and mixed LLW for disposal. Disposal in Trench 31 began in May 2005, and disposal in Trench 34 began in September 1999. The first operational layer of waste packages have been covered with compacted gravel and soil, and the covering of the second waste layer has been initiated for Trenches 31 and 34.

Trench 31 contains approximately 209,091 ft³ (5,921 m³) of waste in 3,612 waste packages. Trench 34 contains approximately 183,340 ft³ (5,192 m³) of waste in 5,296 waste packages. In 2015, a total of 9,455 ft³ (268 m³) of waste was disposed of in Trenches 31 and 34.



Figure 5.5. LLBG Trenches 31 and 34

5.3.3.5.2 Low-Level Waste Burial Ground, Trench 94

The LLBG Trench 94 (Figure 5.10) received no defueled U.S. Navy reactor compartments in 2015. The total number of reactor compartments received into Trench 94 (218-E-12B Burial Ground) to date is 127. All U.S. Navy reactor compartments shipped to the Hanford Site for disposal originated from decommissioned defueled nuclear-powered submarines or cruisers. Decommissioned submarine reactor compartments are approximately 33 ft (10 m) in diameter, 47 ft (14.3 m) long, and weigh between 1,000 and 1,500 tons (900 and 1,400 MT). Decommissioned cruiser reactor compartments are approximately 33 ft (10 m) in diameter, 42 ft (12.8 m) high, and weigh approximately 1,500 tons (1,362 MT).



Figure 5.6. LLBG Trench 94

5.3.3.6 Waste Encapsulation and Storage Facility (WESF)

DJ Watson

Located in the 200 East Area, the WESF (Figure 5.11) was constructed in 1970 and 1971 on the west end of B Plant and became active in 1974. The WESF is operating under interim status standards specified in the RCRA Permit (WA7890008967), WESF Part A Form. The WESF is a storage-only unit for strontium and cesium encapsulated salts in double-containment stainless-steel capsules in underwater pool cells; and does not generate regulated waste. The water provides cooling and shielding for the capsules that are considered sealed sources.



Figure 5.7. Waste Encapsulation and Storage Facility

The mission of the WESF was encapsulation and storage of cesium chloride and strontium fluoride salts that had been separated from the Hanford Site's high-level radioactive tank waste. The facility is a two-story, 20,000-ft² (1,860-m²) building 157 ft (48 m) long and 40 ft (12 m) high. The facility is constructed of steel-reinforced concrete and partitioned into seven hot cells, a hot cell service area, operating areas, building service areas, and a pool cell area. The hot cells are labeled A through G, and activities within the hot cells are performed remotely using manipulators. Waste and drum load-out can be performed in Hot Cell A. Hot Cells B through E are pending stabilization until final closure. Of these, only Hot Cells F and G remain active for supporting cesium and strontium capsule storage. The operating areas and other building service areas associated with the hot cells provide areas for instrumentation monitoring, utility support, or manipulator repair as required.

5.3.3.7 Integrated Disposal Facility (IDF)

LC Petersen



Figure 5.8. Integrated Disposal Facility

The IDF (Figure 5.12) is located in the south-central part of the 200 East Area, and is a new, unused landfill that is not actively operating. The landfill is an expandable RCRA hazardous waste-compliant unit (i.e., a double high-density polyethylene-lined trench with leachate collection and a leak detection system). The IDF operates in accordance with the RCRA Permit. The landfill is divided lengthwise (north to south) into two distinct cells: the east cell is for disposal of low-level radioactive waste (non-RCRA permitted), and the west cell is for disposal of

low-level mixed waste (radioactive and RCRA-regulated hazardous waste). The IDF has a process design capacity of 2.89 million ft³ (82,000 m³). The IDF is referenced in [DOE/EIS-0391](#) as a future disposal option for Hanford Site wastes.

5.3.3.8 Environmental Restoration Disposal Facility (ERDF)

MA Casbon

ERDF (Figure 5.13) is the largest disposal facility in the DOE cleanup complex. The massive landfill located near the 200-West Area covers 107 ac – roughly equivalent to 52 football fields – and has a current capacity of approximately 21 million tons (19.1 million MT). Regulated by the EPA, the facility began operations in July 1996 and serves as the central disposal site for contaminated waste removed during Hanford Site cleanup



Figure 5.9. Environmental Restoration Disposal Facility

operations conducted under CERCLA regulations. The total available expansion area of the ERDF site was authorized in a 1995 ROD ([EPA/Ecology/DOE-RL 1995](#), Hanford 200 Area Record of Decision) to cover as much as 1.6 mi² (4.1 km²). To provide a barrier preventing contaminant migration into the vadose zone from the in-ground facility, the ERDF was constructed to RCRA Subtitle C minimum technology requirements, which includes a double liner and leachate collection system ([40 CFR 264.301](#), Subpart N, “Landfills”). Remediation waste disposed in the facility includes soil, rubble, or other solid waste materials contaminated with hazardous, low-level radioactive, or mixed (combined hazardous and radioactive) LLW.

Designed to be expanded as needed, ERDF consists of disposal areas called cells. Each pair of cells is 500 ft (152 m) wide, and 1,456 ft (444 m) long. A more recent configuration, the supercell, has the dimensions and

capacity of a pair of the original sized cells. There are currently 10 cells at ERDF, eight original and two supercells. In late 2015, ERDF received approval for a 20-ft vertical expansion that will eliminate the need for one supercell. A permanent cap will be placed over the facility when Hanford cleanup is complete.

DOE and its contractors have disposed 17.5 million tons (15.9 million MT) of contaminated material at the ERDF since the facility began operations in 1996. The disposed quantity is a measure of the tremendous amount of progress being made at the Hanford Site. The majority of cleanup waste at ERDF comes from the 220 m² River Corridor located along the banks of the Columbia River. The LLW consists mainly of soil contaminated by the effluent of Hanford's nine plutonium production reactors that operated from 1943–1987 as well as contaminated rubble from building demolition. In addition, ERDF receives cleanup waste from other Hanford contractors.

5.3.4 Liquid Waste Management

AL Prignano

Facilities are operated on the Hanford Site to store, treat, reduce, and dispose of various types of liquid effluent generated by site cleanup activities. These facilities are operated and maintained in accordance with federal and state regulations, and facility permits. In addition to the facilities described below, remediation systems pump and treat contaminated groundwater in the 100-D, 100-H, and 200 West areas as described in Section 8.0, Groundwater Monitoring.

5.3.4.1 200 Area Effluent Treatment Facility (ETF)



Figure 5.10. 200 Area Effluent Treatment and Liquid Effluent Retention Facilities

The 200 Area ETF (Figure 5.14, on the left) is located in the 200 East Area. The 200 Area ETF stores and treats liquid effluent to remove toxic metals, radionuclides, and ammonia, in addition to destroying organic compounds. The treatment process constitutes best available technology and includes pH adjustment; filtration; ultraviolet light and peroxide oxidation to destroy 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 and has a maximum treatment capacity of 150 gal (570 L) per minute. The 200 Area ETF operates in accordance with the RCRA Permit.



Figure 5.11. Effluent Treatment Facility

The effluent discharges are managed in accordance with limitations set forth in the State Waste Discharge Permit ST-4500 and the 200 Area ETF Delisting Petition approval conditions. 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), an underground drain field located just north of the 200 West Area. Percolation rates for the field were established by site testing and evaluation of soil characteristics. Tritium in the liquid effluent from the ETF cannot be practically removed. The location of the disposal site maximizes the time for migration of tritium to the Columbia River to allow for radioactive decay (the half-life of tritium is 12.35 years).

The 200 Area ETF did not operate in 2015 due to a failed heat exchanger, which was replaced in 2015 (Figure 5.15).

5.3.4.2 Liquid Effluent Retention Facility (LERF)

Across from the ETF, the LERF (Figure 5.14, on the right) consists of three RCRA-compliant surface impoundments to store process condensate from the 242-A Evaporator, groundwater from various operable unit pump-and-treat systems, leachate from ERDF and from LLBG Trenches 31 and 34, and other aqueous waste. The LERF provides a steady flow and consistent pH for the 200 Area ETF feed. Each basin has a maximum capacity of 7.8 million gal (29.5 million L) and 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 the other liners fail. Each basin has a floating membrane cover constructed of low-density polyethylene to keep out windblown soil and weeds and minimize evaporation of organic compounds and tritium that may be present in the basin contents. The facility began operating in April 1994 and received liquid waste resulting from RCRA and CERCLA regulated cleanup activities. Historically, RCRA and CERCLA wastewaters were segregated in the surface basins and processed with different disposal destinations; however, this process became unnecessary after the ROD for ERDF was amended to allow receipt of all RCRA and CERCLA waste ([DOE 2007](#)); thus, segregation is no longer required.

The volume of wastewater received for the LERF basin storage in 2015 was approximately 3.95 million gal (15 million L). The majority of wastewater received at the LERF was pipeline-transported CERCLA-regulated leachate from ERDF, totaling approximately 1.74 million gal (6.59 million L). The other major contributor to wastewater received into LERF was approximately 1.53 million gal (5.79 million L) of process condensate from the 242-A Evaporator. Approximately 0.41 million gal (1.54 million L) of wastewater was received by tanker trucks from various other facilities. The volume of wastewater being stored in the LERF at the end of 2015 was approximately 17.4 million gal (65.9 million L).

5.3.4.3 200 Area Treated Effluent Disposal Facility (TEDF)

Located east of the 200 East Area, the 200 Area TEDF (Figure 5.16) is a collection and disposal system for non-RCRA waste streams. Individual waste streams must be treated or otherwise comply with best available technology and all known available and reasonable treatment methods in accordance with [WAC 173-240](#), “Submission of Plans and Reports for Construction of Wastewater Facilities,” which is the responsibility of the generating facilities. Effluent discharges comply with the limitations established in State Waste Discharge Permit ST-4502.

The 200 Area TEDF consists of approximately 11 mi (18 km) of buried pipelines connecting three pumping stations, the 6653 Building (known as the disposal sample station) and two 5-ac (2-ha) disposal ponds. The facility began operating in April 1995 and has a capacity of 3,400 gal (12,900 L)/min. The volume of unregulated effluent disposed to this facility in 2015 was approximately 238 million gal (901 million L).



Figure 5.12. 200 Area TEDF Ponds A and B

5.3.4.4 242-A Evaporator



Figure 5.13. 242-A Evaporator

Located in the 200-East Area, the 242-A Evaporator (Figure 5.17) concentrates dilute liquid tank waste by evaporation in accordance with the RCRA Permit. The resultant water vapor is captured, condensed, filtered, sampled, sent to the nearby LERF for storage, and then further treated at ETF. This process reduces the volume of liquid waste sent to the double-shell tanks for storage and reduces the potential need for additional tanks.

A milestone was reached in 2015 when four operating campaigns were

completed at the 242-A Evaporator, creating nearly 2 million gallons of available storage space in the double-shell tank system. Prior to 2015, the evaporator underwent 4 years of upgrades to increase its efficiency and dependability.

5.4 Underground Waste Storage Tanks

AL Prignano

Hanford's 56 million gallons of highly radioactive and chemical waste is stored in 177 underground tanks until it is prepared for disposal (Figure 5.18). The tank waste is material left over from years of World War II and post-war production of nuclear weapons. The waste is stored in 149 older SSTs and 28 safer DSTs that are grouped into 18 farms



Figure 5.14. 200 Area Tank Farms Aerial Overview

in the 200 East and 200 West Areas. This section provides information about the SSTs and DSTs and activities that occurred in 2015 related to their operation and closure.

5.4.1 Single-Shell Tank (SST) System

The SST system includes 149 tanks that were constructed between 1943 and 1964 to store mixed waste generated on the Hanford Site; 61 of the tanks are assumed to have leaked. Pumpable liquids in the SSTs



Figure 5.15. Working Continuing at C Farm

were transferred to the newer and safer DSTs several years ago under the Interim Stabilization Program to help prevent additional environmental releases. The SST system is undergoing closure in accordance with TPA Appendices H and I and currently operates under interim status standards.

In 2015, progress continued in retrieving waste from the C Farm tanks and transferring it to newer, safer DSTs to prepare to feed tank waste to the WTP

(Figure 5.19). C Farm is one of 18 tanks farms located on the Hanford Site. The retrieval status for the 16 tanks is 14 complete (one was completed in 2015, and two are in progress). Retrieval of C-102 was completed on May 9, 2015, and the retrieval certificate for C-102 was submitted to the state in November 2015. Retrieval activities continue at C-105 and C-111. By the end of 2015, more than 42% of the waste has been retrieved from tank C-105 using the Mobile Arm Retrieval System (MARS), a robotic arm mounted on a central mast that uses powerful jets to wash down the inside of the tank and drive the waste to a central pump. In addition, over 32% of the waste from tank C-111 has been retrieved using high pressure water, and slow retrieval gains are still being made with sluicing.

5.4.2 Double-shell Tank (DST) System

The DST system includes 28 DSTs: 25 tanks in 200 East Area and three in 200 West Area located in five tank farms (AN, AP, AW, AY, AZ, and SY) that were constructed between 1968 and 1986 to store mixed waste generated on the Hanford Site. The DST system is operating under interim status standards specified in the RCRA Permit (WA7890008967), Double-Shell Tank System Part A Form. One of the tanks (AY-102) is assumed to have leaked waste into the annulus. The tanks contain liquids and settled solids from past nuclear operations, including waste transfers from older SSTs. The DST system storage capacity is approximately 32.5 million gal (123 million L) of radioactive and chemical waste. DST space is being managed to store waste pending treatment by the WTP and includes emergency pumping space available at all times for 1.25 million gal (4.7 million L). Sample ports continued to be installed in ventilation exhaust ducts to directly measure flow rates from the tank waste in the ventilation outlet to address flammable gas safety concerns, including installing sample ports in ventilation exhaust to directly measure gases from the tank waste in the tank ventilation outlet.

At the end of 2015, there were 25.8 million gal (97.7 million L) of waste in the DSTs. Quantities of liquid waste generated in 2015 and stored in underground storage tanks are provided in the *Hanford Site Annual Dangerous Waste Report: Calendar Year 2015* ([DOE/RL-2016-06](#)). Table 5.5 summarizes the waste retrieved and stored in the DST system from 2009 through 2015.

Table 5.1. Tank Farm System Quantities of Waste* Retrieved and Stored

Type of Waste	Units [†]	2009	2010	2011	2012	2013	2014	2015
DSTs year-end volume [‡]	gal	25,971	25,835	25,948	26,580	26,733	26,575	25,791
	L	98,311	97,796	98,224	98,000	101,195	100,597	97,630
242-A Evaporator volume evaporated	gal	960	548	0	0	0	793	1329
	L	3,634	2,074	0	0	0	3,002	5031
Single-shell tanks volume pumped [§]	gal	102	240	560	238	70	262	78
	L	386	909	2,120	900	263	991	295

*Quantity of waste is defined as waste sent to double-shell underground storage tanks during these years, rounded to the nearest 1,000; and does not include containerized (e.g., barreled) waste included in the solid waste category.

[†]Multiply volumes shown by 1,000.

[‡]Includes other miscellaneous additions or reductions (e.g., dilution and flush waters and corrosion controls) not represented elsewhere on this chart

[§]Volume does not include dilution or flush water.

5.4.3 Underground Waste Storage Tanks and Associated Facilities Progress on Defense Nuclear Facilities Safety Board (DNFSB)

JM Garcia

Throughout 2015, ORP and its contractors met with and provided information to the DNFSB and its technical staff to resolve concerns regarding Hanford Site underground storage tank farm projects.

The following issues were addressed:

222-S Laboratory	Waste Feed Delivery
DST space management	Waste Transfer System
Low Activity Waste Pretreatment System	Recommendation 2012-2

Defense Nuclear Facilities Safety Board Recommendation 2012-2

On September 28, 2012, the DNFSB issued Recommendation [2012-2](#), *Hanford Tank Farms Flammable Gas Safety Strategy*. The DNFSB's recommendation documented their position that DOE needs to upgrade the DST ventilation systems and other instrumentation systems used for safety-related functions at the Hanford tank farms.

On June 6, 2013, DOE delivered the *Implementation Plan for Board Recommendation 2012-2* ([DOE 2013](#)) to the DNFSB. Implementation Plan actions completed and provided to the DNFSB included:

- Action 1-1 and 4-1, implementation of the DOE-approved Documented Safety Analysis and associated Technical Safety Requirements for DST primary tank ventilation systems, completed March 2013.
- Action 1-3, a feasibility study for inspecting the condition and integrity of DST primary ventilation ductwork between the tank and flow monitoring locations, completed August 2014.
- Action 2-1, installation and testing of flow meters in selected DST ventilation exhausts to evaluate instrument performance, completed January 2014.
- Action 4-2, demonstration of current capabilities to recover from a loss of ventilation, completed February 2014.
- Action 5-1, evaluation of potential means to reduce the inventory of retained flammable gases in DSTs in a controlled manner, completed February 2015.
- Action 1-2, development of streamlined approach to implementing the planned improvements for upgrading the DST tank ventilation systems to meet SS requirements, completed October 2015.

Work will continue in 2016 on implementing Action 2-2, installation of safety significant instrumentation for real-time monitoring of the ventilation exhaust flow from each DST. Once complete, the selected air flow meter will be used to monitor DST ventilation exhaust flow in real time.

In addition, DOE began the process of revising the Implementation Plan to incorporate recommendations formally from Action 1-2 for the use of Safety Significant portable exhaust units during off-normal events. All related information to Recommendation 2012-2 is available online ([DNFSB 2012](#)).

5.4.4 SST Closure and Corrective Measures Program

P Rutland

The SST Closure and Corrective Measures Program (formerly known as the Vadose Zone Program) is responsible for the closure of SST Waste Management Areas (WMAs), conducting performance assessments, and performing agreed upon interim measures in and around SST WMAs. Current efforts are focused on the development of closure documentation for WMA C; conducting performance assessments for WMA C and the Integrated Disposal Facility (IDF). Additional activities include documenting past characterization work, planning for future interim measures, and monitoring the performance of implemented interim measures.

5.4.4.1 Closure of WMAs

Closure activities in 2015 focused on the production of both a development of closure strategies and closure documents being prepared to meet requirements of [DOE Order 435.1](#), RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Closure documents in preparation

during 2015 include DOE Order 435.1, *Tier 1 Closure Plan for WMA C*; DOE Order 435.1, *Tier 2 Closure Plan for the 241-C-200 Series Tanks*; Waste Incidental to Reprocessing (WIR) basis document for WMA C; RCRA Tier 1 Closure Plan for all SSTs WMAs; RCRA Tier 2 Closure Plan for WMA C; RCRA Tier 3 Closure Plan for the 241-C-200 series tanks; Phase 2 RCRA Facility Investigation Report (RFI) for WMA C; and a RCRA Corrective Measures Study Report (CMS) for WMA C.

The purpose of the closure documents is to reach agreement with regulatory agencies on closure requirements for WMA C and to enable closure activities to proceed.

5.4.4.2 Performance Assessments

Performance assessments (PAs) for WMA C and the IDF are under development. The WMA C PA supports closure of WMA C, while the IDF PA will support operations of the IDF.

5.4.4.3 Interim Surface Barriers

The effectiveness of the T and TY Tank Farm interim surface barriers at reducing infiltration is assessed through a barrier-monitoring program. Barrier monitoring continued during 2015, with information being reported annually. The barriers are resulting in slow drying of the vadose zone as water is diverted, which normally would recharge from the surface. Two interim barriers were previously designed to be placed over most of the tanks in the SX Tank Farm. Modified asphalt was selected as the impermeable surface, and an evapotranspiration basin will be located south of the SX Tank Farm to redirect any runoff back to the atmosphere. The design and monitoring plan was approved by Ecology for future construction.

5.5 Waste Treatment and Immobilization Plant (WTP)

BA Walker

The WTP (Figure 5.20) is being built on 65 ac (26 ha) in the 200 East Area to treat radioactive and hazardous waste stored in 177 underground tanks on the Central Plateau. The WTP comprises four major facilities (Pretreatment [PT] Facility, High-Level Waste [HLW] Facility, Low-Activity Waste [LAW] Facility, and Analytical Laboratory [Lab]) along with support buildings and associated infrastructure (Balance of Facilities). Construction of the WTP is managed in accordance with the RCRA Permit. A description of the WTP facilities and the progress at each facility in 2015 is provided in the following sections.

Pretreatment Facility. The PT Facility is where waste is received from the tank farms and separated into low-activity and high-level waste streams for transport to the LAW and HLW Facilities for processing. In 2015, work continued to resolve the remaining technical issues that have impacted design and construction at the PT Facility since 2012. Significant progress on the technical issues was made in 2015. Testing of the mixer controls confirmed the existing design, and vessel procurement was completed to begin full-scale testing of the standard high-solids vessel. The vessel will be received and testing will begin in 2016.



Figure 5.16. Waste Treatment and Immobilization Plant

High-level Waste Vitrification Facility. The HLW Facility is where high-level waste from the PT Facility will be combined with glass-forming materials in high-temperature melters, poured into waste canisters, and allowed to cool to form a solid, immobilized glass form. Construction in 2015 included making 22 concrete placements.

Low-activity Waste Vitrification Facility. The LAW Facility is where low-activity waste will be mixed with glass-forming materials in high-temperature melters, and poured into containers to form a solid, immobile glass form. Construction continued on interior equipment and commodities installation. Workers completed melter refractory installation for the two glass melters in the LAW Facility and neared completion of the Thermal Catalytic Oxidizer, which is a major component of the off-gas treatment system.

Analytical Laboratory. Once operational, the Lab will process about 10,000 waste samples annually to support glass formulation and waste-form compliance. Most of the work in 2015 moved toward outfitting the laboratory with equipment and fixtures before turning the facility over to the startup group, which will ensure that systems are working properly.

Waste Treatment and Immobilization Plant Progress on Defense Nuclear Facilities Safety Board Recommendations Board

JM Garcia

Throughout 2015, ORP and its contractors met with and provided information to the DNFSB and its technical staff to update and review WTP technical topics. DOE provided a response on February 11, 2015 to a safety issue identified in 2014 in which the DNFSB communicated a concern that the WTP design did not include an adequate control strategy to address the most recent volcanic ashfall hazard assessment at the Hanford Site. In the response, DOE detailed the multi-agency efforts to incorporate additional modeling,

evaluation, and testing to define the ashfall criteria. In 2014 and 2015, the DNFSB issued letters related to preliminary control strategies identified in the WTP High-Level Waste (HLW) Vitrification Facility's Safety Design Strategy (SDS) document. Three responses related to the HLW Facility SDS were provided in 2015:

Hydrogen Explosions. In a January 21, 2015 letter to DOE, the DNFSB communicated a concern that the HLW SDS does not define a nuclear safety control strategy for hydrogen explosions following the loss of mixing in process vessels containing non-Newtonian waste. The June 5, 2015 response from DOE detailed a path forward for establishing a nuclear safety control strategy.

Seismic Categorization. In a February 2, 2015 letter to DOE, the DNFSB communicated a concern that the SDS does not ensure the confinement ventilation system known as "C5V" will be able to effectively perform its credited safety functions following a seismic design basis accident. The July 24, 2015 response from DOE described actions to be taken to resolve this issue.

HLW Melter Accidents. Additionally, DOE provided a response on March 9, 2015 to a safety issue identified in 2014 related to a concern with the proposed nuclear safety control strategy for the HLW Vitrification Facility melter and associated support systems.

Defense Nuclear Facilities Safety Board Recommendation 2011-1. The DNFSB issued Recommendation 2011-1, *Safety Culture at the Waste Treatment and Immobilization Plant*, on June 9, 2011 ([DNFSB 2011](#)). The DOE Office of Enterprise Assessments (EA) conducted a follow-up assessment in December 2014 through February 2015 on WTP safety culture. The follow-on review was similar to the 2011 independent oversight review and the 2014 follow-up assessment. The final report was transmitted on June 24, 2015, by EA. The report noted both ORP and BNI have made improvements since the 2014 assessment.

On July 21, 2015, EM completed Action 2-13 by transmitting to the DNFSB the Program Secretarial Officer approval of site-specific safety culture sustainment tools. On August 26, 2015, the DNFSB held a Public Hearing in Richland, WA on Safety Culture at the WTP. The DOE panel members included the Director of EA, the Principal Deputy Assistant Secretary for Environmental Management, the Office of River Protection (ORP) Manager, and the ORP WTP Federal Project Director.

5.6 Long-term Stewardship

R Ranade

The MSA long-term stewardship (LTS) Program is focused on integrating the draft transition and turnover packages provided by the River Corridor Closure contractor and managing the long-term stewardship responsibilities for geographic areas transitioned to MSA. The transitioned areas, 101,522 ac (41,084 ha), are shown in Figure 5.21. Transition and turnover packages (TTP)s for IU-2/Segment 4a and 100 B/C Area were completed in 2015. The TTPs describe the activities that lead to placing the reactors into interim safe storage configuration (ISS), a process of demolishing all but the shield walls surrounding the reactor core, removing or stabilizing all loose contamination within the facility, and placing a new roof on the remaining structure. The remaining structure is termed Safe Storage Enclosure (SSE), access to which is provided for surveillance and maintenance work. Access doorways are welded shut, and all other openings in the shield walls are sealed to prevent intrusions and the release of radioactive materials.

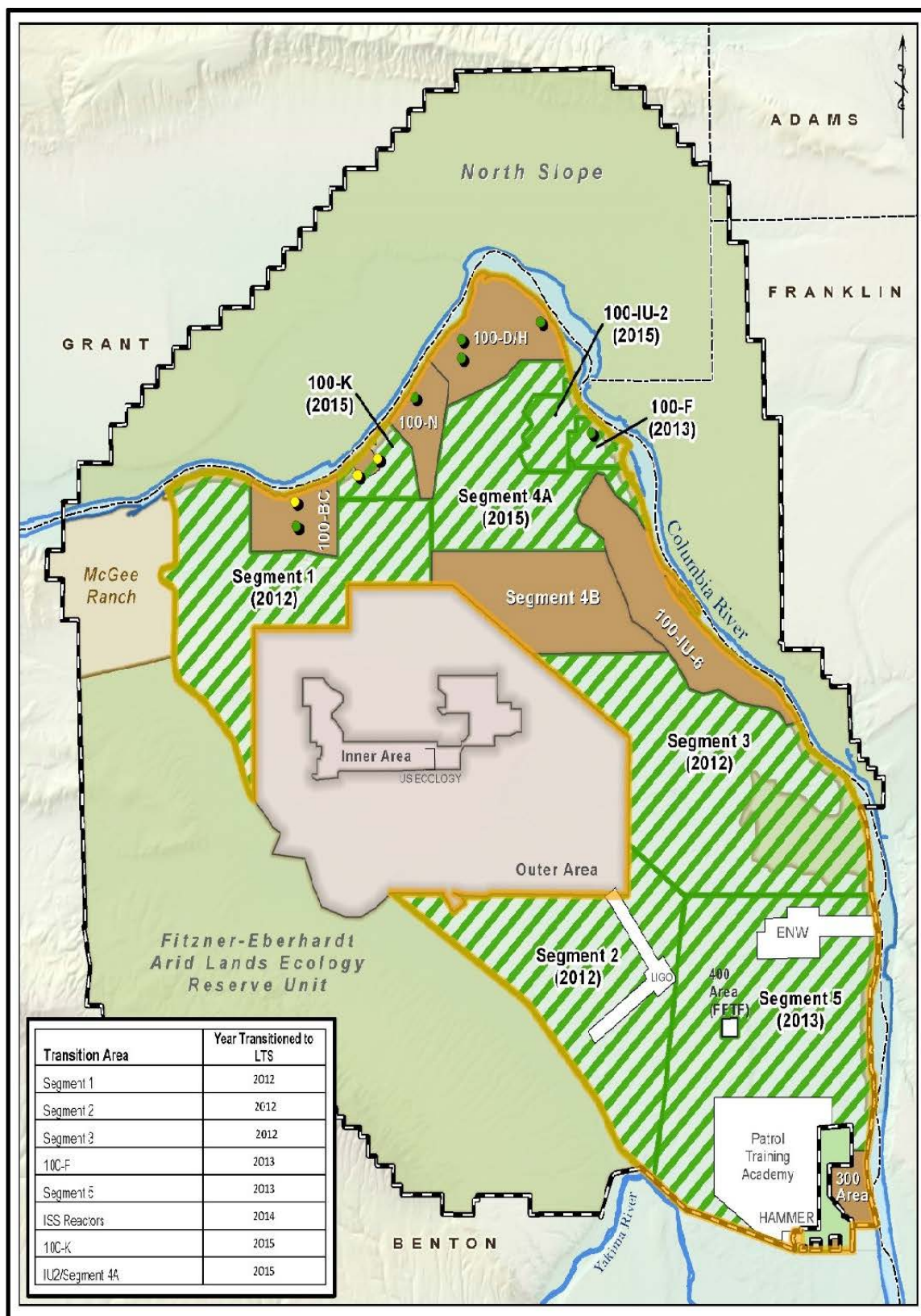


Figure 5.17. MSA LTS Managed Areas



Figure 5.18. Surveillance Team Working Inside the SSE

MSA conducted surveillance of the 105-C, 105-D, 105-H, and 105-N/109-N SSEs in March-April 2015. Conducted every 5 years, the SSE surveillances involved conducting structural and radiologic assessment and inspection of the temperature and flood level sensor located inside the building (Figure 5.22). Radiological, biological and physical safety conditions inside the SSE were evaluated prior to assessment teams entering the SSEs. The surveillances found no significant change in the conditions from the previous surveillances. MSA LTS program also conducted annual external surveillance of the SSEs with no significant findings. Other LTS activities included assessment of ICs at the LTS managed waste sites/areas and the sitewide ICs which included access controls such as fences and signs.

MSA LTS also has Information Management Program. The program objective is to maintain records for future generations. The functions of the program are best described as those activities to identify, locate, store, protect, and make accessible MSA LTS IM records and data. The type of records maintained include the TTP documents and the references cited therein. Other documents such as Sitewide Institutional Control Plan, LTS S&M Plan, CERCLA 5-year Plan. These data sets are captured for long term retention using LTS records collection within the Hanford site's certified records repository. This repository is the mechanism for long-term access to LTS information (searching and retrieval). The LTS records collection has a retention schedule applied. The records are scheduled according to National Archives and Records Administration approved record schedule.

5.7 Scientific and Technical Contributions to Hanford Site Cleanup

MD Freshley, MH Lee, RA Peterson

PNNL scientific and technical contributions to cleanup at the Hanford Site were focused on applied science, technology development and maturation, and basic science contributions. These contributions were funded through the DOE Office of Environmental Management (EM)'s Offices of Soil and Groundwater Remediation and Tank Waste and Waste Processing, RL, CH2M, ORP, WRPS, and BNI. Efforts included performing scientific and technical evaluations and reviews and developing and advancing new technologies to address site cleanup challenges.

5.7.1 Waste Processing and Tank Waste Management

Contributions to waste processing and tank waste management during 2015 include conducting fundamental engineering development to support resolution of mixing issues associated with the Waste Treatment Plant. This activity included working with BNI to identify necessary and sufficient testing to

demonstrate single high solids vessel full-scale mixing. In addition, PNNL provided leadership in resolution of technical issues associated with pulse-jet mixing operations within the WTP.

In collaboration with WRPS and the Savannah River Site, researchers evaluated cast stone as a technology to treat low-activity waste at the Hanford Site. Researchers at PNNL teamed with Savannah River National Laboratory, Catholic University, and the Missouri University of Science and Technology to develop new glass formulations capable of significantly reducing the volume of both low- and high-activity waste glass.

WRPS initiated design efforts for the Low-activity Waste Pretreatment System (LAWPS), which PNNL is supporting by testing filtration and ion exchange systems to demonstrate operability over a wide range of conditions. In addition, researchers are performing work to confirm gas generation rates in the ion exchange columns planned for LAWPS.

Researchers continued an effort to identify the speciation of technetium in tank wastes. Under normal processing conditions, technetium is usually present as the pertechnetate ion. However, a significant portion of the technetium in Hanford waste tanks is present as a complexed soluble species. Several candidate complexes may be present in tank wastes, and actual waste samples are being identified for further testing during 2016.

Researchers at PNNL continued to support the advancement of glass formulations for both WTP low-activity and high-level wastes. Significant advancements have been made in waste loading and melting rate, including increasing the Al_2O_3 and Cr_2O_3 concentrations in glass from 13 to greater than 26 wt% and from 0.5 to 1.5 wt%, respectively. These advancements provide the opportunity to reduce (if not eliminate) planned pretreatment options associated with caustic or oxidative leaching. In addition, the advanced glass formulations will lead to a significant reduction in glass canister/container counts and increased waste throughput, which ultimately will have a significant impact on reducing overall mission life for the WTP.

In support of WRPS efforts to test and evaluate a tank farm vapor monitoring and detection system, researchers at PNNL designed and initiated integrated outdoor testing of commercial instruments and software to detect, quantify, model, and predict vapor plume migration. The testing supports technology maturation in preparation for subsequent evaluation in an actual tank farm environment.

5.7.2 Soil and Groundwater Remediation

The Deep Vadose Zone Applied Field Research Initiative (AFRI) focused on improving best practices to enhance current baseline remediation technologies being deployed for soil and groundwater remediation at the Hanford Site, conducting high impact research to define alternatives to the current baseline and developing next generation solutions. The AFRI is 1) developing the technical basis for remediation of vadose zone and groundwater contaminants; 2) developing and implementing systems-based approaches for remediation that provide alternatives to the current baseline; and 3) implementing systems-based characterization and monitoring of contaminant sources and residual vadose zone contamination. Specifically, PNNL contributed to the areas detailed below in 2015.

5.7.2.1 Technical Basis for Remediation

Researchers at PNNL submitted a technology evaluation plan for iodine-129 at the 200-UP-1 Operable Unit, a key step in advancing groundwater and soil remediation efforts at the site. Iodine-129 is a key contaminant of concern at Hanford because of its long half-life, high mobility in groundwater, and long-term risk to human health and the environment. The plan updated the conceptual model and outlined an approach for evaluating technologies for remediating iodine-129 contamination in the subsurface. Draft A of the plan was submitted for DOE and EPA review, meeting the DOE-RL milestone.

Additionally, researchers investigated the biogeochemistry of iodine-129 in Hanford groundwater, including performing a speciation analysis to define the composition and characterization to determine how microbial reduction can provide a technical basis for remediation or natural attenuation approaches. These microbial communities are also being studied to determine the potential for reducing technetium-99, nitrate, and uranium when supplemented with different carbon sources. The understanding of microbial processes provides critical input to develop strategies for remediation of contaminants in place, which will reduce the overall cost of cleanup.

Biogeochemical analysis of core samples obtained from uranium extraction wells being installed within the 200-UP-1 Operable Unit showed that microbes can transform mixtures of contaminants, including technetium-99, uranium, iodine-129, and nitrate, when provided with various carbon and electron sources. Results from these studies are important because they demonstrate the potential for bioremediation of contaminant mixtures in the 200-UP-1 groundwater.

Researchers applied understanding of microbial communities to optimize performance of the fluidized bed reactor in the 200-West pump and treat system for treating carbon tetrachloride and nitrate, resulting in uninterrupted operation of the system and more efficient contaminant removal. In particular, issues with reinjection wells were addressed (PNNL-24811).

Finally, PNNL tested the performance of new sorbent materials for iodine-129 removal for pump-and-treat systems using groundwater collected from a 200-West Area well. Two bismuth-based sorbents were developed and characterized to demonstrate their applicability for iodine-129 removal. Further testing is needed for scale-up and to determine the stability of sorbed material and rate of iodine-129 capture for potential deployment.

5.7.2.2 Systems-Based Assessment of Remediation

Because converting pump-and-treat systems to alternative remediation strategies can be challenging, a structured approach was developed to assess pump-and-treat performance for optimization, transition, or closure. In collaboration with the U.S. Army Corps of Engineers with input from the EPA, other branches of the DoD, and DOE reviewers, guidance was developed for evaluating an endpoint for pump-and-treat operations for systems with diminishing returns ([PNNL-24696](#)).

Researchers developed site-specific attenuation data for 100 Area chromium that enabled a pump-and-treat system to be shut down and a monitored natural attenuation (MNA) approach applied. The study evaluated biological and abiotic reduction mechanisms for Cr(VI) to develop lines of evidence for transitioning active pump-and-treat remedies to MNA ([PNNL-24705](#)). The transition of pump-and-treat systems to MNA is a critical step for long-term stewardship of the Hanford Site and will enable cost-effective, sustainable remedies at waste sites on the river corridor.

Additionally, researchers developed a template for MNA of technetium-99, iodine-129, and uranium in the Central Plateau vadose zone (previously, MNA has been applied to groundwater contaminants, but not the vadose zone). Several different attenuation processes affect contaminant transport, and a structured approach was developed to enable consideration of these processes ([PNNL-24731](#)). The approach provides guidance for conducting and presenting the evaluation of contaminant transport based on EPA protocols for evaluating MNA and offers a case study of vadose contaminant flux to the groundwater beneath the S-SX Tank Farm Waste Management Area ([PNNL-23737](#)).

PNNL evaluated the technical and economic feasibility of using solar-powered groundwater extraction at the Hanford Site ([PNNL-24741](#)). The study showed that the most appropriate locations for successful implementation of solar extraction are remote or distant extraction wells in which the primary remedial objective is contaminant mass removal (as opposed to hydraulic containment) and three-season (March through October) intermittent pumping is acceptable.

Following a Remedial Investigation Work Plan ([DOE/RL-2012-64](#)), researchers characterized the extent of lead and arsenic in surface soils across 5000 ac (2023 ha) of historical orchard lands within the 100-OL-1 Operable Unit. The project uniquely deployed hand-held X-ray fluorescent analyzers in the field. Previous Hanford Site cleanup decisions for contaminated soil regions did not use these devices, requiring soil sample collection and analysis. The project demonstrated the utility of the hand-held devices in meeting Hanford-specific quality control and assurance requirements. Current efforts are focused on completing the report noted above.

5.7.2.3 Systems-Based Monitoring

Researchers completed technical review of groundwater monitoring plans to identify opportunities to streamline operations and reduce overall cost. The panel assembled for the review decreased efforts by over 50% by establishing monitoring requirements driven by technical objectives, knowledge of plume behavior, and integration with remedial actions.

PNNL completed performance monitoring for the Prototype Hanford Barrier ([DOE/RL-2016-37](#)), which reviewed and summarized over two decades (1994 to 2015) of data. The report provides a technical basis for future surface barrier deployment.

5.7.3 Advanced Simulation Capability for Environmental Management (ASCEM)

ASCEM continued to enhance capabilities as demonstrated in several applications, including the Hanford Site. Developed as a workflow for understanding and predicting contaminant fate and transport in natural and engineered systems, ASCEM contains modular and open source toolsets that facilitate integrated approaches to modeling and site characterization that enable standardized assessments of performance and risk for DOE EM cleanup and closure activities. The demonstration results were summarized in PNNL-24993.

6.0 Air Monitoring

CJ Perkins, SJ Johnson

The purpose of Hanford Site air monitoring programs is to ensure the protection of environmental and public health for the air pathway. Air quality is monitored using stack sampling at the sources and ambient air monitoring at receptor locations. The specific objectives are to measure airborne radionuclides and chemicals to calculate the doses to humans, plants, and animals. Measured and calculated results are compared with DOE, EPA, and/or WDOH standards. This report presents 2015 measurement results.

6.1 Air Emissions

SJ Johnson

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

Emission data are documented in this current and other reports, all of which are available to the public. For example, DOE submits annually to EPA and the WDOH a report of Hanford Site radionuclide air emissions (e.g., [DOE/RL-2016-10](#)) in compliance with [40 CFR 61, Subpart H](#), 61.94, "Compliance and Reporting" and [WAC 246-247](#).

6.1.1 Radioactive Airborne Emissions

Small quantities of particulate and volatilized forms of radionuclides are emitted to the environment through state and federally permitted radioactive emission point sources (i.e., stacks and vents) during routine operations. Tritium (i.e., hydrogen-3), strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/-240, plutonium-241, and americium-241 are the isotopes most commonly measured in the emissions. Emission points are monitored continuously if they have the potential to exceed 1% of the public dose limit of 10 mrem/yr or 100 mSv/yr.

Distinguishing Hanford Site-produced radionuclides in the environment is challenging because concentrations of site stack emissions are comparable to widespread background concentrations of radionuclides that originated from historical atmospheric nuclear weapons testing. Gross alpha and gross beta concentrations in stack emissions are, on average, equivalent to concentrations in the environment, including concentrations at distant locations upwind of the Hanford Site. Radioactive emissions decreased on the Hanford Site largely because the production and processing of nuclear materials ceased.

The continuous monitoring of radioactive emissions from facilities requires analyzing samples collected at points of discharge to the environment, usually a stack. Samples are analyzed for gross alpha and gross beta as well as for selected radionuclides. Specific radionuclides are selected for sampling, analysis, and

reporting based on an evaluation of the hypothetical maximum potential of emissions of known radionuclide inventories in a facility or an outside activity occurring under normal operating conditions. Other factors that are considered include removal of the calculated effect of pollution-abatement equipment, sampling criteria provided in contractor environmental compliance manuals, and the potential of each radionuclide to contribute to the public dose. Continuous air monitoring systems with alarms also are used at selected emission points where the potential exists for radioactive emissions to exceed normal operating ranges to levels that require immediate personnel alert.

Radioactive emission points are located on the Hanford Site in the 100, 200, 300, and 400 areas. The prime sources of emissions and the number of emission points by operating area are as follows:

- In the 100 Areas, three radioactive emission points were active. Emissions originated from the 100-K West Fuel Storage Basin, which in previous years contained irradiated nuclear fuel, and from the Cold Vacuum Drying Facility (CVDF).
- In the 200 Areas, 33 radioactive emission points were active. The primary locations of these emission points were the Plutonium Finishing Plant (PFP), T Plant, B Plant, Waste Encapsulation and Storage Facility (WESF), underground tanks storing high-level radioactive waste, a waste evaporator, the Waste Receiving and Processing Facility (WRAP Facility), 222-S Laboratory, and PUREX Plant. In the 300 Area, four radioactive emission points were active. The primary sources of these emissions were laboratories and research facilities, including the 324 Waste Technology Engineering Laboratory, 325 Applied Chemistry Laboratory, and 331 Life Sciences Laboratory.
- In the 400 Area, three radioactive emission points were active, the sources of which have been shut down: Fast Flux Test Facility (FFTF), Maintenance and Storage Facility, and the Fuels and Materials Examination Facility.

Air emission data collected in 2015 were comparable to those collected in 2014. Table 6.1 summarizes Hanford Site radioactive airborne emissions in 2015.

Table 6.1. Hanford Site Radioactive Airborne Emissions

Radionuclide	Half-Life [†]	2015 Releases, Ci*				
		100 Area	200-East Area	200-West Area	300 Area	400 Area
Actinium-227	21.6	NA	NA	NA	1.8×10^{-09}	NA
Alpha (gross) [‡]	NA	1.1×10^{-05}	1.1×10^{-06}	3.9×10^{-05}	7.2×10^{-08}	2.5×10^{-07} §
Americium-241	432.2	3.4×10^{-06}	2.1×10^{-08}	4.6×10^{-06}	1.2×10^{-09}	NA
Americium-243	7,380	NA	NA	NA	4.5×10^{-08}	NA
Beta (gross)**	NA	1.3×10^{-05}	2.4×10^{-04}	6.2×10^{-06}	5.3×10^{-06}	1.3×10^{-06} ††
Carbon-14	5,730	NA	NA	NA	1.2×10^{-04}	NA
Cesium-134	2.1	ND	ND	ND	ND	NA
Cesium-137	30	3.6×10^{-06}	3.9×10^{-05}	ND	1.9×10^{-06}	NA
Curium-243/244	29.1	NA	NA	NA	ND	NA
Europium-152	13.5	ND	ND	ND	1.8×10^{-09}	NA
Europium-154	8.6	ND	ND	ND	1.2×10^{-08}	NA
Gadolinium-153	240.4 days	NA	NA	NA	7.0×10^{-11}	NA
Iodine-129	16,000,000	NA	2.3×10^{-04}	NA	NA	NA
Krypton-85	10.7	NA	NA	NA	5.8×10^{-07}	NA
Neptunium-237	2,144,000	NA	NA	NA	1.4×10^{-08}	NA
Plutonium-238	87.7	5.1×10^{-07}	4.7×10^{-12}	5.4×10^{-07}	3.8×10^{-08}	NA
Plutonium-239/-240	24,110	3.8×10^{-06}	2.3×10^{-10}	2.3×10^{-05}	6.0×10^{-09}	9.1×10^{-15} ‡‡
Plutonium-241	14.4	2.0×10^{-05}	ND	1.6×10^{-05}	6.7×10^{-07}	NA

Table 6.1. Hanford Site Radioactive Airborne Emissions

Radionuclide	Half-Life [†]	2015 Releases, Ci*				
		100 Area	200-East Area	200-West Area	300 Area	400 Area
Protactinium-231	32,760	NA	ND	NA	NA	NA
Radium-226	1,600	NA	NA	NA	4.1×10^{-10}	NA
Radon-219	3.96 sec	NA	NA	NA	$6.2 \times 10^{+00}$	NA
Radon-220	55.6 sec	NA	NA	NA	$3.9 \times 10^{+02}$	NA
Ruthenium-106	373.6 days	NA	1.9×10^{-06}	7.2×10^{-07}	1.9×10^{-09}	NA
Sodium-22	2.6	NA	NA	NA	NA	1.4×10^{-09} ††
Strontium-90	29.1	2.3×10^{-06}	1.0×10^{-04}	ND	2.2×10^{-07}	NA
Technetium-99	211,100	NA	NA	NA	4.1×10^{-06}	NA
Tritium (elemental)	12.3	NA	NA	NA	$1.3 \times 10^{+02}$	NA
Tritium (tritiated water vapor)	12.3	NA	NA	NA	$2.8 \times 10^{+02}$	1.8×10^{-03} ††
Uranium-232	68.9	NA	NA	NA	5.4×10^{-09}	NA
Uranium-233	159,200	NA	NA	NA	1.8×10^{-08}	NA
Yttrium-90	1.5 sec	NA	ND	NA	NA	NA

NA=not applicable; ND=not detected (either radionuclide not detected in any sample during the year or average of all measurements for given radionuclide or type of radioactivity during the year was below background levels); NM=not measured.

*To convert to the International System of Units; multiply pCi/g by 0.037 to obtain Bq/g.

†In years, unless otherwise specified.

‡For dose modeling, gross alpha is assumed to be Pu-239/-240.

§Release value derived from gross alpha emissions calculated from 400 Area stacks.

**For dose modeling, gross beta is assumed to be Cs-137.

††Release value derived from gross beta emissions measured from 400 Area stacks.

‡‡Calculated from estimated residual sodium inventory remaining in FFTF primary coolant piping.

6.1.2 Criteria and Toxic Air Pollutants

Criteria and toxic air pollutants emitted from chemical-processing and electricity-generating engines fueled by petroleum are monitored when activities are known to release pollutants of concern, such as particulate matter, sulfur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, and lead. Total annual releases of these constituents are reported in accordance with the air quality standards established in [WAC 173-400](#). Based on the quantities of petroleum fuel consumed at Hanford Site power plants, emissions were calculated using EPA-approved formulas (*Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources* [EPA 1995]). Table 6.2 summarizes the Hanford Site emissions of nonradioactive criteria and toxic air pollutants discharged to the atmosphere.

Table 6.2. Hanford Site Criteria and Toxic Air Pollutant Emissions

Constituent	2015 Releases	
	lb	kg
Criteria Pollutants		
Particulate matter-total	0	0
Particulate matter-10	2,000	907
Particulate matter-2.5	0	0
Lead	0	0
Nitrogen oxides	60,000	27,216
Sulfur oxides	2,000	907
Carbon monoxide	22,000	9,979
Volatile organic compounds	14,000	6,350
Ammonia	4,000	1,814

Table 6.2. Hanford Site Criteria and Toxic Air Pollutant Emissions

Constituent	2015 Releases	
	lb	kg
Toxic Air Pollutants		
Acetic acid	0	0
Acetone	6	2.7
Benzene	1	0.45
1-Butanol	4	1.8
Carbon tetrachloride	286	129.7
Chloroform	4	1.8
Dichloromethane	14	6.4
1,1,1-Trichloroethane	2	0.91
Trichloroethylene	1	0.45
Trichlorofluoromethane	34	15.4

6.2 Ambient Air Monitoring

CJ Perkins

Atmospheric releases of radioactive materials from Hanford Site facilities and operations to the surrounding region are potential sources of exposure to humans. Radioactive constituents in air are monitored at Hanford Site facilities and operations at locations away from site facilities and off site around the perimeter as well as in nearby and distant communities. Information about these ambient air-monitoring efforts, including detailed descriptions of air sampling and analysis techniques, is provided in RL's environmental monitoring plan ([DOE/RL-91-50](#)).

Comparing measured radionuclide concentrations from locations on and around the Hanford Site with those 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.

6.2.1 Hanford Site Ambient Air Monitoring

A network of continuously operating samplers at 60 locations across the Hanford Site was used during 2015 to monitor radioactive airborne materials in air near Hanford Site facilities and operations (Table 6.3). Most air samplers were located at or within approximately 1,640 ft (500 m) of sites and facilities having the potential for or a history of environmental releases. The samplers were primarily located in the prevailing downwind direction. Samples were collected according to a schedule established before the 2015 monitoring year. Airborne particle samples were collected at each location by drawing air through a cellulose filter. The filters were collected biweekly, field-surveyed for gross radioactivity, held for at least 5 days, and then analyzed for gross alpha and beta activity. The 5-day holding period is 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 on-site facility environment.

Table 6.3. Hanford Site Monitoring Locations and Analyses for Ambient Air Monitoring Samples

Site/Project	No. of Samplers	EDP Code	Bi-Weekly	Analyses	
				Composite	
100-K Area	6	N476, N534, N535, N575, N576*, N578	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium-234/-235/-238, americium-241	
200-East Area	17	N019, N158, N498, N499*, N957, N967, N968, N969, N970, N972, N973, N976, N977, N978, N984, N985, N999	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium-234/-235/-238	
Canister Storage Building (200-East Area)	2	N480, N481	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium-234/-235/-238	
Integrated Disposal Facility (200-East Area)	2	N532, N559	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium-234/-235/-238	
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	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium -234/-235/-238	
300 Area D4 and Field Remediation Project†	2	N557, N130	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium-234/-235/-238	
Environmental Restoration Disposal Facility	5	N482*, N168, N517, N518, N963	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium-234/-235/-238	
600 Area (WYE Barricade)	1	N981*	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium-234/-235/-238	
618-10 Burial Ground	4	N548*, N549, N579, N580	Alpha, Beta	GEA, strontium-90, plutonium-238, -239/-240, uranium-234/-235/-238	

D4=deactivation, decommissioning, decontamination, and demolition; EDP=environmental data point code=sampler location code; GEA=gamma energy analysis

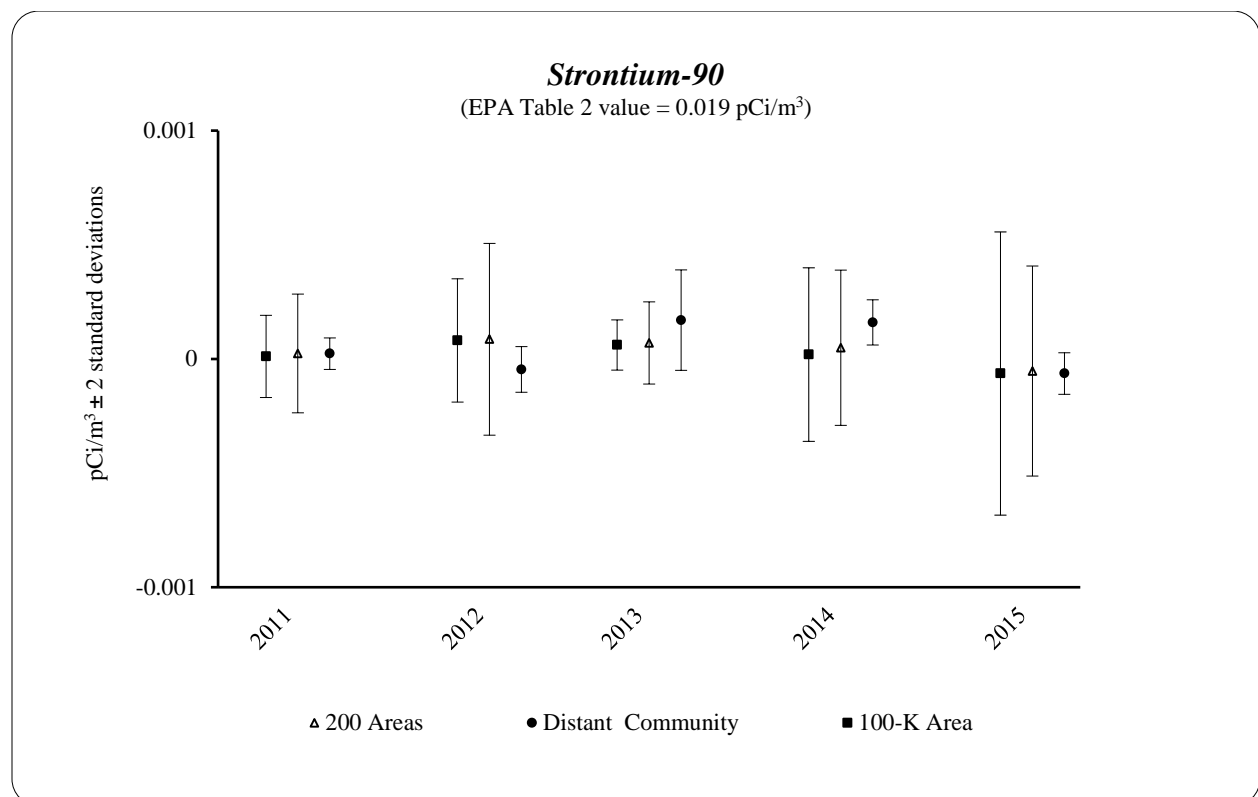
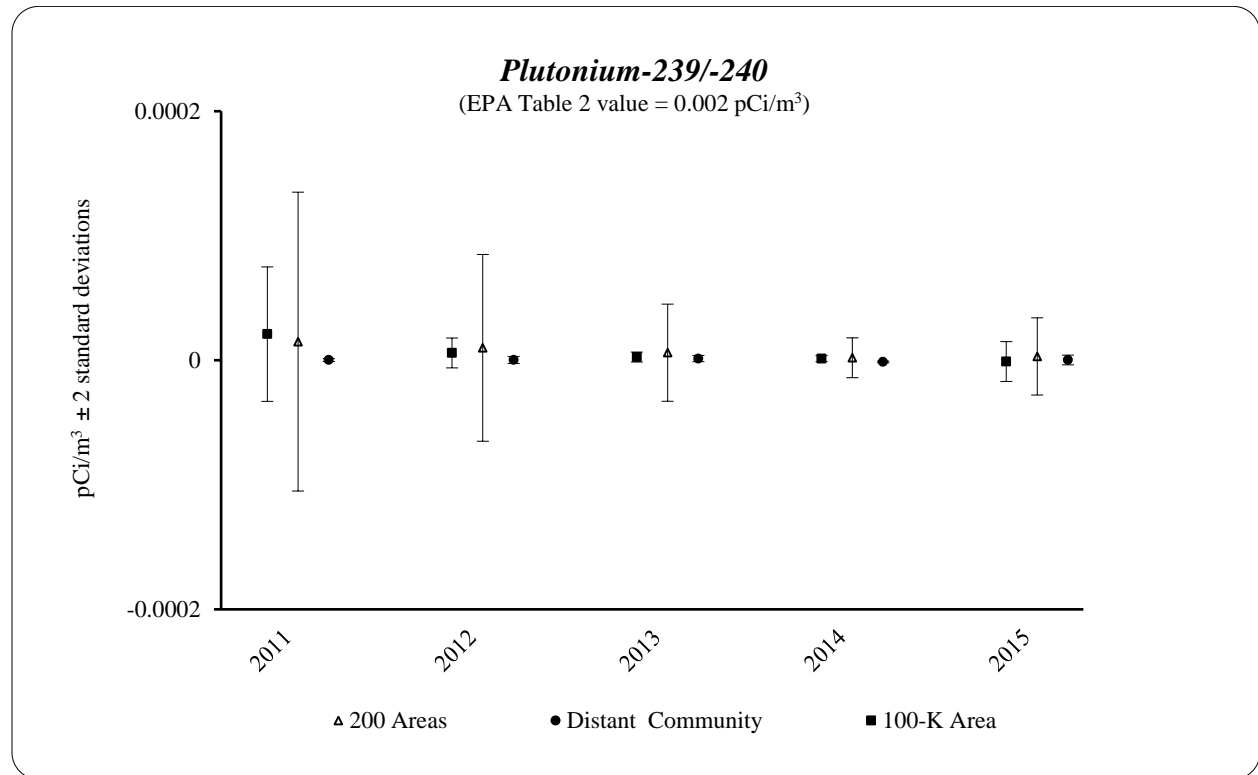
*Collocated sampling location with WDOH.

†Off-site air sampling station(s) provide supplemental air monitoring data; see Table 6.4 for locations.

For most specific radionuclide analyses, radioactive material collected on a single filter during a 2-week period was too small to be measured accurately. Individual samples collected at each location were combined into semiannual, location-specific composite samples (Table 6.3) to increase accuracy.

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

Figure 6.1 shows the annual average air concentrations of selected radionuclides in the 100, 200, and 600 Areas compared to EPA concentration values and air concentrations measured in distant communities. EPA concentration values for environmental compliance ([40 CFR 61, Appendix E, Table 2](#)) are dose-based reference values used as indices of performance. The concentration values are concentrations that would result in a dose of 10 mrem (100 mSv)/yr under conditions of continuous exposure. The 2015 data indicate a large degree of variability by location. Air samples collected from locations at or directly adjacent to Hanford Site facilities had higher radionuclide concentrations than 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 off site. Data also show that concentrations of certain radionuclides were higher and widely variable within different Hanford Site operational areas. Appendix C, Table C.5 shows the annual average and maximum concentrations of radionuclides in air samples collected near Hanford Site facilities and operations during 2015.



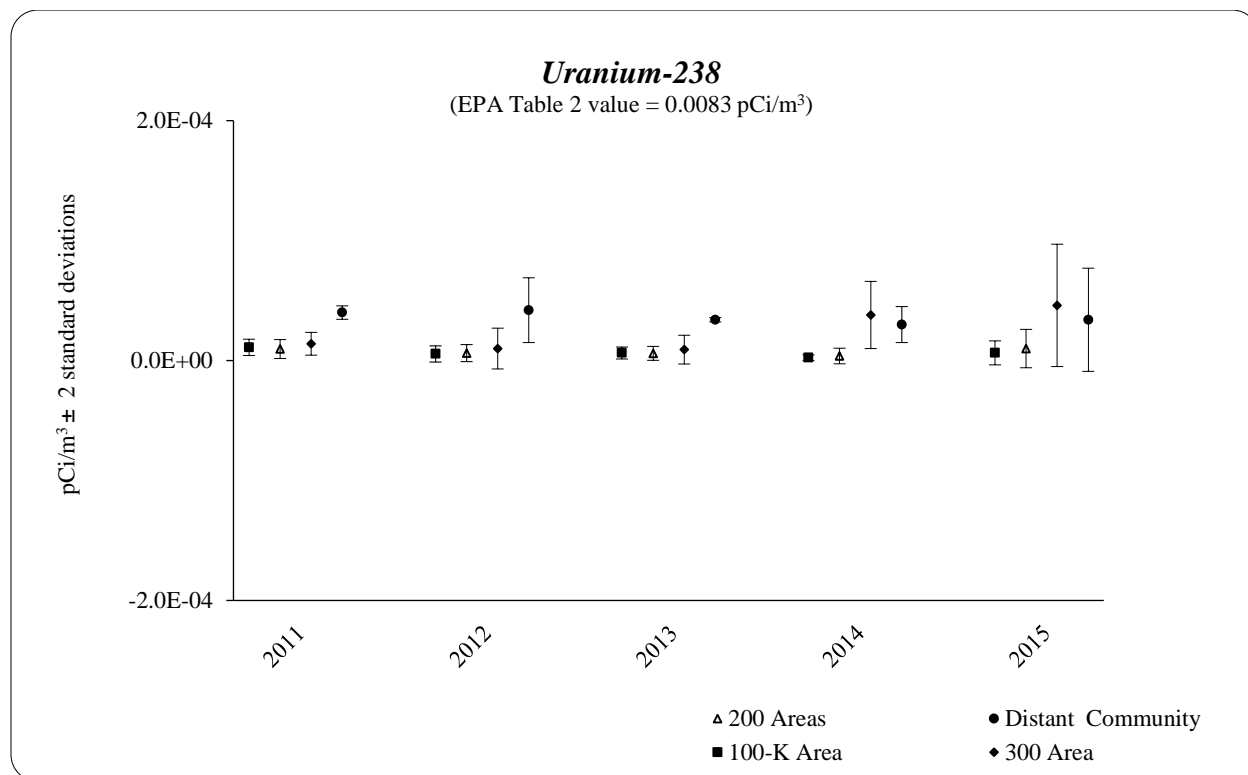
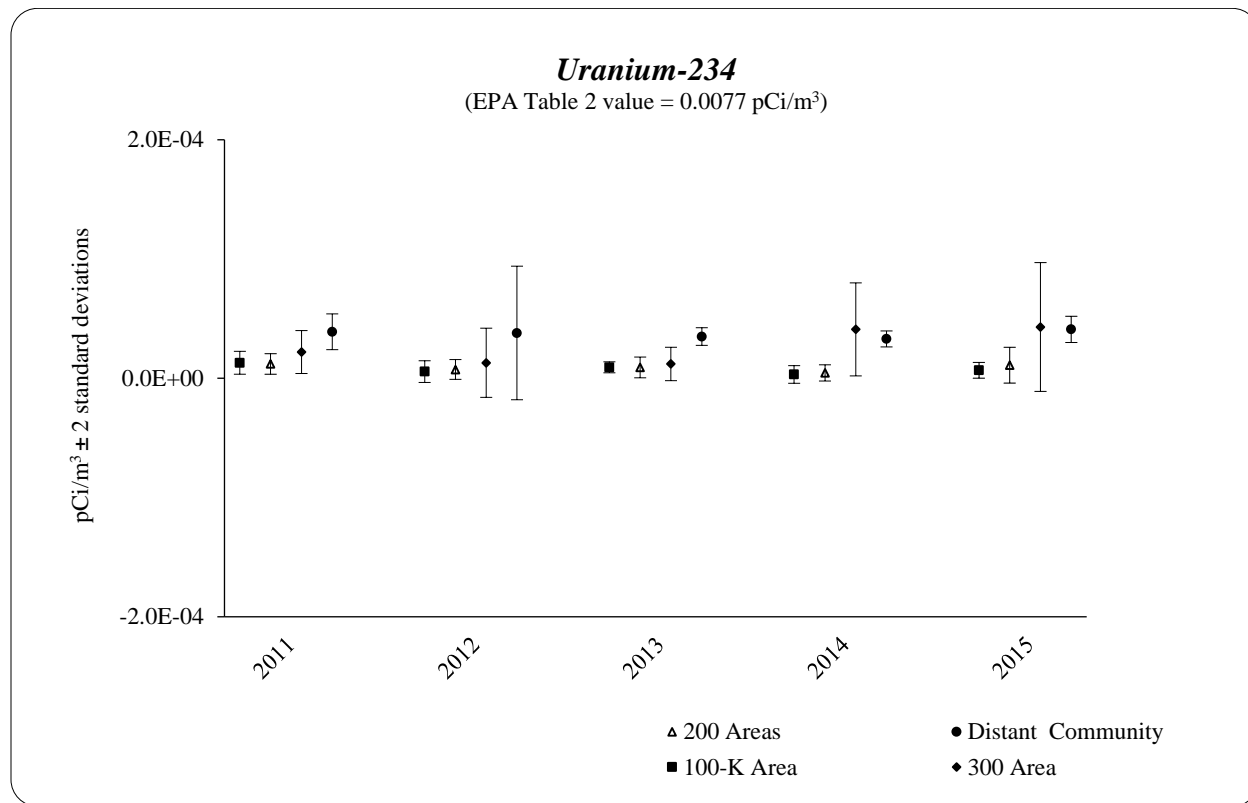


Figure 6.1. Hanford Site Average Radionuclide Concentrations in Ambient Air Samples Compared to Distant Community Samples

*Because of figure scale, some uncertainties (error bars) are concealed by the point symbol

Ambient air was monitored in 2015 at six locations in the 100-K Area, and analytical results showed radionuclide concentrations at or below typical Hanford Site levels. Uranium-234 and -238 were detected in approximately 20% of the samples, and tritium was detected in approximately 28% of the samples. All other radionuclides of concern were below analytical detection limits.

Air sampling was conducted at 21 locations in the 200 East Area during 2015. Generally, radionuclide levels measured in the 2015 air composite samples were similar to those measured in previous years. Uranium-234 and -238 were detected in approximately 28% of the samples. All other radionuclides of concern were below analytical detection limits.

Air sampling was conducted at 23 locations in the 200 West Area during 2015. Radionuclide levels measured were similar to results for previous years. Uranium-234 and -238 were detected in approximately 26% of the samples. Plutonium-239/-240 was detected in approximately 5% of the samples.

Clean-up activities at the 300 Area D4 and Field Remediation project concluded in August 2105 and air sampling was discontinued in September. Uranium-234 and -238 were detected in 67% of the samples at levels similar to those measured in previous years.

Air sampling was conducted at five locations at ERDF (200 West Area). Radionuclide levels measured at this site were similar to typical Hanford Site levels. Uranium-234 and -238 were detected in 37% of the samples.

Air monitoring was conducted at four locations at the 618-10 Burial Ground Project north of the 300 Area. Plutonium-239/-240 was detected in 63% of the samples, uranium-234 and -238 in 43%, and americium-241 in approximately 38%. No 2015 air monitoring results were greater than 10% of EPA's concentration values ([40 CFR 61, Appendix E, Table 2](#)). Plutonium-239/-240 concentrations at station N548 that had historically been measured above this value, decreased in 2015 to levels just below it (Figure 6.2).

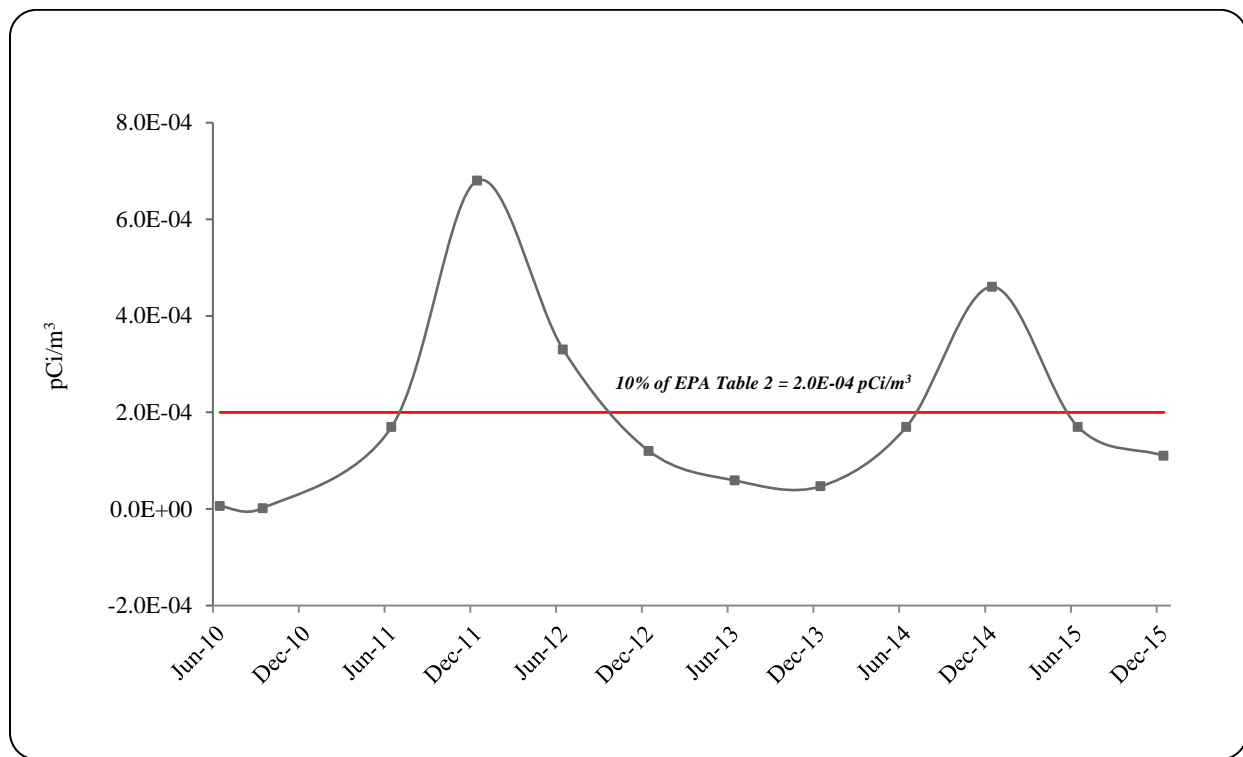


Figure 6.2. Plutonium-239/-240 Air Concentrations at 618-10 Station N548

6.2.2 Hanford Site and Off-Site Ambient Air Monitoring

Airborne radionuclide samples were collected in 2015 by 40 continuously operating samplers at or in the vicinity of the Hanford Site. The stations were grouped into four location categories: Hanford Site (21 stations), perimeter (11 stations), nearby Hanford Site communities (7 stations), and distant community (1 station; Figure 6.3; Appendix C, Table C.6). Hanford Site air samplers were located primarily around major operational areas to maximize the ability to detect radiological contaminants resulting from site operations. Perimeter samplers were located around the site boundary with emphasis on prevailing downwind directions to the south and east. Samplers located in Basin City, Benton City, Kennewick, Mattawa, Othello, Pasco, and Richland, WA provided data for the nearest population centers. A sampler in Yakima, WA provided background data from a community essentially unaffected by Hanford Site operations.

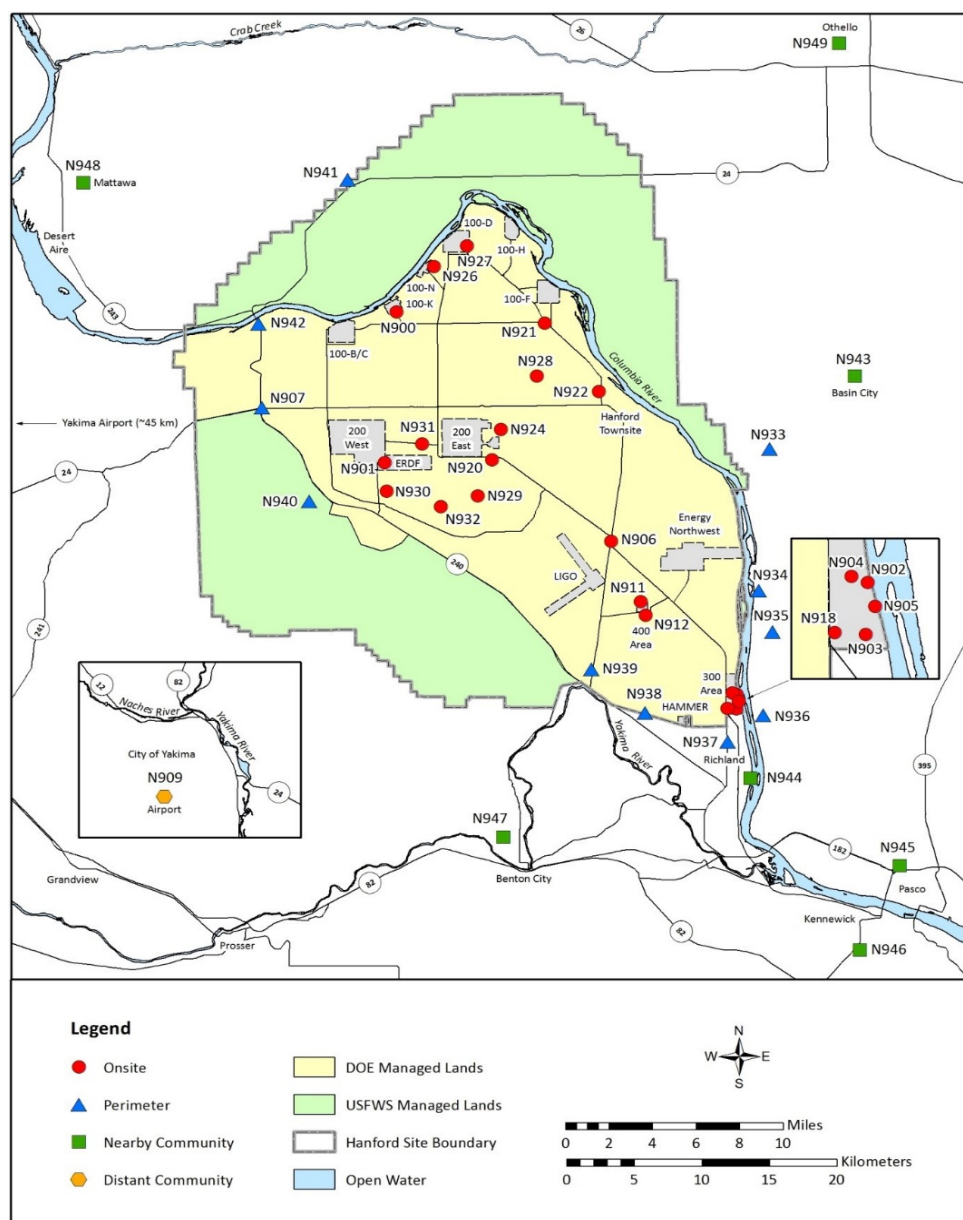


Figure 6.3. Ambient Air Sampling Locations

6.2.2.1 Sampling and Analysis

Samples were collected and analyzed according to a schedule established prior to the monitoring year for off-site samples ([DOE/RL-2013-53, Rev. 1](#), *Hanford Site Environmental Surveillance Master Sampling Schedule Calendar Year 2015*). Airborne particle samples were collected biweekly at each location by continuously drawing air through a glass-fiber filter. The samples were transported to an analytical laboratory and stored for at least 72 hrs, allowing for the decay of short-lived naturally occurring radionuclides (e.g., radon gas decay products) that would otherwise obscure the detection of longer-lived radionuclides potentially present from Hanford Site emissions. The filters were then analyzed for gross beta radiation, with select filters analyzed for gross alpha radiation. For most radionuclides, the amount of radioactive material collected on a filter historically during a 2-week period has been too small to analyze accurately. Biweekly samples were combined into semiannual composite samples to increase the sensitivity and accuracy of the analysis. The compositing procedure results in a 26-week average concentration for specific radionuclides present in the atmosphere as particulates. Composite samples were analyzed for gamma-emitting radionuclides, mostly for strontium-90, uranium-234, uranium-235, plutonium-238, uranium-238, and plutonium-239/-240. Table 6.4 shows the analyses for the discrete filters and composite samples.

Table 6.4. Hanford Site and Off-site Ambient Air Sampling Locations and Analytes

EDP Code*	Location	Bi-Weekly	Monthly†	Analyses Composite‡
Hanford Site				
N900	100 K Area	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N926	100 N-1325 Crib	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N927	100 D Area	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N921	100 F Met Tower	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N922	Hanford Townsite	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N928	Gable Mountain	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N920	200 ESE	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N929	S of 200-E	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N924	B Pond	Alpha, Beta		GEA, plutonium-238/-239/-240, uranium-234/-235/-238
N930	Army Loop Camp	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N931	200 Tel. Exchange	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N932	SW of B/C Cribs	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N901	200 W SE	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N905	300 Water Intake\$, **, ††	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N903	300 South Gate††, §§	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N918	300 South West††	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N904	300 Trench††	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N902	300 NE††	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240
N911	400 N	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240
N912	400 S	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240
N906	Wye Barricade\$, ***	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
Hanford Site Perimeter				
N933	Ringold Met Tower	Alpha, Beta	Tritium	GEA, plutonium-238/-239/-240
N934	W End of Fir Road\$, **	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N935	Dogwood Met Tower	Alpha, Beta	Tritium	GEA, strontium-90, uranium-234/-235/-238
N936	Byers Landing	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N937	Battelle Complex\$, **	Alpha, Beta	Tritium	GEA, uranium-234/-235/-238
N938	Horn Rapids Substa.	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240
N939	Prosser Barricade\$, **	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240
N907	Yakima Barricade\$	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240
N940	Rattlesnake Springs	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240
N941	Wahluke Slope	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240
N942	S End Vernita Bridge	Beta, Alpha		GEA, strontium-90, plutonium-238/-239/-240
Nearby Hanford Site Communities				
N943	Basin City School	Alpha, Beta	Tritium	GEA, plutonium-238/-239/-240, uranium-234/-235/-238
N944	Leslie Groves-Richland	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N945	Pasco	Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238

Table 6.4. Hanford Site and Off-site Ambient Air Sampling Locations and Analytes

EDP Code*	Location	Analyses		
		Bi-Weekly	Monthly†	Composite‡
N946	Kennewick-Ely Street	Alpha, Beta		GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
N947	Benton City	Beta		GEA
N948	Mattawa	Beta		GEA
N949	Othello	Beta		GEA, uranium-234/-235/-238
Distant Hanford Site Community				
N909	Yakima	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238/-239/-240, uranium-234/-235/-238
*EDP code=environmental data point code = sampler location code; refer to Figure 6.2. †Atmospheric water vapor samples for tritium analysis are collected every 4 weeks using silica gel columns. ‡GEA=gamma energy analysis §WDOH particulate air sampler also at this location. **WDOH tritium air sampler also at this location. ††Data from this location is used to support 300 D4 and Field Remediation project. §§Two tritium samples are collected from this location, one as a Quality Assurance duplicate sample. ***Quality assurance duplicate sample collected at this location.				

Atmospheric water vapor was collected for tritium analysis at 20 locations in 2015 by continuously drawing air through multi-column samplers containing adsorbent silica gel. The water-vapor samplers were exchanged every 4 weeks to prevent sample loss as a result of breakthrough (i.e., oversaturation). The collection efficiency of the silica gel adsorbent is discussed in “Ambient Air Sampling for Tritium-Determination of Breakthrough Volumes and Collection Efficiencies for Silica Gel Adsorbent” (Patton, Cooper, and Tinker 1997). The collected water was distilled from the silica gel and analyzed for its tritium content.

6.2.2.2 Monitoring Results

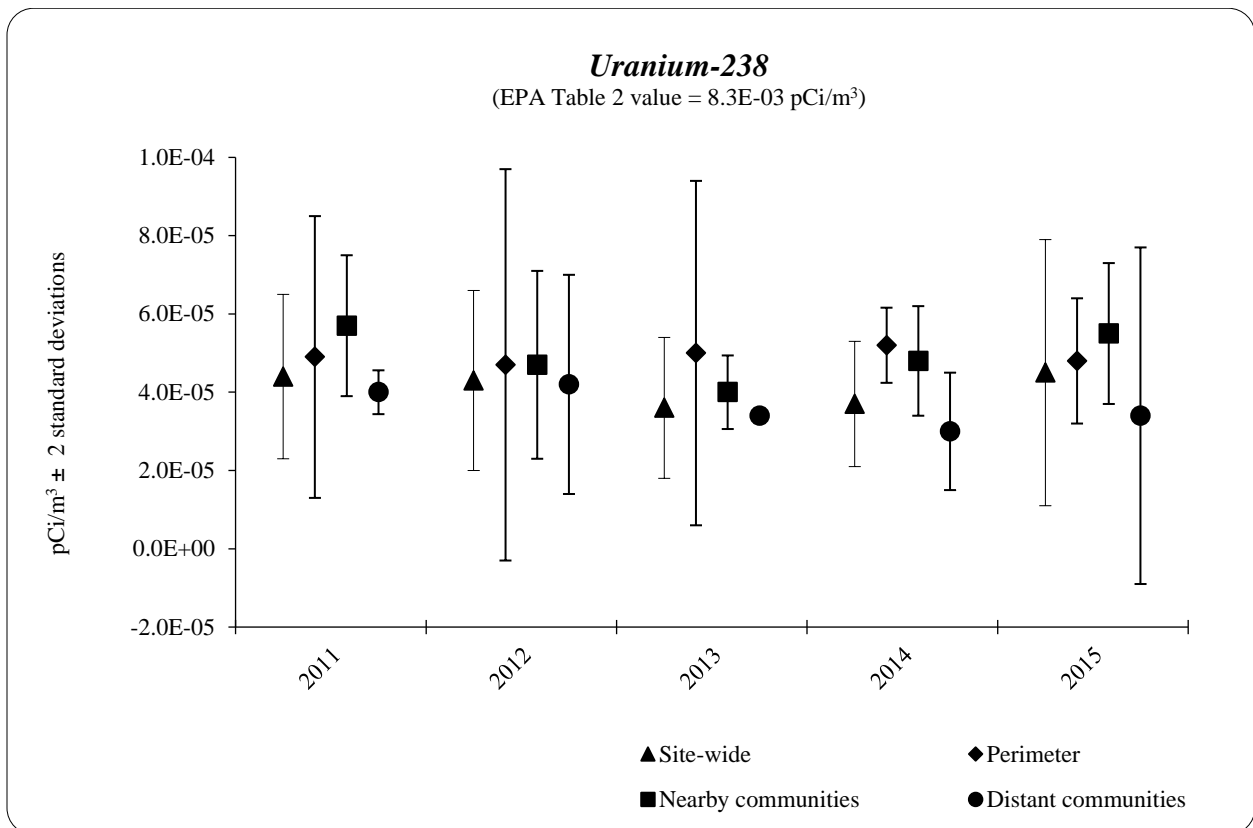
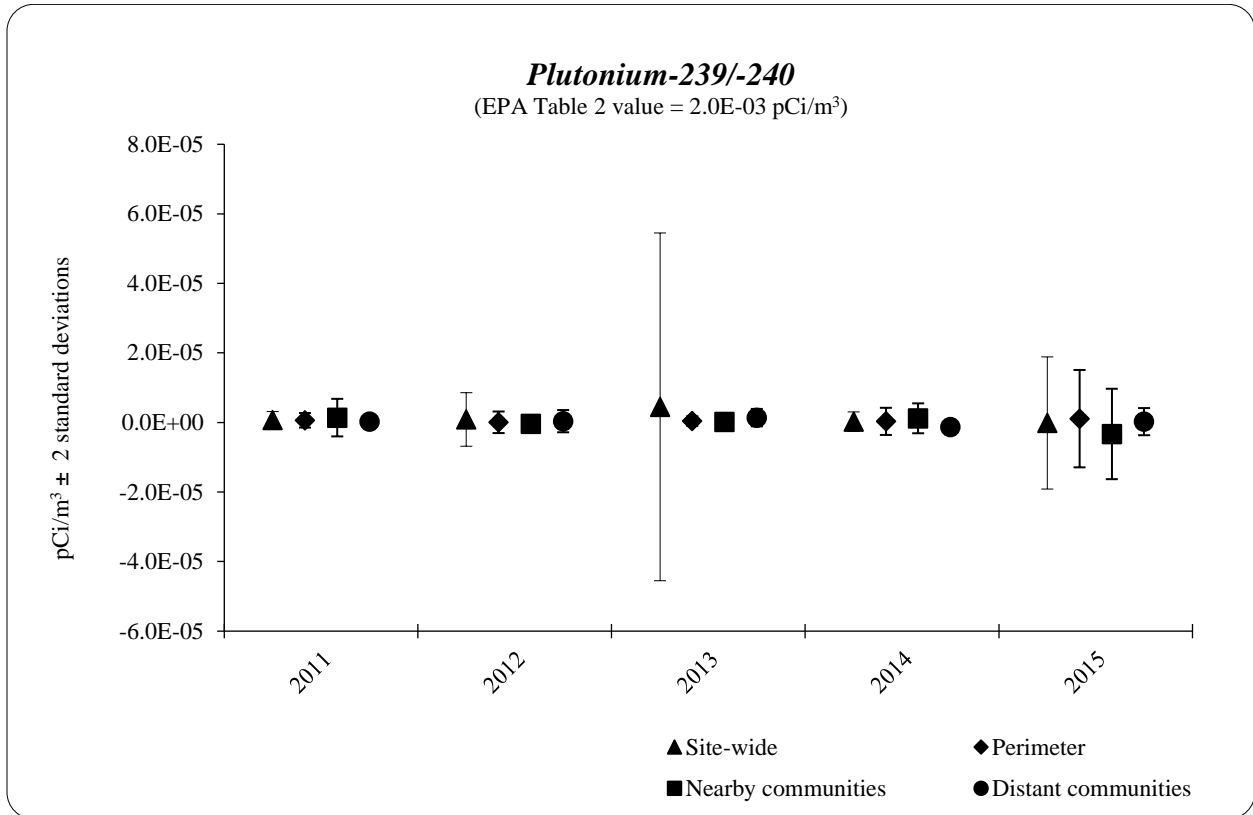
All sample results in 2015 showed very low radiological concentrations in air. All radionuclide concentrations (Appendix C, Table C.6) were less than their respective EPA Table 2 concentration values. The EPA concentration values ([40 CFR 61, Appendix E, Table 2](#)) are concentrations that would result in an annual dose of 10 mrem (100 mSv)/yr from airborne radiological material.

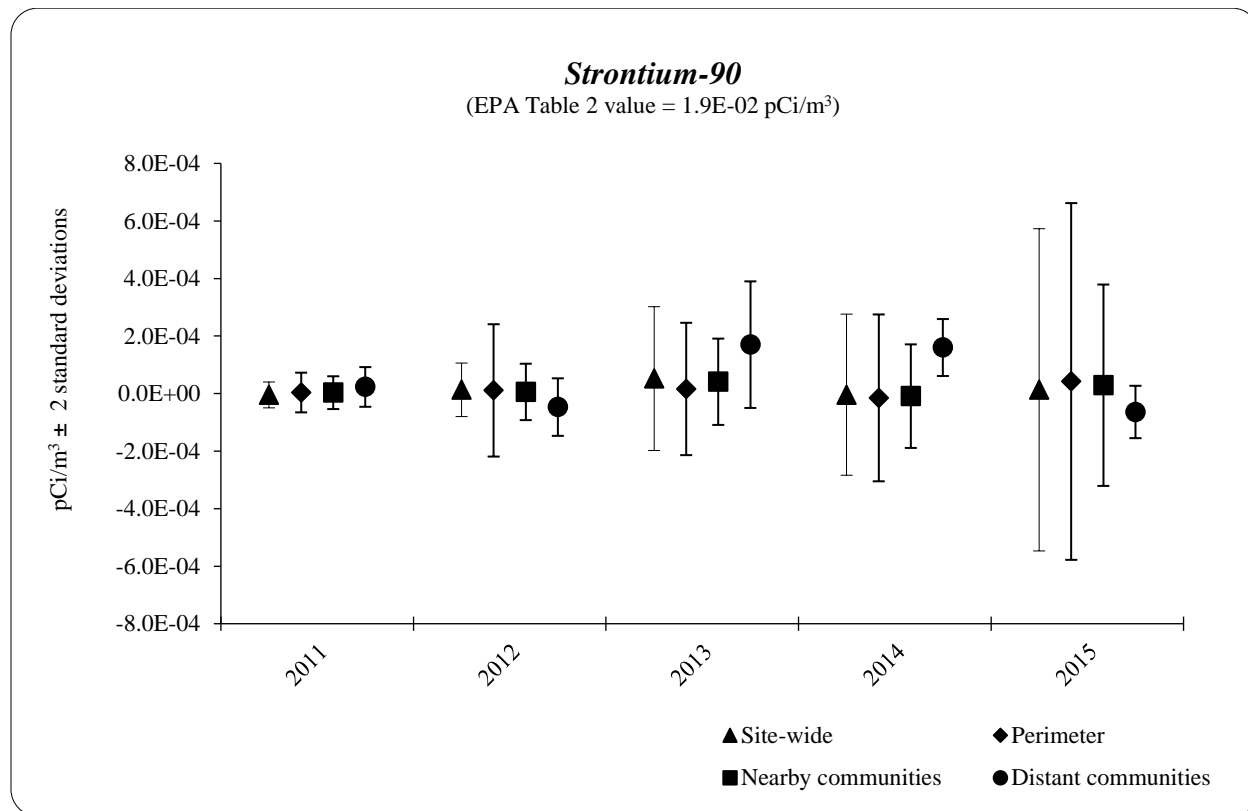
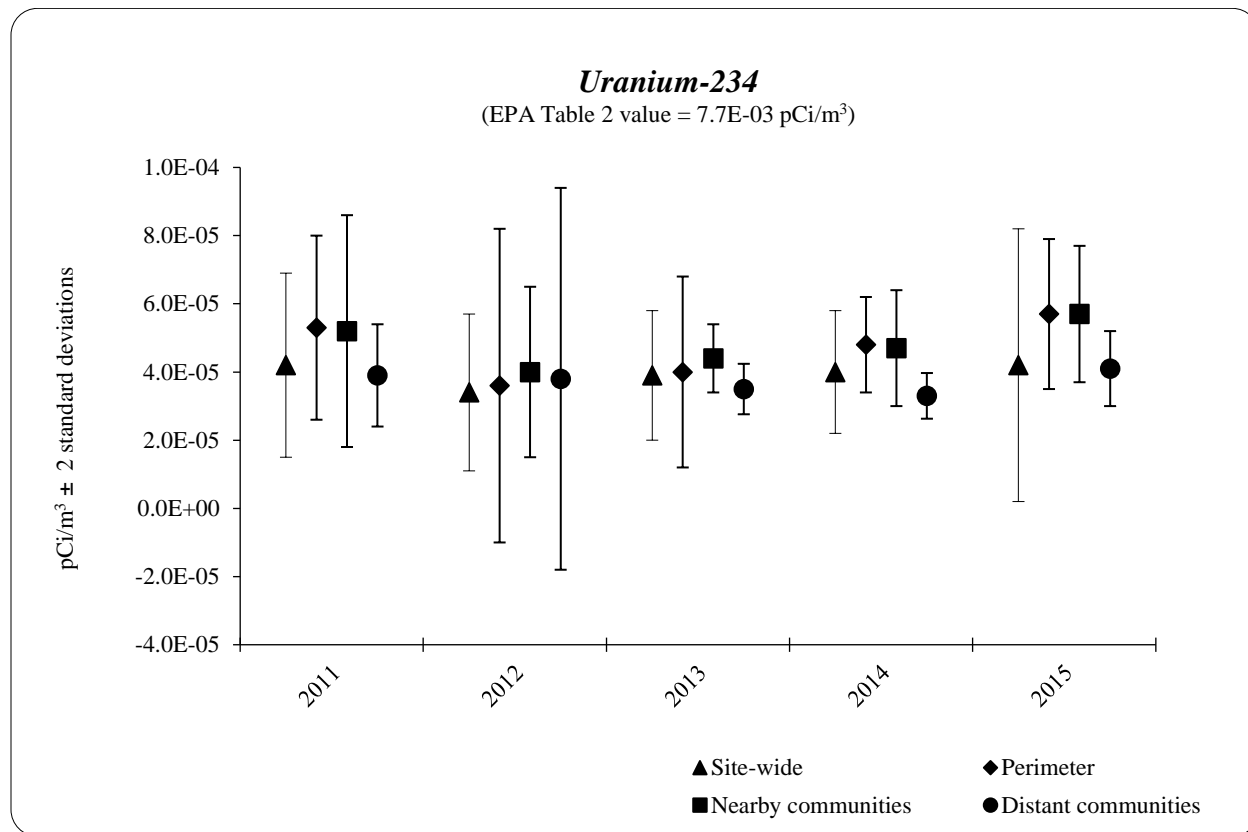
Gross alpha and gross beta concentrations in the air samples collected in 2015 from Hanford Site, perimeter, and nearby Hanford Site communities were comparable to each other and slightly higher than samples from the distant community. Concentrations in 2015 were comparable to concentrations seen in the previous 5 years. Gross beta and gross alpha concentrations in air peak during the fall and winter months, exhibiting a pattern of natural radioactivity fluctuations (Eisenbud 1987). This fluctuation is seen in both Hanford Site and distant location concentrations.

Plutonium-239/-240 was detected at a very low level in 1 out of 64 air samples collected in 2015, which is <1% of the EPA concentration value. Figure 6.4 shows that plutonium-239/-240 concentrations in the air samples collected in 2015 were at levels similar to those measured in previous years.

Uranium-234 and -238 were both detected in approximately 90% of the air samples collected in 2015 from all locations. Figure 6.4 shows that uranium-234 and uranium-238 concentrations were at levels similar to those measured in previous years. The maximum concentrations measured in all locations were less than 10% of the EPA concentration values for both radionuclides.

Cesium-137 and strontium-90 was not detected in any of the samples collected during 2015.





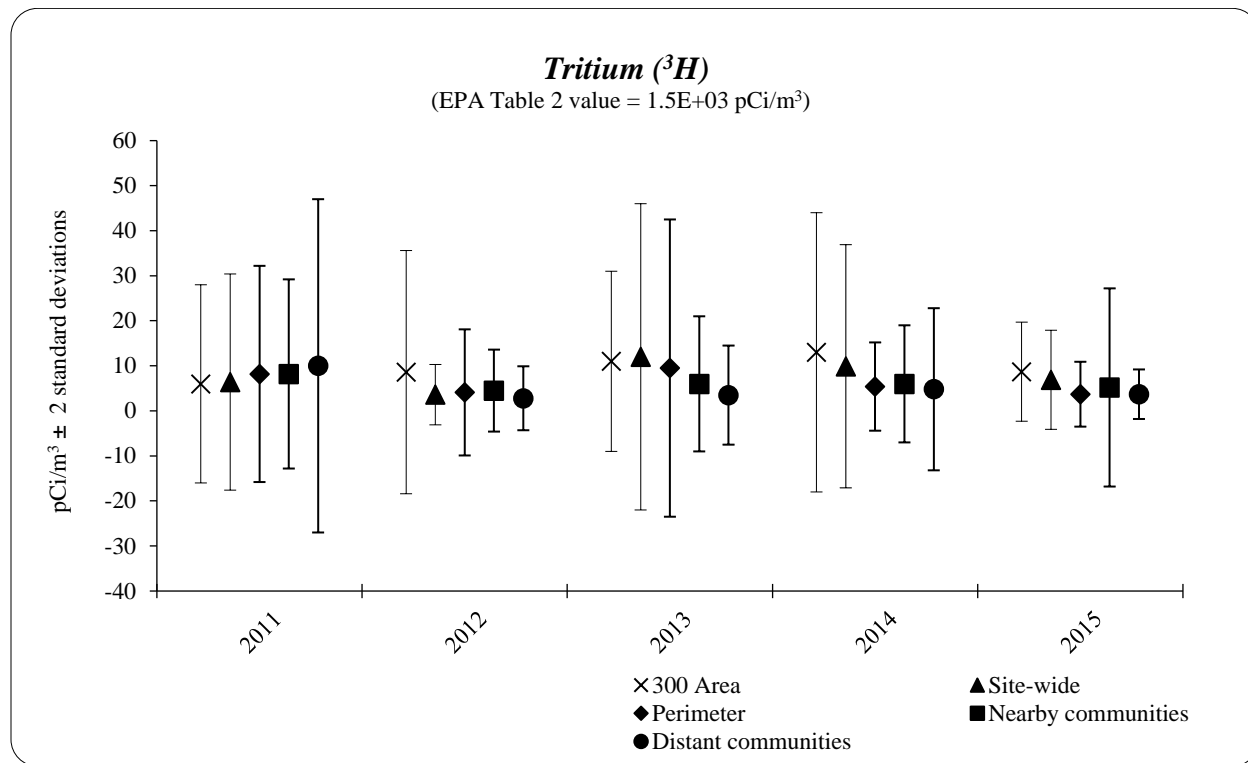


Figure 6.4. Radionuclide Concentrations in Ambient Air Samples
(1 pCi = 0.037 Bq)

7.0 Water Monitoring

7.1 Drinking Water Systems

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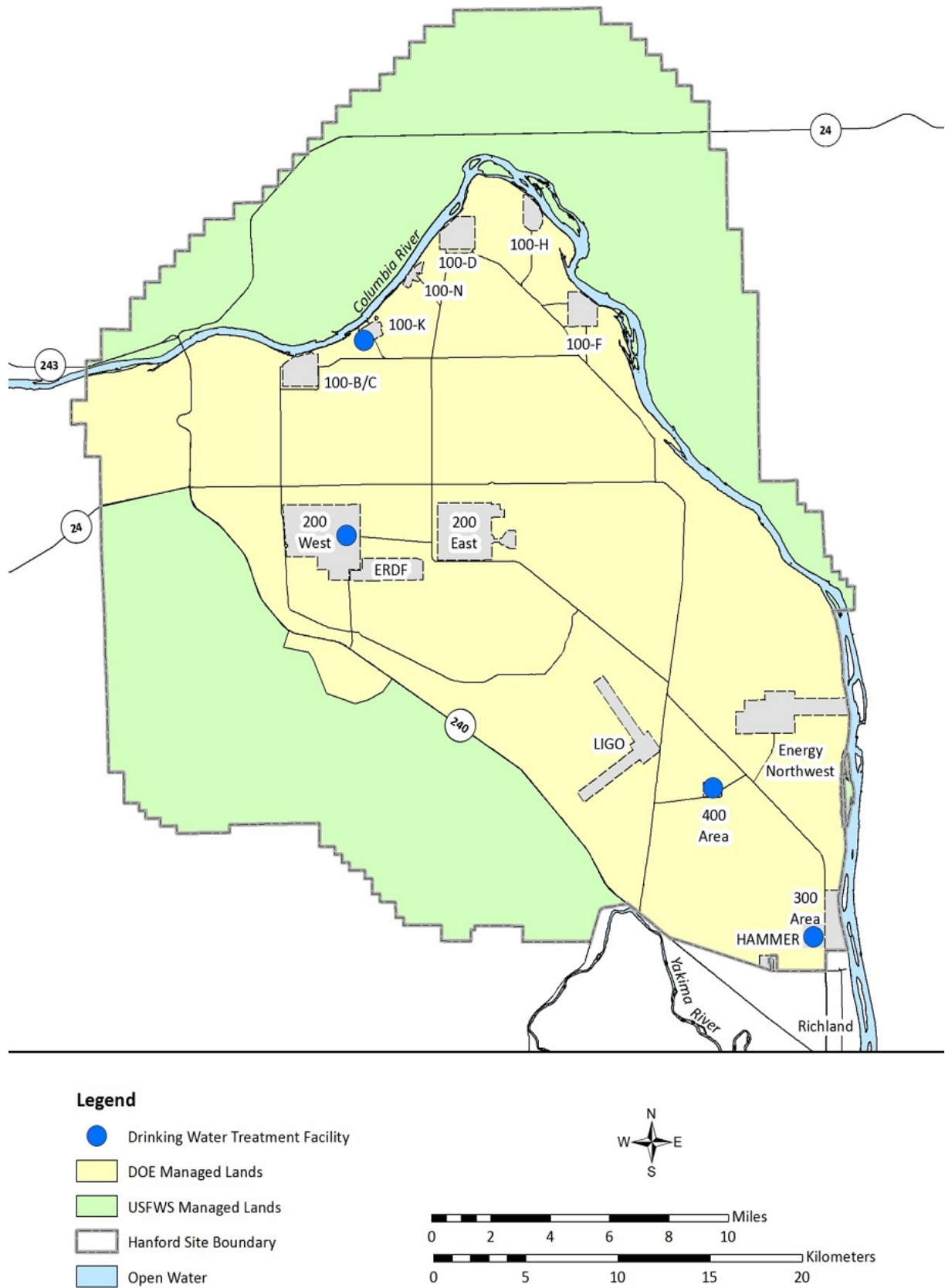
Eight DOE-owned, contractor-operated, public water systems supply drinking water to DOE facilities on the Hanford Site (Table 7.1). MSA operates six of the public water systems and CHPRC operates two systems. The City of Richland supplies water to the 300 Area, Richland North Area, and HAMMER.

Table 7.1. Drinking Water Systems

Public Water System	Water Source	Operator
100-K Area	Columbia River	CHPRC
200 West Area	Columbia River	MSA
251 Substation	Trucked Water from 283-W Water Treatment Plant	MSA
Wye Barricade	Trucked Water from 283-W Water Treatment Plant	MSA
Yakima Barricade	Trucked Water from 283-W Water Treatment Plant	MSA
300 Area	City of Richland (Columbia River and Wells)	MSA
400 Area	400 Area Groundwater Wells	CHPRC
609 Fire Station	Trucked Water from Water Treatment Plant 283-W Water Treatment Plant	MSA

7.1.1 Drinking Water Treatment Facilities

Source water was treated at four DOE-owned water treatment facilities in the 100-K, 200 West, 300 and 400 Areas (Figure 7.1). All facilities treated the water with a form of chlorine to ensure adequate disinfection prior to distribution. The source of supply water for the 100-K Area and 200 West Area facilities was the Columbia River. The 100-K Area water treatment plant (189-K) employed membrane filtration, a pressure-driven process, and coagulation to remove particulate matter and microbial pathogens from the water. The 200 West water treatment plant (283-W) used conventional filtration treatment, which is a series of processes including coagulation, flocculation, sedimentation, and filtration that together achieved substantial particulate removal. The City of Richland supplied water to the 300 Area booster pumping station 385, where sodium hypochlorite was added as necessary prior to distribution to 300 Area consumers. The 400 Area source of supply was groundwater provided from one of three wells. The 400 Area primary supply well 499-S1-8J (P-16) was the source of drinking water for all of 2015. Emergency backup wells 499-S0-8 (P-14) and 499-S0-7 (P-15) did not supply water to 400 Area consumers during the reporting period.

**Figure 7.1. Drinking Water Treatment Facilities**

7.1.2 Monitoring

Samples at 100-K, 200 West, and 400 Area drinking water treatment facilities were collected monthly and analyzed quarterly or annually for radiological contaminants. All were samples of treated water collected before the water was distributed for general use. DOE contractor personnel did not routinely monitor drinking water in the 300 Area, Richland North Area, and HAMMER for radiological contaminants. However, Public Safety and Resource Protection personnel routinely collected water samples from the Columbia River at the City of Richland 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 this section and tabulated in Appendix D. The City of Richland monitors its water for radiological and chemical contaminants as well as for general water quality. Because it is a community water system, city officials are required to report monitoring results annually and characterize risks (if any) from exposure to contaminants in the water in what is known as a Consumer Confidence Report. The annual water quality report is mailed to all utility consumers as an insert with a monthly utility bill and is available on the City of Richland website at <https://www.ci.richland.wa.us/Home/ShowDocument?id=2106>.

7.1.3 Radiological Results

Scientists conducted radiological monitoring of drinking water at one DOE-owned pump and three water treatment facilities. In addition, routine chemical, physical, and microbiological monitoring of Hanford Site drinking water was performed. Individual water systems operated by MSA and CHPRC (Table 7.1) performed process monitoring (including 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 WDOH. Radiological results for Hanford Site drinking water samples are reported to the state through this annual environmental report. The contractor responsible for operating the water system provides process-monitoring reports directly to the state each month. Chemical, physical, and microbiological data are reported to the state directly by the state-accredited laboratory performing the analyses to MSA; however, the reports are not published.

All DOE-owned Hanford Site drinking water systems were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels during 2015. Contaminant concentrations measured during the year were similar to those observed in recent years as described in the annual Hanford Site environmental reports for 2013 ([DOE/RL-2013-47](#)) and 2014 ([DOE/RL-2014-52](#)).

Environmental Assessment personnel collected drinking water samples for radiological analysis, which were analyzed for gross alpha, gross beta, tritium, and strontium-90 (Table 7.2). The maximum amount of beta-gamma radiation from manmade radionuclides allowed in drinking water by Washington State and EPA is an annual average concentration that will not produce an annual dose equivalent to the whole body or any internal organ greater than 4 mrem (0.04 mSv). Maximum contaminant levels for gross alpha (excluding radon and uranium) are 15 pCi/L (0.56 Bq/L). The maximum allowable annual average limit for tritium is 20,000 pCi/L (740 Bq/L; [40 CFR 141](#) and [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).

Annual average concentrations of all monitored radionuclides in Hanford Site drinking water in 2015 were below state and federal maximum allowable contaminant levels (Table 7.2). The gross alpha, gross beta, tritium, and strontium-90 results from the two facilities where drinking water was obtained from the Columbia River were all below minimum detectable concentration (i.e., concentrations were too low to measure). The 400 Area source of drinking water for 2015 was well 499-S1-8J (P-16). Gross beta and tritium were found in all 400 Area water samples, but were still below the maximum allowable contaminant level. Gross alpha and strontium-90 were not detected in 400 Area water samples.

Table 7.2. Drinking Water Annual Average Concentrations of Selected Radiological Constituents

Constituent	Systems	Samples Analyzed at Each Location	Annual Average* (pCi/L) [†]	Standard
Gross alpha [‡]	100-K Area	4§	-0.059 ± 3.019	15**, ^{††}
	200 West Area	4§	0.085 ± 0.812	
	400 Area	4§	-0.155 ± 3.060	
Gross beta [‡]	100-K Area	4§	1.061 ± 2.381	50 ^{††}
	200 West Area	4§	0.031 ± 1.686	
	400 Area	4	6.960 ± 2.512	
Tritium ^{‡‡}	100-K Area	1§	123 ± 327	20,000 ^{††}
	200 West Area	1§	-51 ± 312	
	400 Area	4	1275 ± 217	
Strontium-90 ^{‡‡}	100-K Area	1§	0.186 ± 0.746	8**, ^{††}
	200 West Area	1§	-0.241 ± 0.544	
	400 Area	1§	-0.347 ± 0.663	

*Annual average is ± 2 times the standard deviation, unless only one sample analyzed in which case it is the single result ± total propagated analytical error.

[†]Multiply pCi/L by 0.037 to convert to Bq/L.

[‡]Gross alpha samples were collected and analyzed quarterly. Gross beta samples were collected monthly, composited, and analyzed quarterly.

§Analytical results are below the minimum detectable concentration.

**[WAC 246-290](#)

^{††}[40 CFR 141](#)

^{‡‡}Samples were collected quarterly, composited, and analyzed annually, with the exception of the 400 Area tritium analyses. In the 400 Area, tritium samples were collected and analyzed quarterly.

Soil and Groundwater Remediation Project personnel collected and analyzed raw (untreated) water samples from all three 400 Area drinking water wells (one primary well and two backup wells). A tritium plume originating in the 200-East Area and extending under the 400 Area historically has affected tritium concentrations in all the 400 Area drinking water wells (Figure 7.2; Table 7.3). In addition, Environmental Assessment personnel collected raw (untreated) water samples from 400 Area drinking water backup well 499-S0-8 (P-14). Samples were collected quarterly, composited for a single annual tritium analysis (13,000 ± 2,480 pCi/L), and fell below the 20,000-pCi/L (740-Bq/L) federal and state annual average drinking water standards.

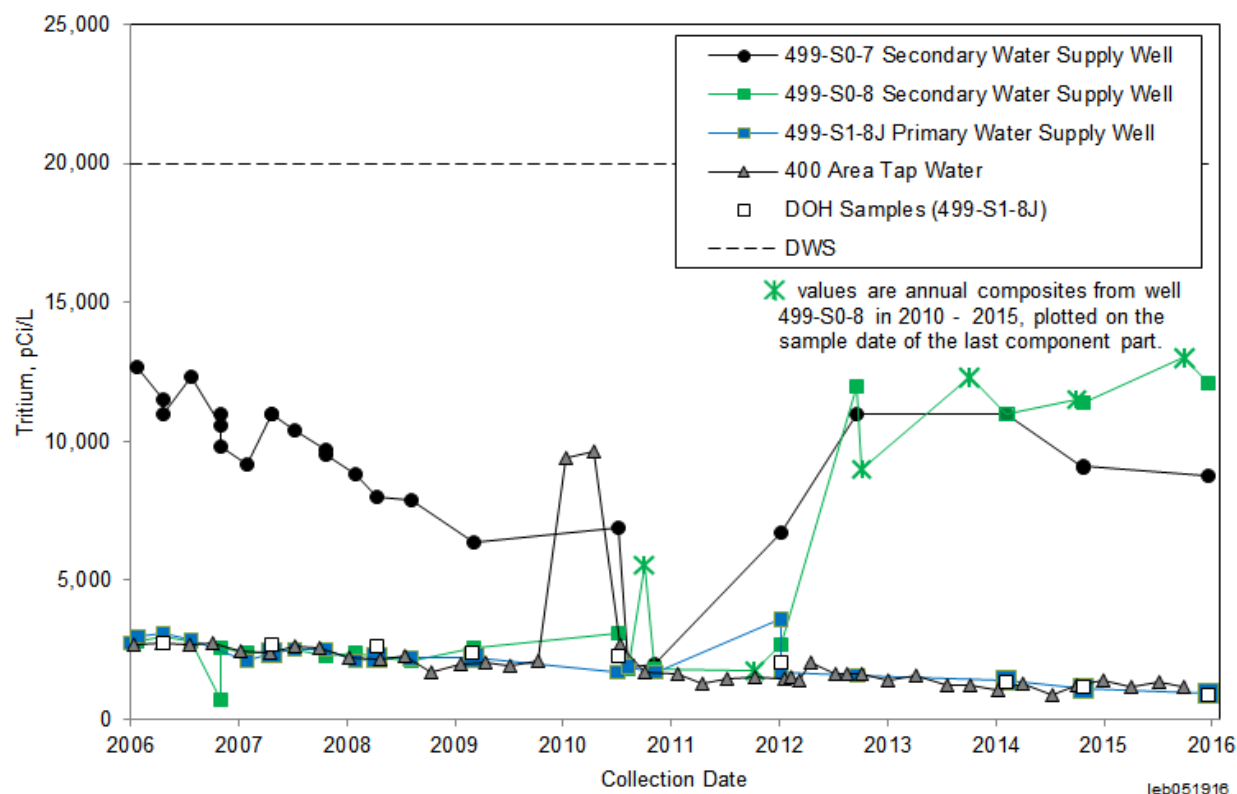


Figure 7.2. 400 Area Tritium Concentrations in Drinking Water

multiply pCi/L by 0.037 to convert to Bq/L

Table 7.3. Tritium Concentrations in Hanford Site 400 Area Drinking Water Wells*

Sampling Date	Primary Drinking Water Well 499-S1-8J (P-16; pCi/L)†	Backup Drinking Water Well 499-S0-8 (P-14; pCi/L)†	Backup Drinking Water Well 499-S0-7 (P-15; pCi/L)†
December 29, 2015	942 ± 170	12,100 ± 2,360	8,740 ± 410

*Reported concentration ±2 total propagated analytical error.
†Multiply pCi/L by 0.037 to convert to Bq/L.

7.2 Columbia River Surface Water

ME Hoefer

Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the concentrations of radiological, inorganic, and organic compounds in the aquatic environment that may be attributed to the Hanford Site. Surface-water bodies monitored included the Columbia River, Hanford Site ponds, and off-site irrigation sources (Figure 7.3). Aquatic sediment monitoring was conducted for the Columbia River and one Hanford Site pond. Tables 7.4 and 7.5 summarize the sampling locations, types, frequencies, and sample analyses included in surface-water and sediment monitoring. This section describes the monitoring efforts and summarizes the results for these aquatic environments.

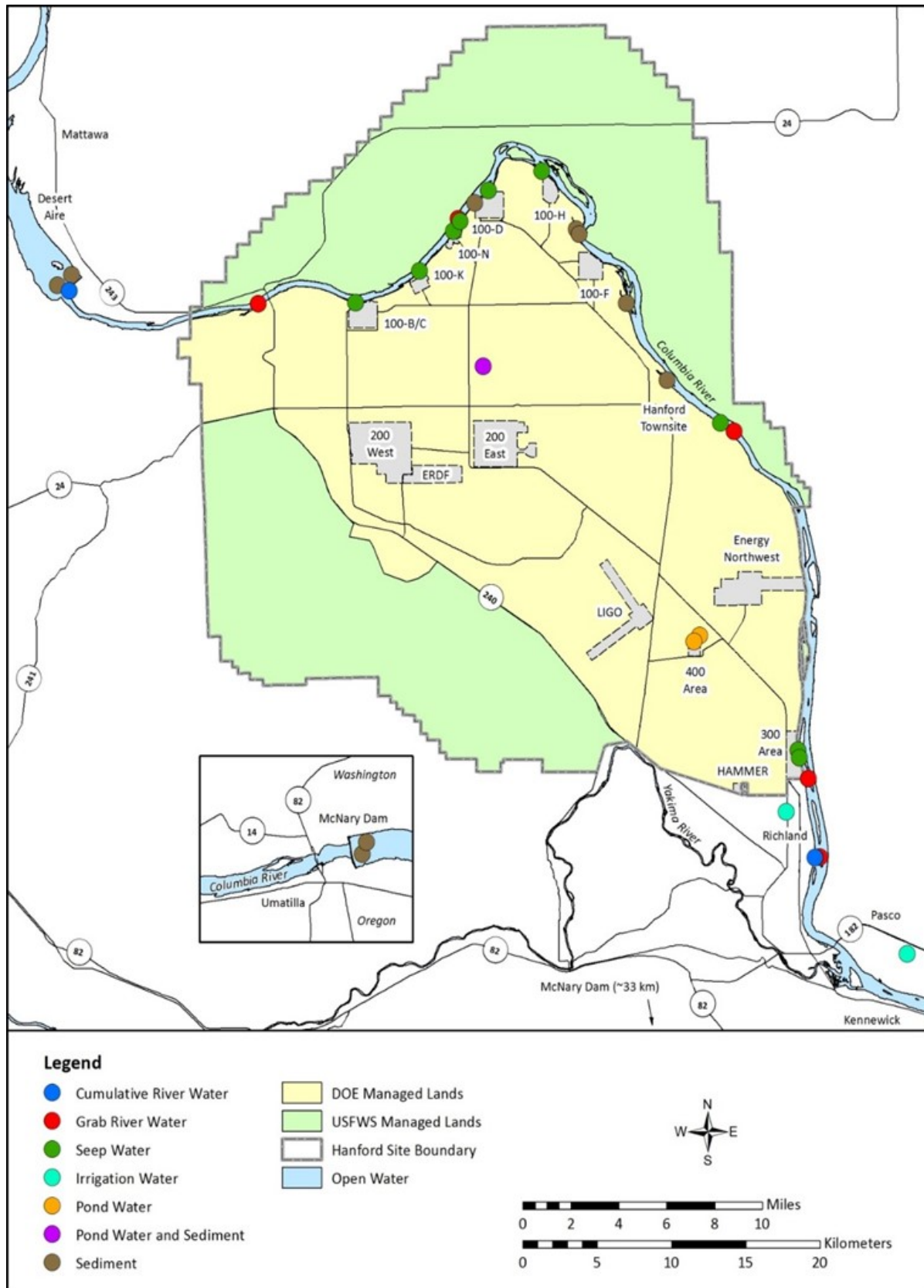


Figure 7.3. Surface-Water and Sediment Sampling Locations

Table 7.4. Surface Water Surveillance

Location	Sample Type	Frequency	Analyses
Columbia River – Radiological			
Priest Rapids Dam and Richland Pump House	Cumulative	M Comp*	Low tritium†, strontium-90, technetium-99, isotopic uranium‡
	Particulate (filter)	M Cont§	Gamma energy analyses, isotopic plutonium**
	Soluble (resin)	M Cont§	Gamma energy analyses, isotopic plutonium**
Vernita Bridge	Grab (transects)	Semi-annual	Gamma energy analyses, low tritium†, strontium-90, isotopic uranium‡, isotopic plutonium**, technetium-99
Richland	Grab (transects)	Semi-annual	Gamma energy analyses, low tritium†, strontium-90, isotopic uranium‡, isotopic plutonium**, technetium-99
100-N, 300 Areas and Hanford Townsite (HTS)	Grab (transects)	Annually	Gamma energy analyses, low tritium†, strontium-90, isotopic uranium‡
Columbia River – Inorganics and Organics			
Vernita Bridge	Grab (transects)	Annually	Anions, mercury, metals (filtered and unfiltered)
	Grab (transects)	Annually	Volatile organic compounds
Richland	Grab (transects)	Annually	Anions, mercury, metals (filtered and unfiltered)
	Grab (transects)	Annually	Volatile organic compounds
100-N, 300 Areas and Hanford Townsite (HTS)	Grab (transects)	Annually	Anions, metals (filtered and unfiltered)
On-site Ponds			
West Lake Seep	Grab	Annually	Tritium, isotopic uranium‡
West Lake Water	Grab	Annually	Tritium, isotopic uranium‡
Off-site Irrigation Water			
Riverview Irrigation Canal	Grab	3/year	Alpha, beta, low tritium†, strontium-90, gamma energy analyses
Horn Rapids	Grab	3/year	Alpha, beta, low tritium†, strontium-90, gamma energy analyses

Comp=composite, Cont=continuous, M=monthly

*M Comp indicates river water was collected at set intervals and composited monthly for analyses.

†Low tritium = Low-level tritium analysis (10-pCi/L detection limit).

‡Includes uranium-234, -235, and -238

§M Cont=River water was sampled for 2 weeks by continuous flow through a filter and resin column. Multiple samples were composited monthly for analyses.

**Includes plutonium-238 and plutonium-239/-240

Table 7.5. Columbia River Sediment

Location	Frequency	Analyses
McNary Dam (two nearby locations)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium†, isotopic plutonium‡, metals, mercury, strontium-90, and total organic carbon
Hanford Reach§	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium†, isotopic plutonium‡, metals, mercury, strontium-90, and total organic carbon
Priest Rapids Dam (two nearby locations)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium†, isotopic plutonium‡, metals, mercury, strontium-90, and total organic carbon
Contiguous Hanford Reach Islands (Locke and Savage)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium†, isotopic plutonium‡, metals, mercury, and strontium-90

*Refer to Figure 7.3
†Uranium-234, -235, and -238
‡Plutonium-238 and plutonium-239/-240
§Hanford Reach consists of sediment collected in the 100D Spring 102-1 and 100K 63-1 Shoreline Seep areas and 100F, Hanford, and White Bluffs sloughs

The Columbia River is one of the largest rivers in the continental U.S. in terms of total flow and is the dominant surface-water body at the Hanford Site. The original selection of the Hanford Site for plutonium production was based partly on the abundant water supply offered by the river. The river flows through the northern portion of the Hanford Site and forms part of the eastern boundary of the site. The river is used as a source of drinking water for Hanford Site facilities and communities downstream of the Hanford Site. Water removed from the river immediately downstream of the Hanford Site also is used for irrigation in Benton and Franklin counties. In addition, the Hanford Reach of the Columbia River is used for a variety of recreational activities, including boating, fishing, hunting, scuba diving, snorkeling, swimming, wakeboarding, and waterskiing.

Originating in the Rocky Mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of approximately 260,000 m² (670,000 km²) before discharging to the Pacific Ocean. Three dams in Canada and 11 dams in the United States regulate the flow of the river; four dams are downstream of the Hanford Site. Priest Rapids Dam is the nearest upstream dam, and McNary Dam is the nearest downstream dam in relation to the Hanford Site.

The Hanford Reach of the Columbia River extends from Priest Rapids Dam downstream to the head of Lake Wallula created by McNary Dam. The Hanford Reach is the last free-flowing stretch of the Columbia River. River flow through the Hanford Reach is controlled primarily by operations at upstream dams, which over the course of the year cause water levels to fluctuate significantly. Figure 7.4 shows the maximum, average, and minimum flow rates of the Columbia River at Priest Rapids Dam for 2015. The annual average flow of the Columbia River downstream of Priest Rapids Dam was approximately 111,669 ft³ (3,162 m³)/sec, slightly below the most recent 10-year average annual flow rate of 115,831 ft³ (3,280 m³)/sec (U.S. Geological Survey [[USGS](#)] 2013). The highest monthly average flow rate occurred during February (160,182 ft³ [4,554 m³]/sec; Figure 7.4). The lowest monthly average flow rate occurred during September (65,397 ft³ [1,852 m³]/sec) based on mean daily flows. Daily average flow rates varied from 38,000 to 188,321 ft³ (1,076 to 5,333 m³)/sec in 2015. Because of fluctuation in discharges, the depth of the river varies significantly. The river stage (river water surface elevation) may change along the Hanford Reach by up to 10 ft (3 m) within a few hours. Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately one-half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam. The relative distance of each area from Priest Rapids Dam and the width of the river vary from approximately 980 to 3,300 ft (300 to 1,000 m) as it passes through the Hanford Site.

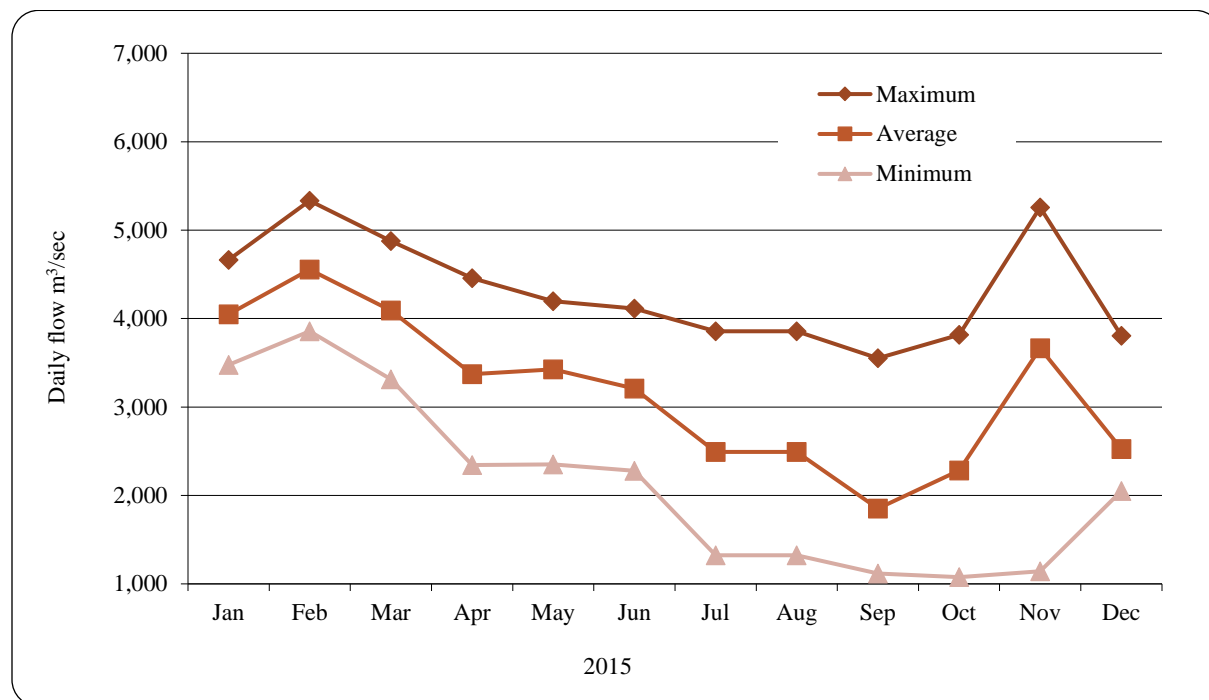


Figure 7.4. Columbia River Flow Rates at Priest Rapids Dam

multiply m³/sec by 35.31 to obtain ft³/sec

7.2.1 Monitoring

In 2015, Columbia River water samples were collected and analyzed for radionuclides from fixed-location monitoring stations at Priest Rapids Dam and at the City of Richland raw water intake facility. Cross-river transects near Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the City of Richland were analyzed for radionuclides, metals, and inorganic and organic compounds (Figure 7.3). Samples were collected upstream of the Hanford Site at Priest Rapids Dam and Vernita Bridge to provide data from locations unaffected by Hanford Site operations. Samples were collected from all other locations, including a municipal drinking water supply and points of withdrawal for irrigation water downstream of the Hanford Site, to identify any increase in contaminant concentrations attributable to the site. Irrigation water systems sampling is discussed in Section 7.6.

The fixed-location monitoring stations at Priest Rapids Dam and the City of Richland raw water intake facility consist of an automated sampler and a continuous flow system. The automated samplers were used to obtain unfiltered samples of Columbia River water (cumulative samples), which were composited for a period of 14 days. The samplers collect water at set intervals of time (e.g., 1 hr) and set incremental volumes (e.g., 55 mL). These bi-weekly samples were combined into monthly composite samples for radiological analyses (Table 7.4). The continuous flow system was used to collect particulate and soluble constituents in Columbia River water 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 monthly composite samples for radiological analyses. The river sampling locations and the methods used for sample collection are discussed in the latest revision of [DOE/RL-91-50](#).

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

- presence in historical effluent discharges from Hanford Site facilities or in groundwater underlying the Hanford Site near the Columbia River
- importance in determining water quality, and in determining compliance with applicable water quality standards
- importance in key pathway-specific exposure dose assumption calculations based on 95th percentile of drinking water ingestion rate of 3.1 L/day for 350 days/yr ([EPA 2011](#), Table ES-1).

Constituents of interest in Columbia River water samples collected at Priest Rapids Dam and the City of Richland raw water intake facility included gamma-emitting radionuclides, tritium, strontium-90, technetium-99, uranium-234, uranium-235, plutonium-238, uranium-238, and plutonium-239/-240. Gamma-energy analysis provides the capability to detect numerous specific radionuclides. 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 C). Unless otherwise noted in this section, the statistical tests for differences are paired sample comparisons and two-tailed t-tests, with alpha at a 5% significance level.

National primary and secondary drinking water standards were used to compare detections at Vernita and Richland Pump house in 2015 (filtered metals), and observations determined concentrations were slightly exceeding some guidelines; however, similar concentrations were observed from both the upstream (Vernita) and downstream (Richland Pump house) locations. Drinking water is consumed, but it travels through the water treatment plant operated by the City of Richland before it is available for public use.

Transect sampling (i.e., a series of samples collected along a line across the Columbia River) was initiated because of findings of a special study conducted in the late 1980s ([PNL-8531](#), *Columbia River Monitoring: Distribution of Tritium in Columbia River Water at the Richland Pump house*). The study concluded that under certain flow conditions, contaminants entering the Columbia River from the Hanford Site are not completely mixed when sampled at routine monitoring stations located downriver. Incomplete mixing results in a conservative bias in the data generated using the routine, single-point sampling system at the City of Richland drinking water intake. Transect sampling allows cross-river concentration profiles to be determined to provide information over a larger portion of the Hanford Site shoreline where the highest contaminant concentrations of concern would be expected.

In 2015, four to five evenly spaced cross-river transect samples were obtained. The Richland Pump house and Vernita Bridge transects are collected semi-annually (typically spring/summer). The 100-N Area, Hanford Townsite, and 300 Area locations were all sampled annually in 2015 during late summer when river flows were low, which provides the highest probability of detecting Hanford Site contaminants carried by groundwater to the Columbia River.

Columbia River transect water samples collected during 2015 were analyzed for radiological, inorganic, and organic contaminants (Table 7.4). Specific metals and anions were selected for analyses following reviews of existing surface-water and groundwater data, various RI/FS work plans, and preliminary Hanford Site risk assessments ([DOE/RL-92-67](#), *Final Remedial Investigation/Feasibility Study-Environmental Assessment Report for the 1100-EM-1 Operable Unit, Hanford*; [WCH-380](#), *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*). Metals analyses included both unfiltered (recoverable) and filtered (dissolved) samples.

7.2.2 Radiological Results

Fixed-location Samples. Results of radiological analyses of Columbia River water samples collected at Priest Rapids Dam and the City of Richland raw water intake facility in 2015, and for the previous 5 years, are summarized in Appendix C, Table C.7. Individual radiological contaminant concentrations measured in Columbia River water during 2015 were less than 1/25 of the DOE-derived concentrations (Appendix D). The DOE-derived concentrations 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 standards and Washington State ambient surface-water quality criteria ([40 CFR 141](#); [WAC 173-201A](#); Appendix D).

Radionuclide concentrations monitored in Columbia River water were low throughout 2015. Tritium, uranium-234, and uranium-238 were consistently measured in river water at levels greater than their reported minimum detectable concentrations. Uranium-235 was occasionally detected, but all values were near minimum detectable values. All other radionuclides were typically less than the minimum detectable concentrations.

The 2015 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in recent years (Figure 7.5). Statistical analyses indicated that monthly tritium concentrations in river water samples at the City of Richland raw water intake facility were slightly higher than concentrations in samples from Priest Rapids Dam. Average tritium concentrations in Columbia River water collected at the City of Richland were 0.15% of the Washington State ambient surface-water quality criterion of 20,000 Ci/L (740 Bq/L).

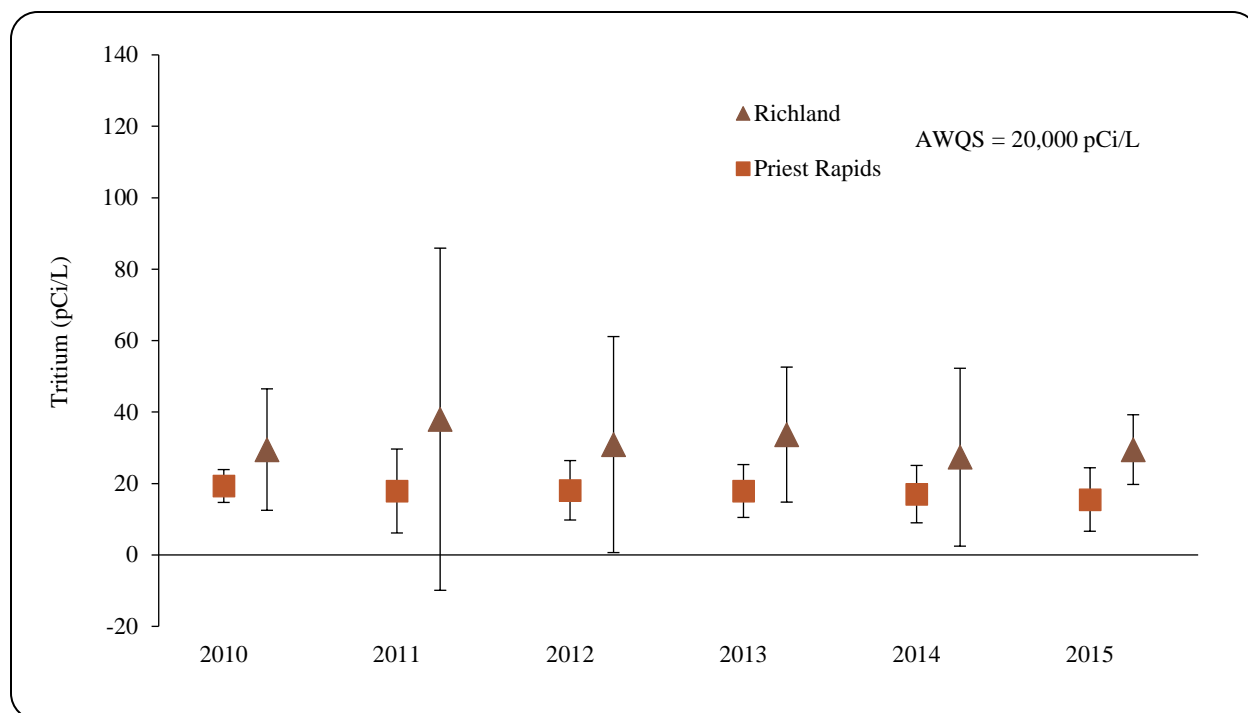


Figure 7.5. Tritium Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site

±X standard deviations, AWQS=ambient water quality standard; Washington State AWQS for tritium is 20,000 pCi/L (740 Bq/L)

The Hanford Site source of tritium entering the river is from groundwater upwelling and shoreline seepage. Although representative of river water used by the City of Richland for drinking water (first municipal water source downstream from the Hanford Site), tritium concentrations measured at the City of Richland shoreline tend to be elevated when compared to average historical tritium concentrations across the river at this location. This bias is attributable to a groundwater plume originating from the 200 East Area entering the river along the shoreline extending from the Hanford Townsite downstream to the 300 Area. The plume is not completely mixed within the Columbia River because of the close proximity to the City of Richland's water intake structure. Sampling along cross-river transects at the City of Richland during 2015 confirmed the existence of a concentration gradient in the river under certain flow conditions discussed in this section. The extent to which samples taken at the City of Richland drinking water intake 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.

Average strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2015 were similar to those reported in previous years (Figure 7.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Area. Some of the highest strontium-90 levels that have been found in Hanford Site groundwater are the result of past discharges to the 100-N Area liquid waste disposal facilities. Although strontium-90 concentrations at Priest Rapids Dam and the City of Richland were below minimum detection limits (0.06 pCi/L), low levels were still statistically compared to show differences. Priest Rapids Dam had a maximum concentration of 0.033 pCi/L (0.0012 Bq/L), and the City of Richland intake had a maximum concentration of 0.034 pCi/L (0.0013 Bq/L). Average strontium-90 concentrations in Columbia River water at the City of Richland were less than 0.4% of the Washington State ambient surface-water quality criterion (8 pCi/L [0.30 Bq/L]) while those at Priest Rapids measured 0% due to negative strontium-90 concentrations.

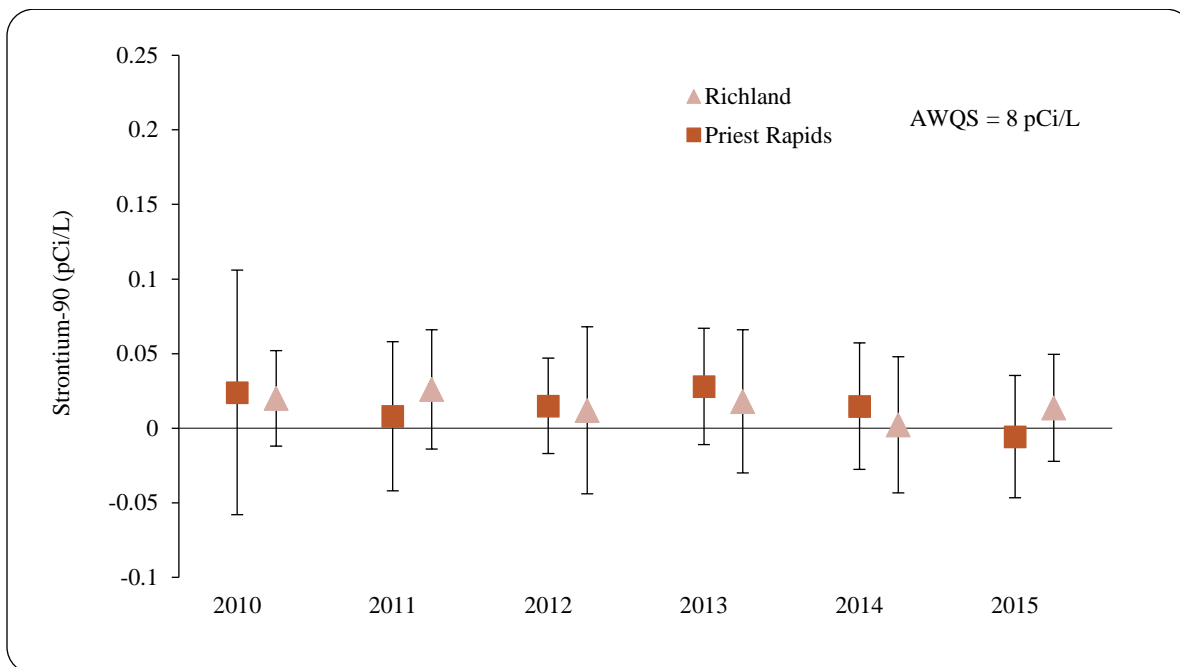


Figure 7.6. Strontium-90 Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site

±2 standard deviations, AWQS = ambient water quality standard

Annual average uranium-234 and uranium-238 concentrations measured in water samples collected upstream and downstream of the Hanford Site in 2015 were similar to those observed during recent years (Figure 7.7). Average monthly uranium concentrations measured at Priest Rapids Dam (0.47 pCi/L total uranium) in 2015 were slightly lower than those averages measured at the City of Richland (0.52 pCi/L total uranium). Uranium is present in the groundwater beneath the 300 Area as a result of past Hanford Site operations, and it has previously been detected at elevated levels in shoreline springs at the 300 Area (Section 7.4; [PNNL-13692](#) and [PNNL-16805](#)). There is no Washington State ambient surface-water quality criterion directly applicable to uranium; however, total uranium levels in the river during 2015 were well below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]; Appendix D).

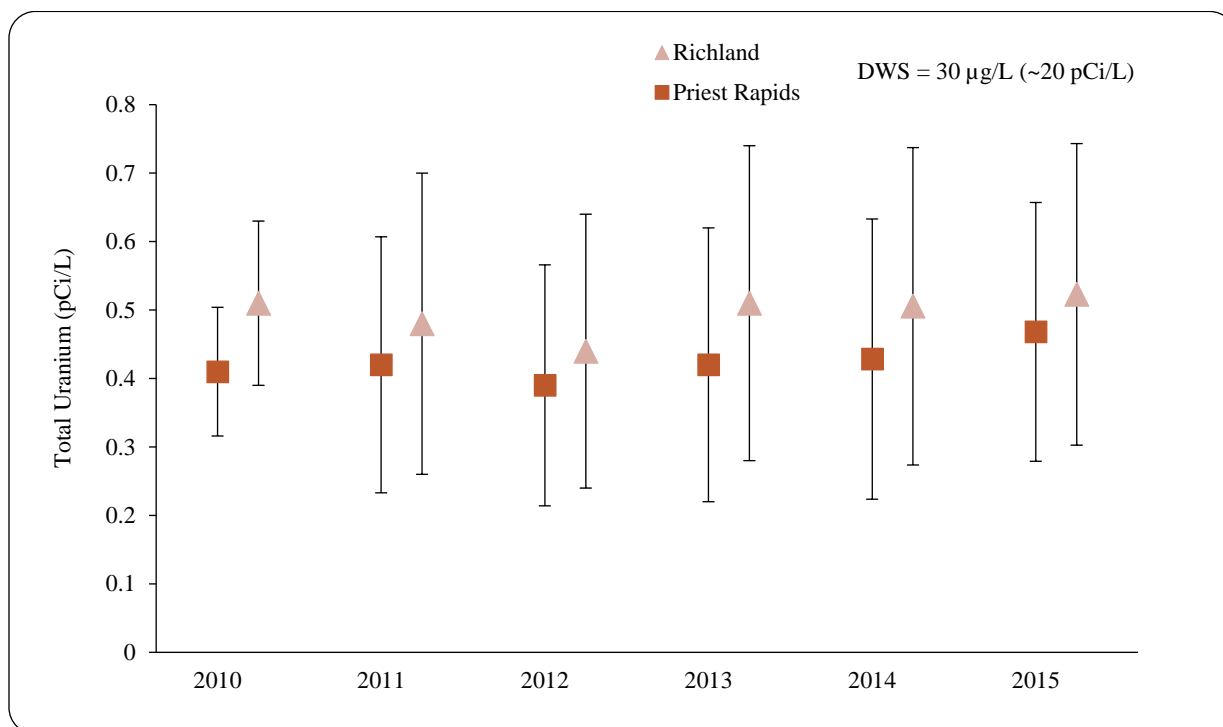


Figure 7.7. Uranium Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site

(±2 standard deviations; DWS = drinking water standard)

Plutonium-238 and plutonium-239/-240 concentrations for river water samples at the City of Richland in 2015 were reported as undetected by the analytical laboratory. All concentrations and detection limits were well below the DOE-derived concentration guide of 30 pCi/L (1.1 Bq/L). No Washington State ambient surface-water quality criterion exists for plutonium-239/-240. Plutonium concentrations at Priest Rapids Dam were not statistically compared with the City of Richland because upstream and downstream concentrations were less than the required minimum detectable concentrations. However, the Priest Rapids Dam data did have a single plutonium-238 detection of 0.0005 pCi/L (0.000019 Bq/L) and a single plutonium-239/-240 detection of 0.0002 pCi/L (0.0000074 Bq/L).

Columbia River Transect Samples. Radiological results from samples collected along Columbia River transects near Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the City of Richland are presented in Appendix C, Table C.8. Sampling locations were documented using a hand-held or vessel-mounted GPS. Station1 at each transect is located along the Benton County shoreline, while the highest

station number for each transect is along the Grant-Franklin County shoreline. Radionuclides consistently measured at concentrations greater than minimum detectable activity included tritium, uranium-234, and uranium-238. Uranium-235 was detected occasionally, and most levels were near minimum detectable concentrations. All measured concentrations of these radionuclides were less than applicable Washington State ambient surface-water quality criteria and EPA drinking water standards.

Tritium concentrations measured along Columbia River transects at Vernita Bridge, 100-N Area, Hanford Townsite, 300 Area, and the City of Richland during 2015 are depicted in Figure 7.8. The Vernita Bridge transect is the most upstream location. The 100-N Area, Hanford Townsite, 300 Area, and City of Richland transects have higher tritium concentrations near the Hanford Site shore (Benton County) when comparing levels to the opposite shoreline. The presence of a tritium concentration gradient in the Columbia River at the City of 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 merged within the river water at the City of Richland. The gradient is most pronounced during periods of relatively low river flow. Historically, the average tritium concentration measured along the City of Richland transect has been less than that measured in monthly composited samples from the fixed-location monitoring station in the City of Richland, illustrating the conservative bias (i.e., highest estimate) of the fixed-location monitoring station. However, 2015 was somewhat of an anomaly, as the transect results had a maximum of 24.9 ± 6.67 pCi/L (0.92 ± 0.25 Bq/L) and the fixed monitoring station had a maximum result of 37.1 ± 14.1 pCi/L (1.37 ± 0.52 Bq/L). The highest tritium concentration measured in cross-river transect water was 79.5 ± 12.3 pCi/L (2.94 ± 0.46 Bq/L) at the Hanford Townsite.

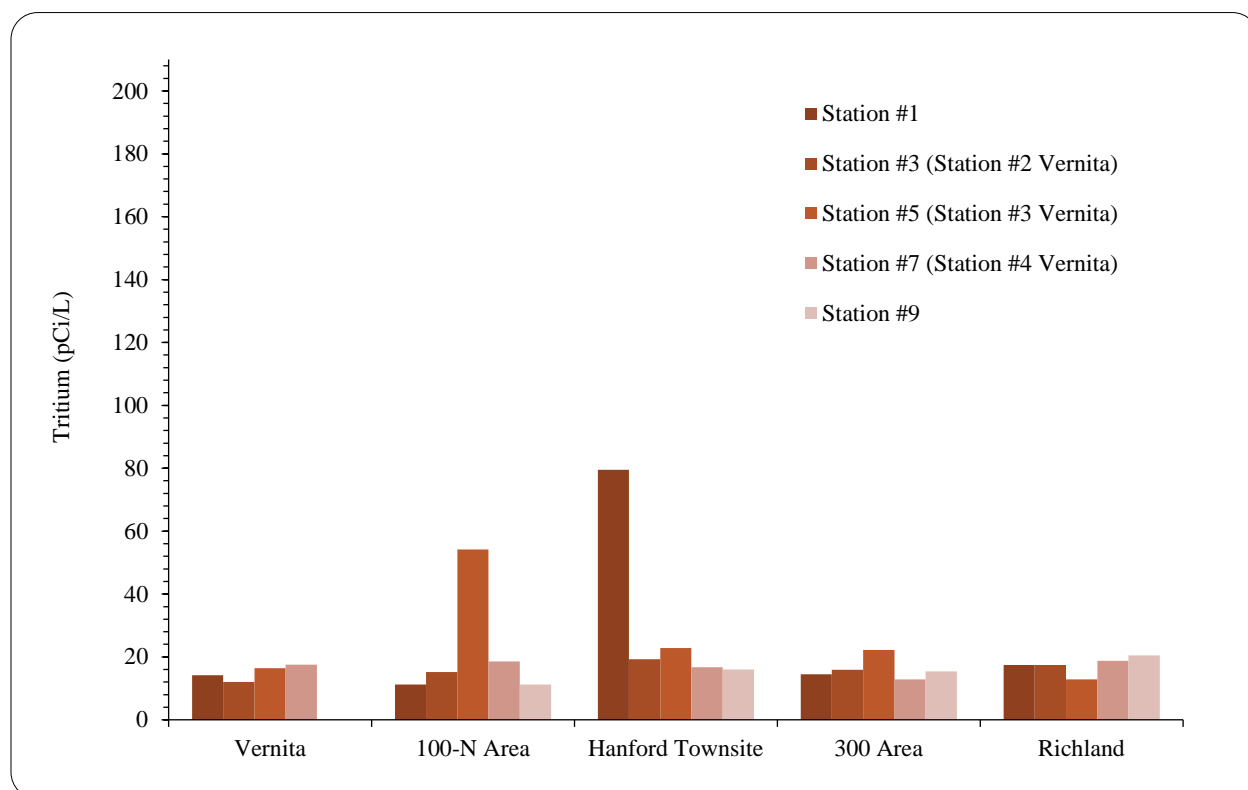


Figure 7.8. Tritium Concentrations in Cross-River Transect Water Samples (Hanford Reach, Columbia River)

Strontium-90 concentrations in Hanford Reach river water for transect samples collected in 2015 were similar to upstream reference concentrations for most locations. The maximum strontium-90 concentration was 0.045 ± 0.036 pCi/L (0.0017 ± 0.0013 Bq/L) from a sample collected along the Vernita Bridge transect. The average strontium-90 concentrations found during sampling at the City of Richland transect were less than those measured in monthly composite samples at the Richland Pumphouse and at Priest Rapids Dam.

Uranium concentrations in all transect samples collected during 2015 were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]). The uranium-234 concentration was highest in the water sample collected near the Franklin County shoreline (300 Area-9 HRM 43.1), which measured 0.45 µg/L (0.30 pCi/L). The maximum uranium-238 concentration was reported along the City of Richland shoreline (Richland Pumphouse-1 HRM 46.4), which measured 0.36 µg/L (0.24 pCi/L).

Uranium isotopes measured in the 300 Area riverbank seep water samples were higher than those reported at the 300 Area-9 HRM 43.1 and other transect location concentrations and are associated with its presence in groundwater as elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area in the vicinity of former uranium fuel fabrication facilities and inactive waste sites.

Average strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2015 were similar to those reported in previous years (Figure 7.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Area. Some of the highest strontium-90 levels found in Hanford Site groundwater are the result of past discharges to the 100-N Area liquid waste disposal facilities. Although strontium-90 concentrations at Priest Rapids Dam and the City of Richland were below minimum detection limits (0.06 pCi/L), low levels were still statistically compared to show differences. Priest Rapids Dam had a maximum concentration of 0.033 pCi/L (0.0012 Bq/L) and the City of Richland intake had a maximum concentration of 0.034 pCi/L (0.0013 Bq/L), respectively. Average strontium-90 concentrations in Columbia River water at the City of Richland and Priest Rapids were less than the Washington State ambient surface-water quality criterion (8 pCi/L [0.30 Bq/L]).

7.2.3 Inorganic and Organic Chemical Results

Inorganic and organic water quality data were compiled in 2015 for the Columbia River. A number of the parameters measured have no regulatory limits but are useful 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; and industrial, agricultural, and mining effluent introduced upstream of the Hanford Site.

Metal and anion concentrations observed in river water were similar to those previously observed and remain below regulatory limits. Metals and anions were detected in Columbia River transect samples both upstream and downstream of the Hanford Site. Aluminum, copper, magnesium, sodium, uranium, and zinc were detected in most samples. All dissolved metal 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.9).

Washington State ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent ([WAC 173-201A](#)). 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 66 mg/L as calcium carbonate, the lowest value based on U.S. Geological Survey monitoring of Columbia River water near Vernita Bridge ([USGS 2007](#)) and the City of Richland in recent years.

For samples collected on the cross-river transects, there were no reportable detections of nitrites. Concentrations of nitrate and sulfate were slightly elevated near the 300 Area compared to other transect locations (Figure 7.9). In many cases, the highest anion concentrations were found in samples collected along the Grant-Franklin County shoreline. These elevated results likely resulted from groundwater seepage associated with extensive irrigation north and east of the Columbia River. Nitrate contamination of some Franklin County groundwater has been documented by *Nitrate Concentrations in Ground Water of the Central Columbia Plateau* ([USGS 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](#); *Water Quality in the Central Columbia Plateau, Washington and Idaho, 1992-95* [[USGS 1998](#)]). Average annual concentrations of chloride were similar at the City of Richland transect when compared with Vernita Bridge transect results. The highest concentrations of nitrates were measured at the Richland Pumphouse-9 HRM 46.4 transect; however, the 100-N, 300 Area, Hanford Townsite, and Vernita Bridge transects also had detections of nitrate in 2015. Additional anion analysis of fluoride in Columbia River transect collections resulted in reportable concentrations (>33 µg/L) of fluoride in all samples; however, these results were less than required detection limits (500 µg/L) per DOE guidelines. When compared to concentrations since 2010, the overall average has dropped from 109 µg/L to 77 µg/L in 2015 transect samples.

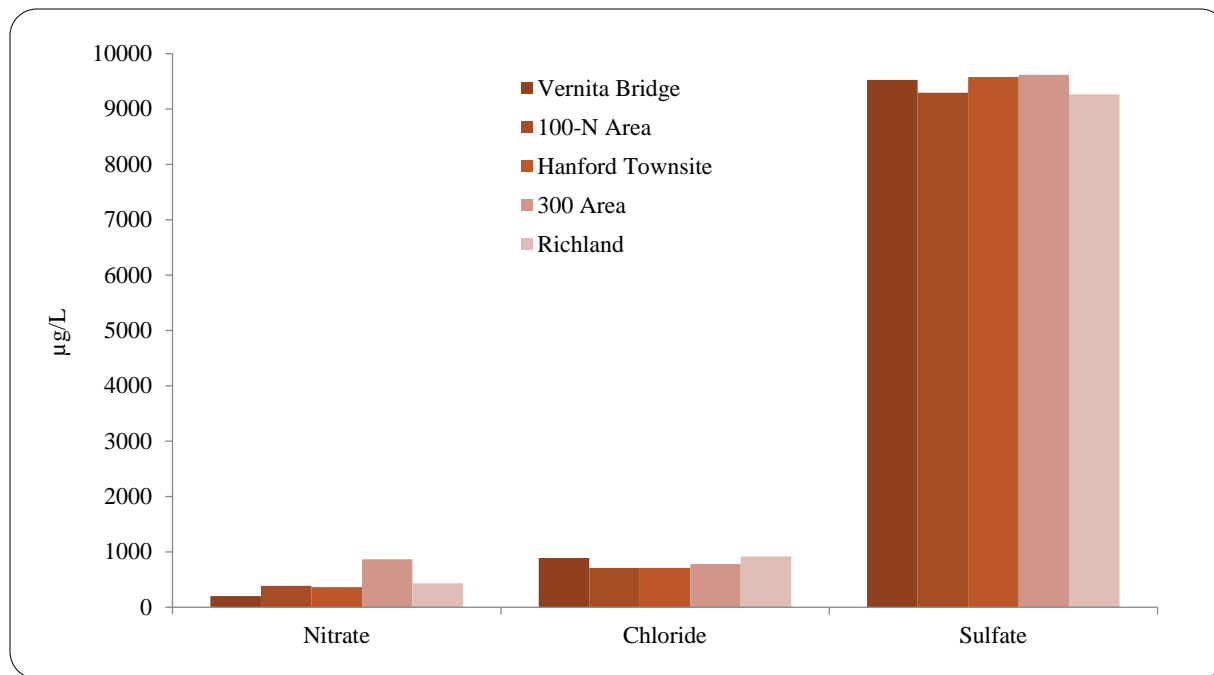


Figure 7.9. Selected Anion Concentrations in Columbia River Transect Samples

Concentrations of chromium (reported in Appendix C) in the Hanford Reach are of interest because groundwater contaminated with chromium above the ambient water quality criterion intersects the Columbia River at several Hanford Site locations. All river transect filtered water samples for 2014 had chromium concentrations below the minimum detectable concentration.

7.3 Columbia River Sediment

ME Hoefler

During peak operating years at the Hanford Site, large amounts of effluents associated with reactor operations were discharged to the Columbia River. Some constituents in these effluents may have become associated with particulate matter that accumulated in riverbed sediment, particularly in slack-water areas and in reservoirs behind the dams located downstream of the Hanford Site. The majority of short-lived radioactive constituents have decayed, but some longer-lived radionuclides such as isotopes of cesium, plutonium, strontium, and uranium are still detectable. Fluctuations in the river flow from upriver hydroelectric dam operations, annual spring high river flows, and occasional floods have resulted in re-suspension, relocation, and subsequent re-deposition of sediment. Upper-layer sediment in the Columbia River downstream of the Hanford Site contains low concentrations of radionuclides, metals of Hanford Site origin, and radionuclides from worldwide atmospheric fallout, as well as metals and other nonradioactive contaminants from mining and agricultural activities ([PNNL-13417](#), *Simultaneously Extracted Metals/Acid-Volatile Sulfide and Total Metals in Surface Sediment from the Hanford Reach of the Columbia River and the Lower Snake River* and [PNNL-16990](#), *Summary of Radiological Monitoring of Columbia and Snake River Sediment, 1988 Through 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 from ingestion of aquatic organisms associated with sediment or re-suspension into drinking water supplies. Sediment with accumulated radioactive materials can be an external radiation source, irradiating people fishing, wading, swimming, sunbathing, or participating in other recreational activities associated with the river or shoreline ([DOE/EH-0173T](#)). Sediment contaminant concentrations are also used to model potential pathway exposures to riparian (e.g., raccoon, coyote) and aquatic receptors (e.g., fish, benthic organisms) and to establish DOE guidelines for organisms within the Hanford Reach.

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 and the effect of grain size and organic content in measured contaminant concentrations ([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 the reservoir behind Priest Rapids Dam upstream of the site, the Hanford and White Bluffs Slough on the Hanford Reach, and downstream of the site in the reservoir pool located above McNary Dam.

7.3.1 Monitoring

Samples of the surface layer of Columbia River sediment were collected at depths of 0 to 6.3 in. (0 to 16 cm) from 10 river locations that were predominantly submerged (some Hanford Reach sampling locations may not be submerged during an extremely low-river stage). Sampling locations were documented using a vessel or handheld GPS. Surface sediment was collected using a clamshell-style sediment dredge sampler (Petite Ponar), capturing several years of integrated deposits, including various sediment grains. Estimated average sediment deposition rates of 0.28 in. (0.723 cm)/yr for Priest Rapids Dam and 0.89 in. (2.25 cm)/yr for McNary Dam (*An Investigation of the Origin of ^{152}Eu in Columbia River Sediments* [Gibbons 2000]). Assuming a maximum sediment sampling depth of 6.3 in. (16 cm) with the Ponar dredge, samples may integrate up to approximately 22 years at Priest Rapids Dam and 7 years at McNary Dam. Sediment

deposition rates have not been estimated for slough areas along the Hanford Reach. 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 those found above Priest Rapids Dam do not necessarily reflect a Hanford Site source. The confluences of the Columbia 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 nuclear fallout may also contribute to the contaminant load found in McNary Dam sediment. Sediment samples were also collected at 100-D Spring 102-1, 100-F Slough, Hanford Slough, White Bluffs Slough, and locations adjacent to Locke and Savage islands located along the Hanford Reach of the Columbia River from slack-water areas where fine-grained material is known to deposit.

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. One location was sampled at 100-D Spring (seep) 102-1 and an additional from 100-F Slough. The White Bluffs Slough monitoring site consisted of two sampling locations in previous years; however, only one sampling location was sampled successfully in 2015 due to rock and aquatic vegetation inclusions in the collection process during both the 2013 and 2014 attempts. One sample was collected at a location in Hanford Slough and two additional samples from locations adjacent to the islands.

7.3.2 Radiological Results

All sediment samples were analyzed for gamma-emitting radionuclides, anions, hexavalent chromium, strontium-90, uranium-234, uranium-235, plutonium-238, uranium-238, plutonium-239/-240, metals, mercury, and total organic carbon ([DOE/RL-91-50](#)). The specific analytes selected for sediment samples were based on findings of previous Columbia River sediment investigations, reviews of past effluent contaminants discharged from site facilities, and reviews of contaminant concentrations observed in Hanford Site groundwater monitoring wells near the Columbia River. No federal or state freshwater sediment criteria are available to assess the sediment quality of the Columbia River. Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2015 included cesium-137, uranium-234, uranium-235, uranium-238, plutonium-239/-240, and decay products from naturally occurring radionuclides. The concentrations of all other radionuclides, including strontium-90, were below the required minimum detectable concentrations for most samples.

Cesium-137 and plutonium isotopes exist in worldwide fallout as well as in effluent from past Hanford Site operations. Uranium isotopes occur naturally in the environment and have been present in past releases of Hanford Site effluent. Analytical results for 2015 showed similar concentrations of cesium-137 at Priest Rapids and McNary dams sediment collection locations. These concentrations were slightly elevated when compared to Hanford Reach sediment collection location results (Figure 7.10). Plutonium-239/-240 sediment results mirrored cesium-137 data as Priest Rapids and McNary dam locations had higher concentrations reported than sediment results along the Hanford Reach (Figure 7.11). Note that for both Figures 7.10 and 7.11, the upper and lower bars represent maximum and minimum values, which may be similar to the average and may not be visible.

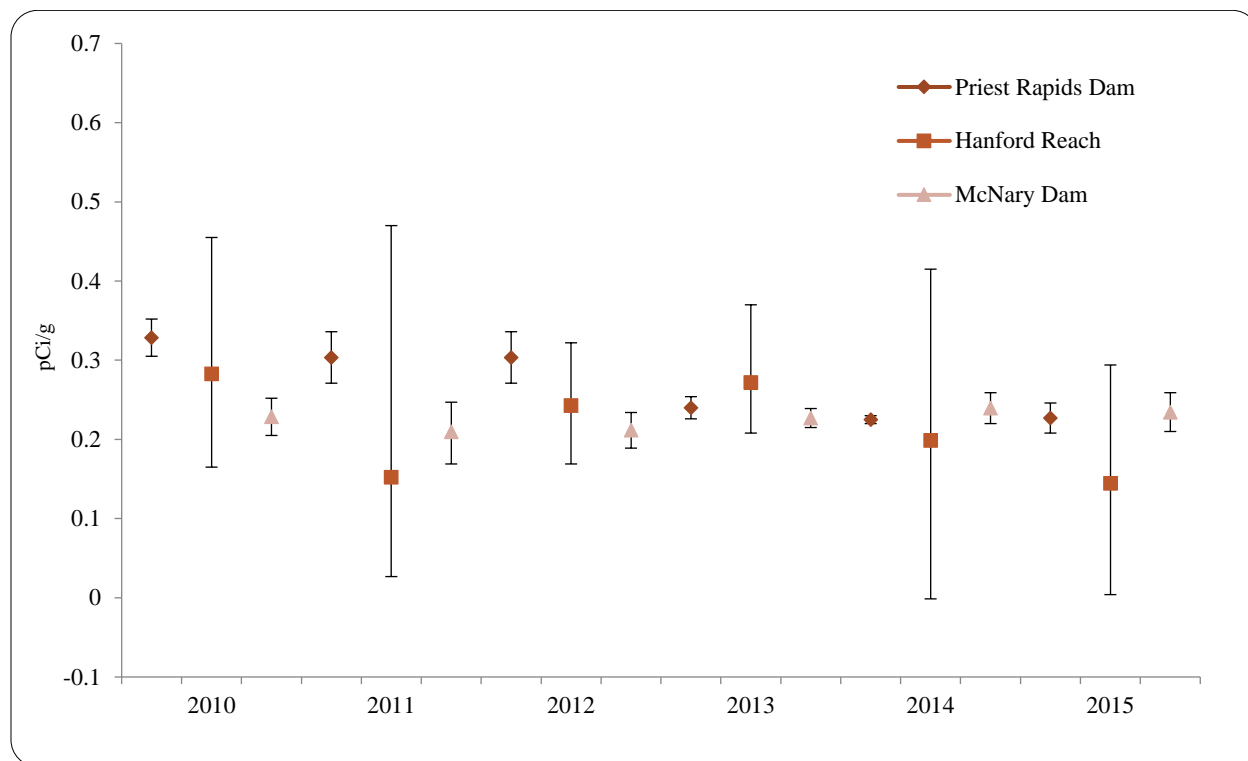


Figure 7.10. Cesium-137 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment

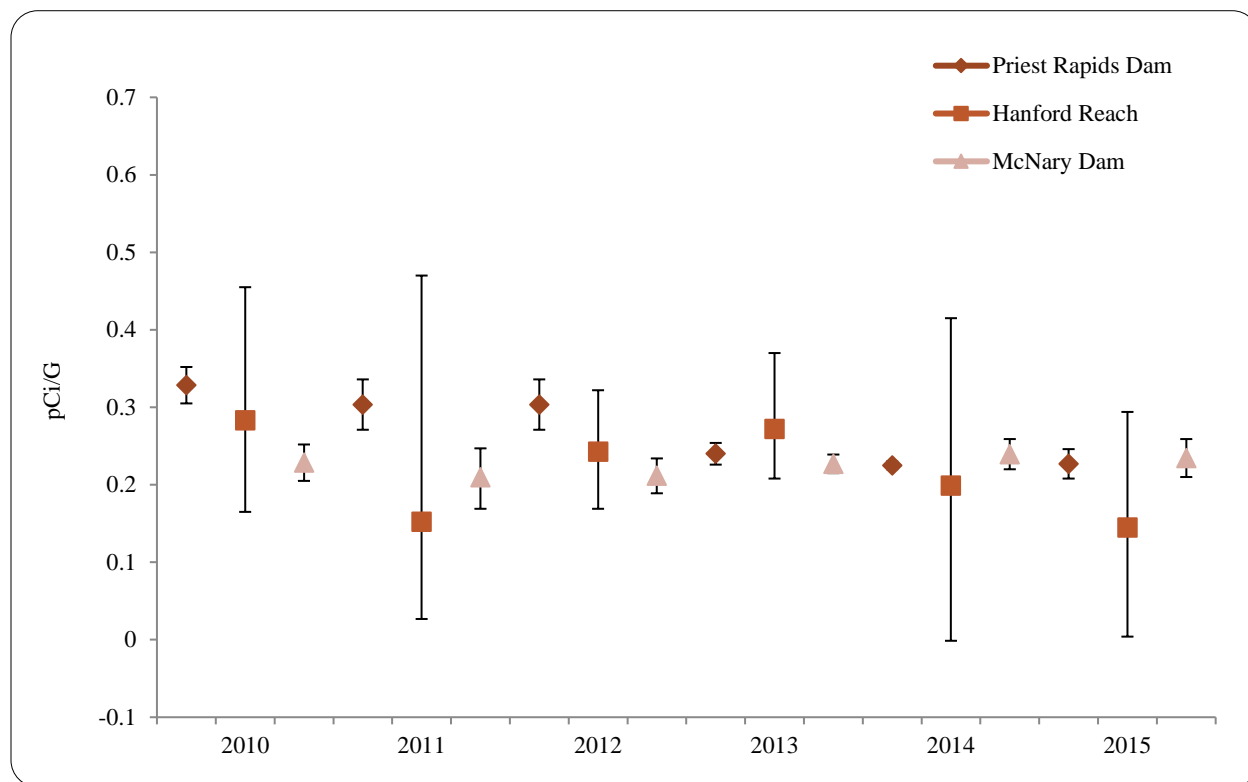


Figure 7.11. Plutonium-239/-240 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment

Uranium-234 concentrations were slightly elevated in the Hanford Reach sediment location adjacent to Locke Island when compared to other sediment collected from the Hanford Reach, McNary Dam, and Priest Rapids Dam samples in 2015. Other radionuclide concentrations in river sediment were similar to those reported for previous years, and there were no obvious differences between locations.

Priest Rapids and McNary dams sediment also had elevated total uranium results compared to Hanford Reach locations in 2015. Hanford Reach averaged 1.7 pCi/g, while Priest Rapids and McNary dams concentrations averaged 2.5 pCi/g and 2.6 pCi/g, respectively (Figure 7.12; note that upper and lower bars represent maximum and minimum values, which may be similar to the average and may not be visible).

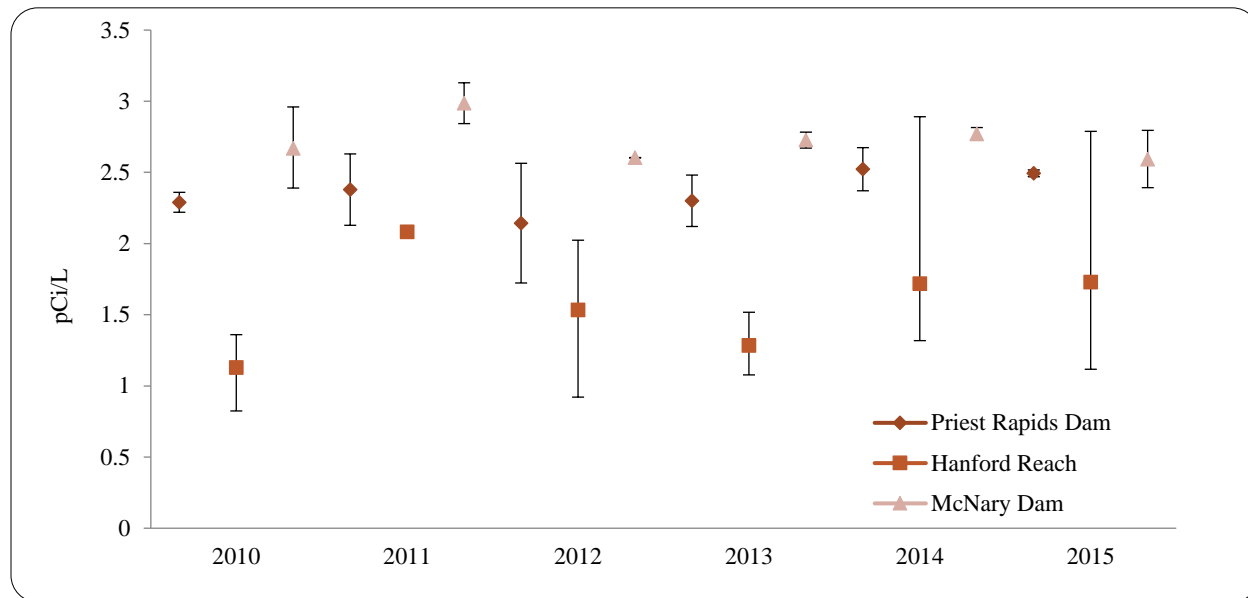


Figure 7.12. Uranium Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment

The values for cesium-137 in the White Bluffs Slough location of the Hanford Reach were slightly elevated compared to other Hanford Reach sample locations, Priest Rapids and McNary dams and all other sediment collection locations. Previous studies of sediment from the White Bluffs Slough detected elevated concentrations of cesium-137. The average, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (2010 to 2015) are presented in Figures 7.10, 7.11, and 7.12.

7.3.3 Chemical Results

Detectable amounts of most metals were found in all river sediment samples (Figure 7.13; note that upper and lower bars represent maximum and minimum values, which may be similar to the average and may not be visible). Maximum and average concentrations of cadmium, chromium, copper, lead, mercury, nickel, thallium, and zinc were higher for sediment collected in the reservoir upstream of Priest Rapids Dam than in sediment from either the Hanford Reach or McNary Dam. Lead concentrations were detected at higher rates in White Bluffs sediment in comparison to all other sediment collection locations. Variations in stream hydraulics and associated sediment depositional zones for differing locations were likely attributable to increased concentrations in areas such as White Bluffs. Currently, there are no Washington State freshwater sediment quality criteria to compare with the measured values.

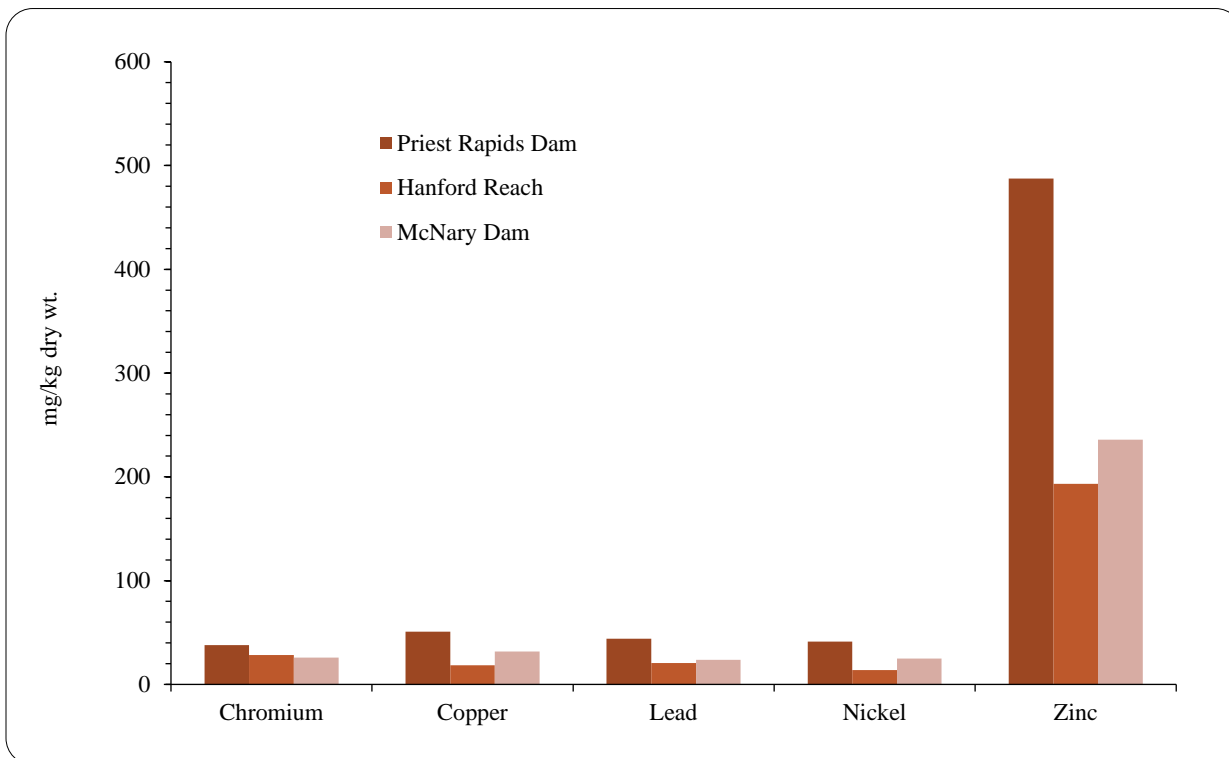
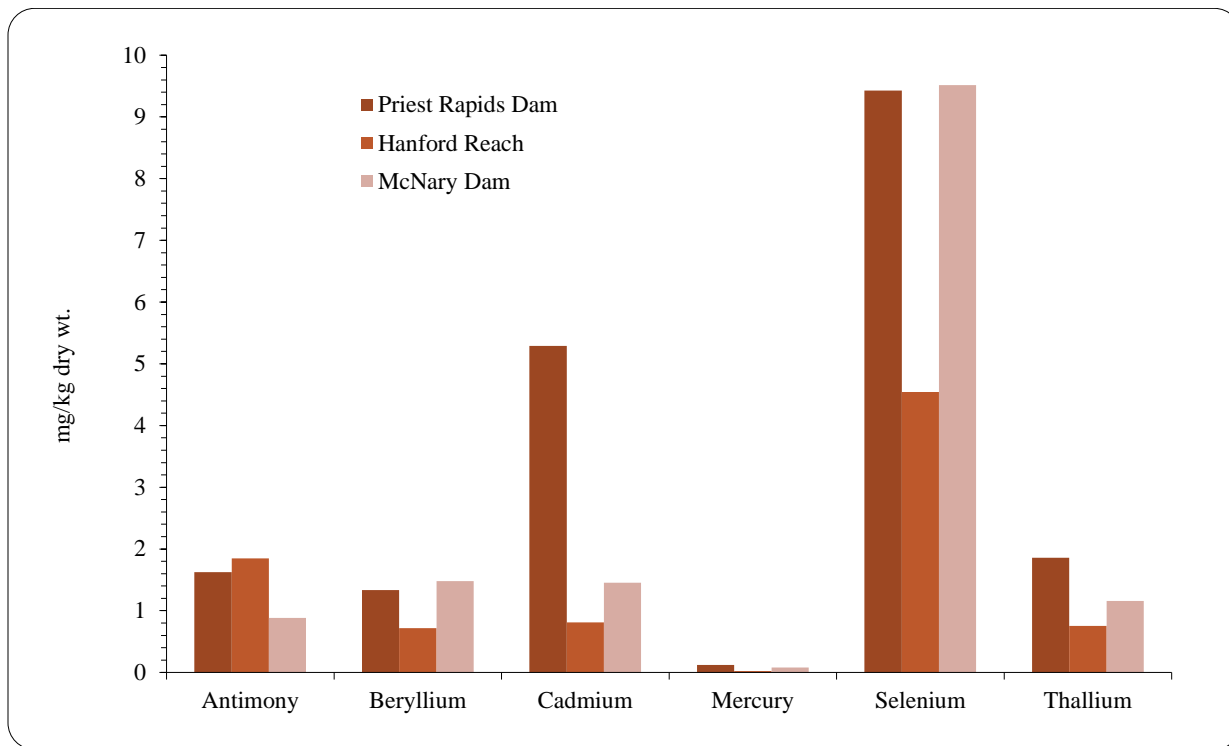


Figure 7.13. Selected Metals Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (WA and OR)

7.4 Columbia River Seep Water

ME Hoefler

In 2015, 12 of 15 targeted samples of Columbia River seep water and two associated shoreline sediment samples were collected along the Hanford Reach (Figure 7.3) and analyzed to determine the potential impact of radiological, inorganic, and organic contaminants from the Hanford Site on the public and the aquatic environment. Various radiological analyses were performed on selected seeps following reviews of existing surface-water and groundwater data, multiple RI/FS work plans, and preliminary Hanford Site risk assessments ([DOE/RL-92-67](#); [WCH-380](#)). Specific analyses performed on samples collected from each location are listed in Table 7.6 and Appendix C.

Table 7.6. Columbia River Seep Monitoring

Location*	Sample Type	Sampling Frequency	Analyses
100B Area	Grab	Annually	Anions, metals (filtered and unfiltered), strontium-90, tritium
100D Area	Grab	Annually	Alpha, anions, beta, metals (filtered and unfiltered), strontium-90, technitium-99, tritium, isotopic uranium [†]
100F Area	Grab	Annually	Anions, metals (filtered and unfiltered), strontium-90, tritium
100H Area	Grab	Annually	Alpha, anions, beta, metals (filtered and unfiltered), strontium-90, technitium-99, tritium
100K Area	Grab	Annually	Alpha, anions, beta, carbon-14, metals (filtered and unfiltered), strontium-90, technitium-99, tritium, VOA [‡]
100N Area	Grab	Annually	Alpha, anions, beta, metals (filtered and unfiltered), strontium-90, TPH, tritium
300 Area	Grab	Annually	Alpha, anions, beta, tritium, isotopic uranium [†] , VOA [‡]
Hanford Townsite	Grab	Annually	Alpha, anions, beta, iodine-129, metals (filtered and unfiltered), strontium-90, technitium-99, tritium, VOA [‡]
*Refer to Figure 7.3; Locations may contain multiple shoreline seeps with differing analyses.			
[†] Uranium-234, uranium-235, and uranium-238 analyzed by alpha spectrometry (alpha energy analysis)			
[‡] VOA=Volatile organic analyses			

7.4.1 Seep Water Monitoring

Columbia River seeps were documented along the Hanford Reach long before Hanford Site operations began during World War II ([Jenkins 1922](#)). 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 (via leaching) from past waste disposal practices to the Columbia River ([DOE/RL-92-12](#); [PNL-5289](#); [PNL-7500](#); [WHC-SD-EN-TI-006](#)). Contaminated groundwater enters the Columbia River through surface and subsurface discharge. Discharge zones, located above the water level of the river, are identified in this report as Columbia River seeps. Routine monitoring of riverbank seeps offers the opportunity to characterize the quality of groundwater being discharged to the river and assess the potential human and ecological risk associated with the seep water. In addition, contaminants in groundwater near the Columbia River are monitored using shoreline groundwater-sampling tubes (aquifer tubes Section 7.5; [BHI-01153](#); [PNNL-14444](#); [PNNL-16805](#); [PNNL-16894](#); [SGW-41497](#)).

During the early 1980s, researchers walked a 41-mi (66-km) stretch of the Benton County shoreline of the Hanford Reach and identified 115 seeps ([PNL-5289](#)). These researchers reported that the predominant areas of riverbank seeps at that time were near the 100-N Area, Hanford Townsite, and the 300 Area.

In recent years, it has become increasingly difficult to locate riverbank seeps in the 100-N Area and other locations along the Hanford Reach. A consequence of the end of 100-N Reactor operations and other ongoing site remediation, declining water table elevations have reduced discharges from the seeps in and around the 100-N Area. Columbia River seeps also vary with river stage (river-water surface elevation). The water table near the Hanford Reach is strongly influenced by river-stage fluctuations. The river stage in the Hanford Reach is controlled by upriver conditions and operations at upriver dams. As river levels fluctuate, groundwater levels change, which cause the presence of seeps in the Hanford Reach to vary. At the 300 Area, the river stage is also influenced by the elevation of the McNary Dam pool.

Columbia 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 riverbank seeps as the river stage falls. Following an extended period of low river flow, groundwater discharge zones above the water level of the river may cease to exist when the level of the aquifer comes into equilibrium with the river level. Thus, seeps are most readily identified immediately following a decline in river stage.

Bank storage of river water affects the contaminant concentration of the seeps. Columbia River seep 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 a seep water discharge increases over time following a drop in the river stage. Measuring conductivity of the seep water discharge provides an indicator of the extent of bank storage. Hanford Site groundwater has higher conductivity readings than Columbia River water. The conductivity of river water typically ranges between approximately 130 and 150 microsiemens (μS)/cm.

The effect of bank storage on groundwater discharges and contaminant concentration variations in aquifer thickness, porosity, and plume concentrations make it difficult to estimate accurately the proportion of contaminated groundwater discharging via seeps to the Columbia River within the Hanford Reach. Studies of riverbank seeps conducted during 1983 ([PNL-5289](#)); 1988 ([PNL-7500](#)); and 1991 ([DOE/RL-92-12](#); [WHC-EP-0609](#)); and results of near-shore studies in 1997 ([PNNL-11933](#)) and 2001 ([PNNL-13692](#)) noted that discharges from the seeps had localized effects on Columbia River contaminant concentrations only. Beginning in 2011, river-stage specified local quality control guidelines were administered for the seep monitoring efforts following the process and findings described in [WCH-380](#). These guidelines help precision and accuracy of the seep monitoring efforts by reducing variability across space and time associated with fluctuating river stages and the influence of bank storage.

7.4.2 Monitoring Results

Routine monitoring of selected Columbia River seeps was initiated in 1988. Currently, seep water samples are collected for contaminant monitoring, and dose calculations and contaminant trends ([DOE/RL-91-50](#)). Table 7.6 summarizes the sampling locations and frequencies as well as sample types and analyses included in Columbia River seep monitoring during 2015. This section describes the monitoring efforts and summarizes results for these aquatic environments. Analytes of interest for samples from seeps were selected based on the findings of previous investigations, reviews of contaminant concentrations observed in nearby groundwater monitoring wells, contaminant plume locations and movements throughout the Hanford site, and results of preliminary risk assessments. Sampling is conducted annually when river flows are low, typically in late summer to early fall to help minimize the effect of bank storage.

All samples collected were analyzed for tritium. Water samples from selected seeps were analyzed for anions, carbon-14, metals, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, and volatile organic compounds. Only unfiltered samples were analyzed, except for metals analyses, in which case both filtered and unfiltered samples were analyzed (Table 7.6).

7.4.2.1 Radiological Results

Contaminants of Hanford Site origin continued to be detected in 2015 in water from riverbank seeps entering the Columbia River along the Hanford Site. Gross alpha, gross beta, carbon-14, strontium-90, tritium, and total uranium (uranium-234, uranium-235, and uranium-238) were detected in seep water samples. Carbon-14 levels measured in a 100-K Area riverbank seep decreased (maximum concentration measured 341 pCi/L) in comparison to those previously measured. In fall 2014, carbon-14 results exceeded DOE biota concentrations with approximately 2,200 pCi/L (609 pCi/L established RESRAD riparian guideline). As a result, conditions were monitored throughout CY 2015. Seep collections and surface water collections were collected quarterly as a result, and carbon-14 levels have shown an exponential decrease since fall 2014. A shoreline sediment sample was also collected in the 100-K area in 2015 as a result of those concentrations seen in fall 2014.

Gross alpha results for the 300 Area DR 42-2 riverbank seep had two detections ($48 \text{ pCi/L} \pm 7.2 \text{ pCi/L}$ and $37 \text{ pCi/L} \pm 6.4 \text{ pCi/L}$) that exceeded both DOE-derived standards (30 pCi/L) and the Washington State ambient water quality criteria (15 pCi/L; [DOE O 458.1](#)).

Gross beta detections occurred in 100-K, 100-D, 100-N, Hanford Spring 28-2, and 300 Area seeps during 2015. Detectable concentrations in riverbank seep water at those locations were elevated compared to maximum gross beta concentrations in irrigation water collected from the Horn Rapids Battelle Sporting Complex and Riverview collection locations. The highest gross beta concentration was measured in the 300 Area DR 42-2 riverbank seep ($30 \pm 4.3 \text{ pCi/L}$ [$1.1 \pm 0.16 \text{ Bq/L}$]), which was 60% of the Washington State ambient surface water quality criterion of 50 pCi/L (1.85 Bq/L ; [WAC 173-201A](#) and [40 CFR 141](#)).

Tritium concentrations varied widely with location. The highest tritium concentration measured in riverbank seeps was at the 100-N Spring 8-13 location ($5,840 \pm 1,160 \text{ pCi/L}$ [$216 \pm 43 \text{ Bq/L}$]), which was less than the Washington State ambient surface water quality criterion of 20,000 pCi/L (740 Bq/L) ([WAC 173-201A](#); [40 CFR 141](#)). No 2015 tritium results exceeded DOE-derived standards for riparian life (265,000,000 pCi/L). Tritium concentrations in riverbank seep water samples were higher when compared to maximum concentrations in 2015 Columbia River fixed-station locations at Priest Rapids Dam and the City of Richland and Columbia River transect station locations. Overall, results in 2015 were comparable to the previous 5 years of concentrations reported in riverbank seeps.

All water samples from riverbank seeps were analyzed for strontium-90, the highest concentration of which was detected in shoreline spring water was in the 100-N Area ($17 \pm 3 \text{ pCi/L}$ [$0.63 \pm 0.11 \text{ Bq/L}$]), approximately 1% of the DOE-Derived Concentration Guide ([DOE O 458.1](#)) of 1,000 pCi/L (37 Bq/L). Historically, groundwater in the 100-N Area has had the highest strontium-90 levels measured at Hanford. The 2015 seep water result at 100-N was slightly higher than the 2014 reported concentration and was within the typical range for this area.

A water sample from a riverbank seep in the Hanford Townsite area was collected in 2015 and submitted to a laboratory for iodine-129 analysis using an ultra-trace method. The water sampled during 2015 from the Hanford Townsite riverbank seep was a non-detect for iodine-129. The Washington State surface water quality criterion for I-129 is 1 pCi/L (0.037 Bq/L; Appendix D), and the DOE-biota concentration guide standards for aquatic and riparian life are 1,000,000 pCi/L and 38,400 pCi/L. From 2007 to 2010, riverbank seep water samples were analyzed with traditional gamma spectrometry, which has a higher detection limit than the ultra-trace method. All samples analyzed for iodine-129 in 2007 to 2010 were below the detection limit of 1 pCi/L (0.037 Bq/L).

Uranium isotopes were monitored in riverbank seep water samples from the 100-D Area and the 300 Area. The highest concentrations of uranium were found in the 300 Area seep water collected at DR 42-2 riverbank seep. This location is down gradient from the retired 300 Area process trenches. The uranium concentrations in this seep water sample were slightly higher ($30 \text{ pCi/L} \pm 5.1 \text{ pCi/L}$ uranium-234) than the EPA DWS limit of $30 \text{ }\mu\text{g/L}$ (approximately 20 pCi/L [0.74 Bq/L]). Maximum and average concentrations of uranium-234, uranium-235, and uranium-238 were slightly lower in 2015 than they were during 2010 to 2014. Elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area near former uranium fuel fabrication facilities and inactive waste sites.

7.4.2.2 Chemical Results

Inorganic and organic contaminants originating from the Hanford Site continued to be detected in water from riverbank seeps entering the Columbia River. Metals and anions of interest (chloride, nitrate, and sulfate) were detected in seep water. Concentrations of volatile organic compounds were near or below the analytical laboratory's required detection limits in all samples.

Appendix C, Table C.14 presents concentration ranges of selected metals and anions measured in riverbank seep water during 2010 through 2015. For most locations, the 2015 sample results were similar to those previously reported ([PNNL-19455](#)). Nitrate concentrations for 2015 were highest in seep water samples from the 100-F Area. Dissolved chromium concentrations in riverbank seeps for 2015 were also highest in the 100-F Area. Hanford Site groundwater monitoring results associated with aquifer tube collections in 2015 indicated concentrations at shoreline areas near 100-N area seeps were greatest for the following contaminants: gross beta, nitrates, strontium-90, and tritium while the 300 Area had the highest uranium results (see Section 8).

The Washington State ambient surface water quality criteria for copper, lead, nickel, and zinc are total-hardness dependent ([WAC 173-201A](#); Appendix D). For comparison purposes, the minimum value of 66-mg/L calcium carbonate for 2006 and 2007 USGS-collected water samples near the Vernita Bridge were used. Concentrations of most metals measured in water collected from seeps along the Hanford Site shoreline during 2010 through 2015 were below the Washington State ambient surface water chronic toxicity levels ([WAC 173-201A](#)). However, for 2010 through 2015, the maximum concentrations of dissolved chromium in riverbank seep water from the 100-B, 100-D, 100-F, 100-H, and 100-K Areas were above the Washington State ambient surface water acute toxicity levels ([WAC 173-201A](#)). In 2015, concentrations from the 100-B and 100-F areas were the only samples collected having results above the Washington State ambient surface water chronic toxicity levels. All other dissolved chromium results for 2015 were below the Washington State ambient surface water acute and chronic toxicity levels.

Arsenic concentrations in riverbank seep water were well below the Washington State ambient surface water chronic toxicity level. A sample collected in the 100-N area (9.7 µg/L or 0.0097 mg/L) was just under the EPA limit of 0.01 mg/L for the protection of human health for the consumption of water and organisms. This EPA value is 19,000 times lower than the Washington State chronic toxicity standard ([40 CFR 141](#)). Nitrate concentrations at all riverbank seep locations were below the EPA drinking water standard of 45 mg/L.

7.4.3 Sediment Monitoring

Beginning in the 1990s, periodic studies were conducted to collect and analyze sediment from riverbank seeps in the 100 Areas and 300 Area ([DOE/RL-92-12](#); [WHC-EP-0609](#); [WHC-SD-EN-TI-125](#); [WHC-SD-EN-TI-198](#)). Routine sampling of sediment from riverbank seeps began during 1993 at the Hanford Townsite and the 300 Area. Sampling of riverbank seeps sediment in the 100-B, 100-K, and 100-F Areas began during 1995; and the 100-H Area was added in 2004. However, Hanford Site releases in these areas are best monitored using seep water samples as compared to sediment samples. As such, only two sediment samples were collected from riverbank seep locations in the 100-D and 100-K areas (100-D Spring 102-1 and 100-K 63-1) in 2015 (Table 7.7).

Table 7.7. Columbia River Sediment Monitoring

Location*	Frequency	Analyses
100-D Area	Annually	Anions, Cr+6, gamma energy analysis, isotopic uranium [†] , isotopic plutonium [‡] , metals, mercury, strontium-90, and total organic carbon
100-K Area	Annually	Anions, carbon-14, Cr+6, gamma energy analysis, isotopic uranium [†] , isotopic plutonium [‡] , metals, mercury, strontium-90, and total organic carbon
*Refer to Figure 7.8		
[†] Uranium-234, uranium-235, and uranium-238 analyzed by alpha spectrometry (alpha energy analysis)		
[‡] Plutonium-289 and plutonium-239/-240		

7.4.3.1 Radiological Results

Results for the 2015 shoreline seep sediment samples were similar to those observed in Columbia River sediment. Cesium-137 and uranium isotopes were the only radionuclides reported above the minimum detectable concentrations. Table C.10 in Appendix C compares radionuclide and total organic carbon concentrations in Columbia River sediment near the Hanford Site collected from 2010 through 2015.

7.4.3.2 Metals Results

Concentrations of metals in shoreline seep sediment samples collected in 2015 were similar to concentrations in Columbia River sediment samples with the exception of chromium. Concentrations reported in 2015 for shoreline sediment collected from 100-D Spring 102-1 had levels that were more than twice as much as the next highest recorded concentration measured in Columbia River sediment samples. Appendix C, Table C.11 compares metal concentrations in sediment samples collected in 2015. Currently, there are no Washington State freshwater sediment quality criteria to compare with the measured values.

7.4.3.3 Hexavalent Chromium Results

The 100-D Spring 102-1 area also had the highest levels of hexavalent chromium, as concentrations were more than twice as much as the maximum of all other sediment results. This is likely due to historical energy conversion when sodium dichromate was used in reactors to produce fluoride for the enrichment

of uranium. The 100-D Area has two separate hexavalent chromium plumes that have been recorded, and surrounding soil and water sampling have shown elevated concentrations ([BHL-01747](#)). All hexavalent chromium concentrations are listed in Appendix C, Table C.14.

7.5 Pond Water and Sediment

ME Hoefer

West Lake Pond (Figure 7.3) was sampled quarterly during 2015; however, FFTF trends showed continual decreases in potential contaminants. The area had not received radioactive discharges for some time, so sampling was discontinued (Figure 7.14); only West Lake was sampled in 2015. West Lake is accessible to migratory waterfowl, deer, and other wildlife, creating a potential biological pathway for the dispersion of contaminants. The FFTF Pond is a retired disposal site that collected process water, primarily cooling water drawn from 400 Area groundwater wells. The only naturally occurring pond on the Hanford Site, West Lake 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. The water level in West Lake fluctuates, and the lake changes from standing water in winter and spring to dry or nearly dry in summer and fall. 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.

7.5.1 West Lake Pond Water

Grab samples were collected quarterly from West Lake in 2015. All water samples collected from the West Lake were analyzed for tritium and uranium.

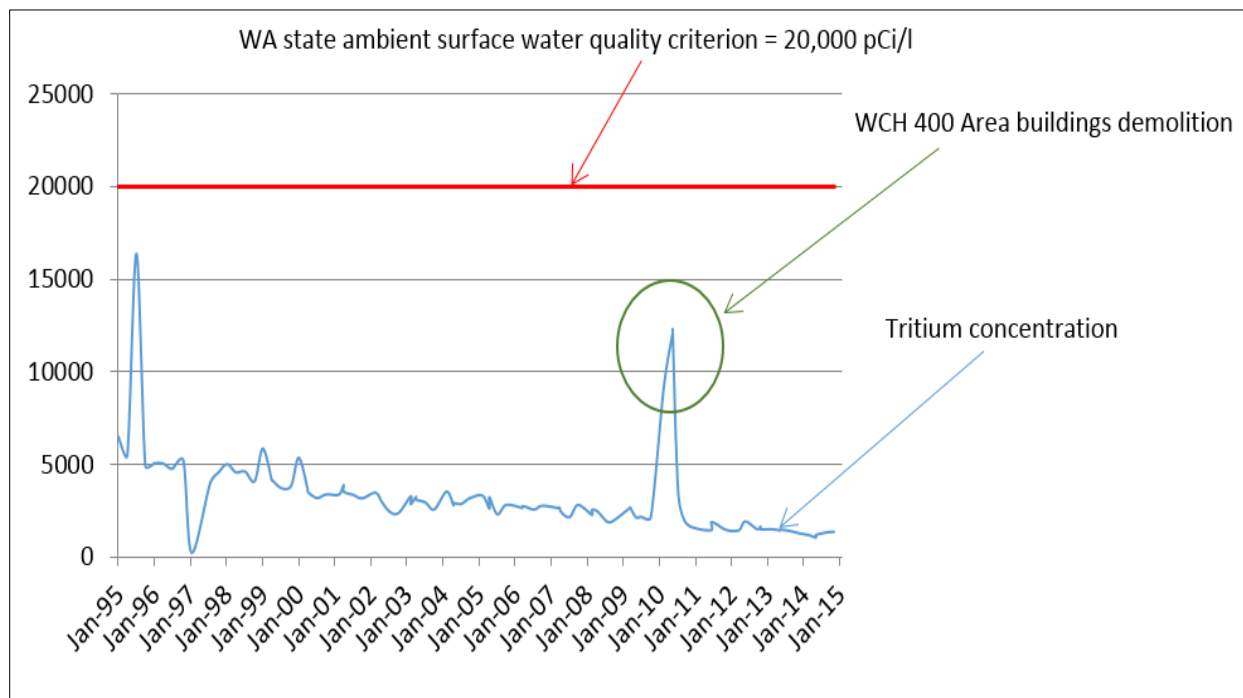


Figure 7.14. Fast Flux Test Facility Pond Water Tritium Concentration

7.5.2 West Lake Water

Water monitoring continued at West Lake in 2015 with sampling conducted quarterly as 2014 results showed uranium results that exceeded the established riparian concentration levels. The groundwater table in the 200-East Area dropped in recent years (Section 8.0), decreasing the size of West Lake and causing the suspended sediment load to increase. West Lake seep and surface water samples collected from 2002 through 2010 were not analyzed for gross alpha, gross beta, strontium-90, technetium-99, uranium-234, uranium-235, or uranium-238 because of the high sediment load. A special year 2000 study ([PNNL-13487](#)) indicated that uranium was present in a soluble form in West Lake water; as a result, analyses of West Lake water for uranium-234, uranium-235, and uranium-238 were resumed in 2011.

During the first quarter of 2015, a grab sample of standing seep water was collected for analysis of uranium-234, uranium-235, and uranium-238. The uranium-234 and uranium-238 results were above applicable DOE-derived concentration standards ([DOE O 458.1](#)).

A grab sample of surface water was attempted for analysis during the second quarter of 2015 when the lake was almost dry. A third quarter collection was attempted in late summer, but the lake was dry. West Lake surface water was collected again in the fourth quarter to monitor uranium levels more closely.

The surface water collected within the footprint of West Lake was analyzed for tritium, uranium-234, uranium-235, and uranium-238. Tritium concentrations in surface water collected from West Lake in 2015 were below the laboratory required detection limit. Figure 7.15 shows annual average concentrations of uranium-234 in West Lake surface water and West Lake seep water from 2013 to 2015. Radionuclide concentrations in the West Lake seep and surface water samples collected during 2015 and in the previous 2 years are shown in Appendix C (Tables C.2 and C.3).

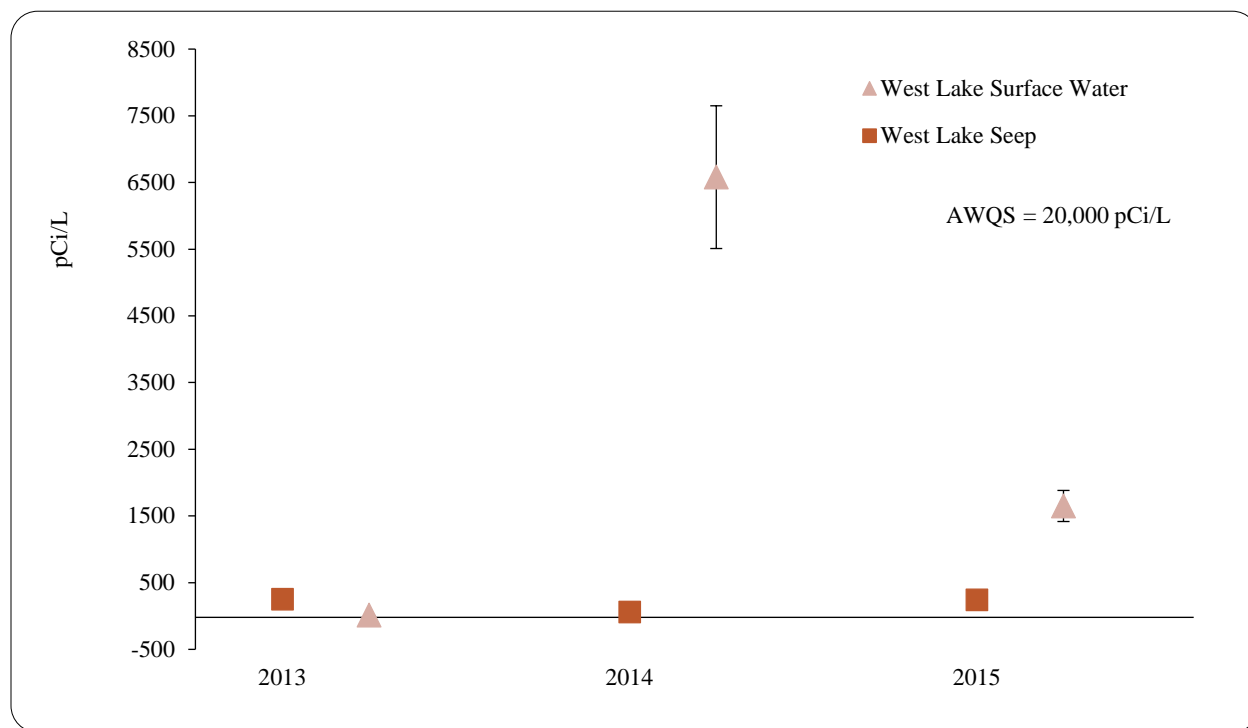


Figure 7.15. Uranium in West Lake Water Samples

7.5.3 West Lake Sediment

One sediment sample was collected from West Lake during the second quarter of 2015. The sediment sample was collected from upper-layer material near the pond shoreline.

The West Lake sediment sample was analyzed for gross alpha, gross beta, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, and other gamma-emitting radionuclides. 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. Detections of all radionuclides during 2015 were similar to previous concentrations.

Uranium concentrations are most likely from naturally occurring uranium in the surrounding soil ([BNWL-1979](#)). Radionuclide levels from samples collected during 2015 and a summary of those collected during the previous 5 years are shown in Appendix C, Table C.1.

7.6 Off-site Irrigation Water

ME Hoefler

As a result of public concern about the potential for Hanford Site-associated contaminants in off-site water, sampling was conducted in 2015 to document the levels of radionuclides in water used by the public. The consumption of food products 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 MEI and any other member of the public (Section 4.2.1).

Off-site Irrigation Water Monitoring. Water samples were collected in 2015 from an irrigation canal located east of the Columbia River and a location downstream of the Hanford Site at Riverview. Samples of the water supply from the Horn Rapids irrigation pumping station (Figure 7.3) were collected from the irrigation valve at the Battelle sporting complex. Each location was sampled three times during the 2015 irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, strontium-90, and tritium.

Sample Results. Most radionuclide concentrations measured in irrigation water in 2015 were at similar levels detected in Columbia River transect water samples collected upstream of the Hanford Site. At the Horn Rapids irrigation pumping station, the tritium results were slightly higher than water collected from the Riverview irrigation system. Strontium-90 was not detected, and results were similar to concentrations measured in historic Horn Rapids and Riverview irrigation samples. All radionuclide results were within the historical range and were less than their respective DOE-derived concentration standards and Washington state ambient surface-water quality criteria ([DOE O 458.1](#); [WAC 173-201A](#); [40 CFR 141](#)).

7.7 Liquid Effluent

SJ Johnson

Liquid effluents are disposed of in a variety of ways at the Hanford Site, with each type of disposal governed by applicable regulations and permits. Primary disposal median for liquid effluents include the soil column and the City of Richland's sewer system. However, only one of those waste streams is permitted for radioactive constituents. Nonetheless, when discharges occur, all are sampled and analyzed for select radioactive parameters and nonradioactive hazardous materials.

Throughout each calendar year, discharge monitoring reports containing contaminant data from the analysis of liquid effluent samples are submitted to Ecology as regulated by [WAC 173-216](#).

7.7.1 Radionuclide Results

The only permitted discharge point for radioactive liquid effluent to the ground in 2015 was the State-Approved Land Disposal Site.

7.7.2 Nonradioactive Hazardous Materials Results

Nonradioactive hazardous materials in several liquid effluent streams discharge to ground disposal units in the 100, 200, and 400 areas. These discharges are authorized by four state-approved discharge permits ([WAC 173-216](#)), which stipulate monitoring requirements. The effluents are monitored for select materials. The EPA is notified immediately if chemicals in the liquid effluents exceed reportable quantities under CERCLA. If chemicals in effluents remain stable at predicted levels, these levels may be reported annually if EPA has approved this practice. Section 2.4.1 provides a synopsis of the state waste discharge permits.

8.0 Groundwater Monitoring

MJ Hartman

Part of DOE's nuclear weapons complex, the Hanford Site encompasses 580 mi² (1,500 km²) along the Columbia River in southeastern Washington State. During World War II and the Cold War period (1945–1991), the government built a total of nine reactors for the production of plutonium and other nuclear materials. During reactor operations, chemical and radioactive waste was released into the environment and contaminated the soil and groundwater beneath portions of the Hanford Site, mostly in the 200 East, 200 West, 300, and 100 reactor areas along the river (e.g., 100-BC, 100-K; Figure 8.1). Since 1989, using its authority under CERCLA, DOE has worked to remediate this contamination. Key elements associated with managing the Hanford Site's groundwater and vadose zone contamination are to protect the Columbia River and groundwater from further contamination, develop a cleanup decision process, and restore groundwater to its highest beneficial use.

Groundwater occurs in an unconfined aquifer within unconsolidated gravel and sand units. Groundwater in the unconfined aquifer generally flows from upland areas in the west toward the regional discharge areas along the Columbia River (Figure 8.2).

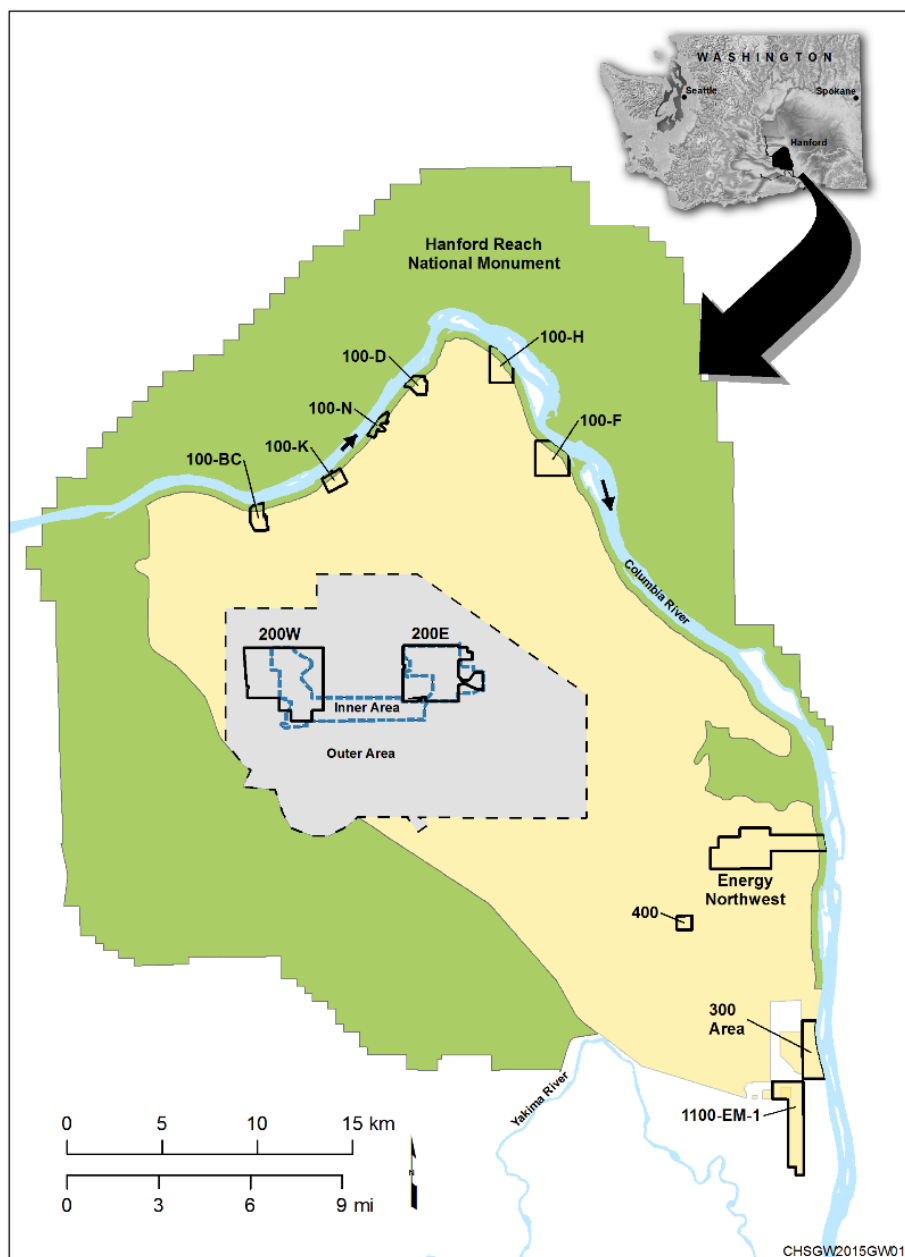


Figure 8.1. Regions of the Hanford Site

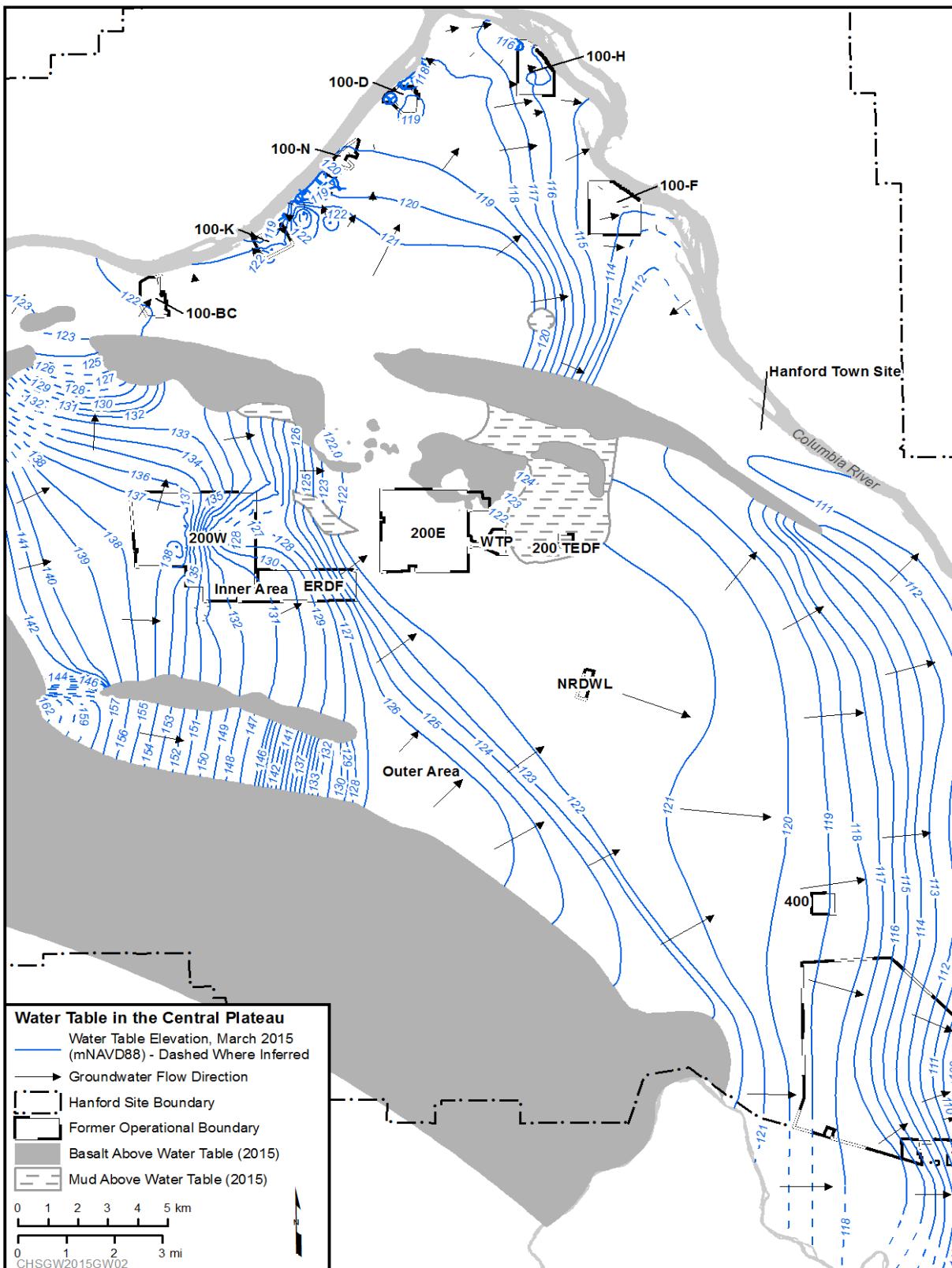


Figure 8.2. Hanford Site 2015 Water Table and Directions of Groundwater Flow

Maximum concentrations of key groundwater contaminants are presented in Tables 8.1 and 8.2. Figure 8.3 presents time-series graphs of plume areas over time for the largest plumes (tritium, iodine-129, nitrate, carbon tetrachloride, and chromium). The figure also illustrates the area of the combined plume footprint for all the plumes, which also include carbon-14, cyanide, strontium-90, technetium-99, trichloroethene, total petroleum hydrocarbon-diesel, and uranium.

Table 8.1. Overview of River Corridor Groundwater Interest Areas

Ground-water Interest Area	Primary Operations	Status of Waste Site Remediation ^a	Status of Groundwater ROD	Groundwater Contamination: Maximum Concentration and Plume Area						
				Carbon-14 (pCi/L)	Hexavalent Chromium (µg/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Trichloro-ethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)
100-BC	Reactor operations -- B Reactor 1944-69; C Reactor 1952-69	94% complete	None to date	N	58	26	35	N	13,800	6.2
100-K	Reactor operations -- KE Reactor 1955-71; KW Reactor 1955-70	51% complete	Interim action pump-and-treat	14,200	348	75	199	8.7	701,000	14
100-N	Reactor operations -- N Reactor 1963-87	93% complete	Interim action permeable reactive barrier	62	120	308	13,600	N	876,000	8.9
100-D & 100-H	Reactor operations -- D Reactor 1944-67; DR Reactor 1950-64; H Reactor 1949-65	97% complete	Interim action pump-and-treat	5.9	614	45.2	32.7	N	14,400	16.3
100-F	Reactor operations -- F Reactor 1945-65; Biological experiments until 1976	100% complete	Final action MNA	N	51	120	176	18.3	N	15.6
300	Nuclear fuel fabrication and research -- 1940s-1960s	95% complete	Final action enhanced attenuation, MNA	N	8.9	(b)	N	2.2	877,000	5,580
1100 and Offsite	Vehicle maintenance, 1954-85; solid waste landfill --1950s- 1970	100% complete	Final action MNA; goals met	N	N	(b)	N	0.61	98	(b)
Standards ^c				2,000	10	45	8	5	20,000	30
Half-life				5,730 yr	N/A	N/A	28.8 yr	N/A	12 yr	>159,000 yr
Mobility in subsurface				High	High to Moderate	High	Slight	Moderate	High	Moderate
Legend										
Colors indicate maximum concentration in 2015										
<div> <div>Red</div> <div>Orange</div> <div>Yellow</div> <div>Green</div> </div>										
<div> <div>≥1000 x standard</div> <div>≥100 x standard and <1000 x standard</div> <div>≥10 x standard and <100 x standard</div> <div>≥Standard and <10 x standard</div> </div>										
N Not detected or not analyzed										
<div> <div>Height of bar indicates plume area above standard (km²)</div> <div> <div>>10</div> <div>>1 and ≤ 10</div> <div>>0.1 and ≤ 1</div> <div>>0, ≤0.1</div> </div> </div>										
NOTES										
(a) Approximate percentage by number of waste sites classified as closed, interim closed, no action, rejected, or not accepted (January 15, 2016).										
(b) Nitrate in 300-FF-5, and nitrate and uranium in 1100-EM-1, originate from offsite sources so plume areas and maximum concentrations are not shown										
(c) Drinking water standards for all but hexavalent chromium (aquatic standard)										
ABBREVIATIONS										
MNA = Monitored Natural Attenuation N/A = Not Applicable ROD = Record of Decision										
CHSGW2015GW19										

Table 8.2. Overview of Central Plateau Groundwater Interest Areas

Ground-water Interest Area	Primary Operations	Status of Ground-water ROD	Groundwater Remedial Action	Groundwater Contamination: Maximum Concentration and Plume Area									
				Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Cyanide (µg/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)	Strontium-90 (pCi/L)	Trichloroethene (µg/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)
200-BP	B Plant Pu separation: 1945-1952; B Plant Sr and Cs recovery: 1967-1985	FS Drafted in 2015 (with 200-PO-1)	B Complex groundwater extraction treatability test 2015; Perched water P&T 2011-2015	0.31	51	1,680	6.1	1,330	1,100	4.8	35,600	45,200	5,600
200-PO	PUREX Plant Pu separation: 1956-1972 and 1983-1989	FS Drafted in 2015 (with 200-BP-5)	Vadose zone desiccation test: 2011	N	52 ^a	N	10.1	139	14.1	1.5	3,020	525,000	43.1
200-UP	REDOX Plant (Pu separation) 1952-1967; U Plant (U recovery) 1952-1957	Signed 2012 (interim action)	Uranium plume P&T began 2015; I-129 containment began 2015; S-SX P&T 2012-present; U plant P&T 1994-2011	See 200-ZP	406	N	6.1	3190	3.1	See 200-ZP	51,400	271,000	1,550
200-ZP	T Plant (Pu separation) 1944-1956; Pu Finishing Plant: 1949-1989	Signed 2008 (final action)	Groundwater P&T and MNA: 1995-present. Soil vapor extraction 1991-2013	1,980	198	N	1.2	810	N	10.4	20,500	60,200	2.9
Standards ^b				5	48	200	1	45	8	5	900	20,000	30
Half-life (years)				N/A	N/A	N/A	1.60E+07	N/A	28.8	N/A	212,000	12	>159,000
Mobility in subsurface				Multi-phase	High to Moderate	Moderate	High	High	Slight	Moderate	High	High	Moderate
Legend													
Colors indicate maximum concentration in 2015													
<div><div></div> ≥100 x standard and <1000 x standard</div>													
<div><div></div> ≥10 x standard and <100 x standard</div>													
<div><div></div> ≥Standard and <10 x standard</div>													
N Not detected or not analyzed													
a. Chromium plume originated in UP-1 and tallied with that area.													
b. Drinking water standards for all but hexavalent chromium (MTCA standard)													
ABBREVIATIONS													
FS = Feasibility Study				MTCA = Model Toxics Control Act				P&T = Pump and Treat				Redox = Reduction-Oxidation	
MNA = Monitored Natural Attenuation				N/A = Not Applicable				PUREX = Plutonium Uranium Extraction				ROD = Record of Decision CHSGW2015GW20	

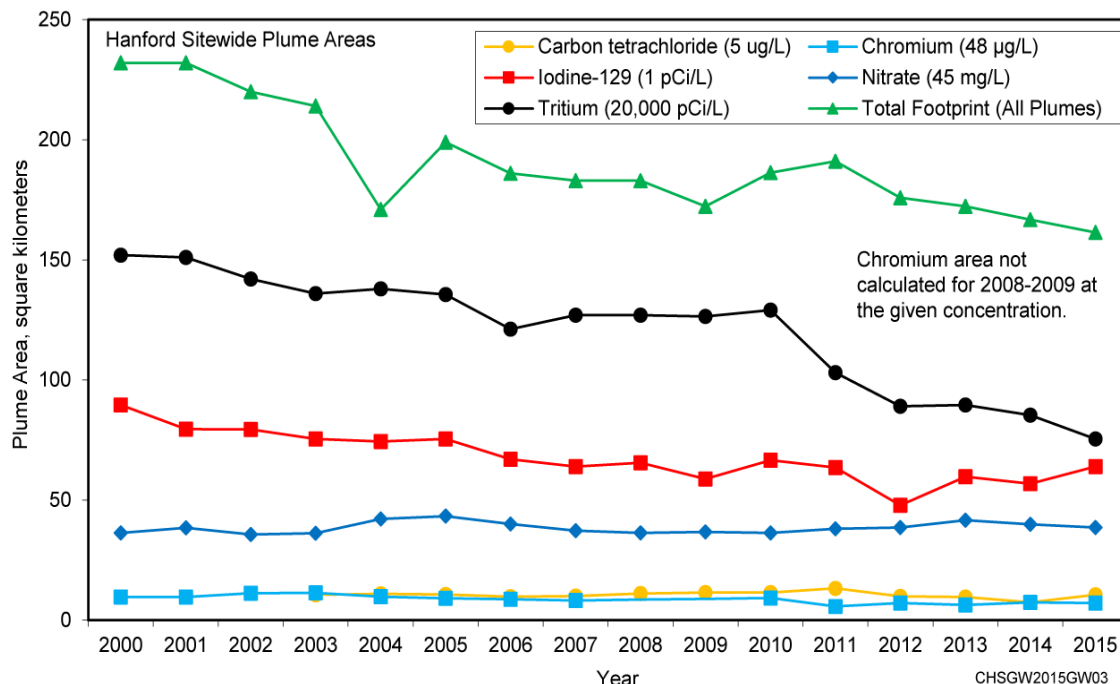


Figure 8.3. Hanford Site Plume Areas

DOE has taken the following actions to protect the Columbia River from contaminated groundwater:

- Ceasing discharge of all unpermitted liquids in the central Hanford Site.
- Remediating waste sites in the 100 and 300 areas.
- Containing groundwater plumes and reducing the mass of primary contaminants through remedial actions such as pump-and-treat (P&T).

DOE operates an extensive groundwater monitoring program on the Hanford Site, collecting thousands of samples from hundreds of wells each year (Figure 8.4). In addition to monitoring wells, DOE monitors

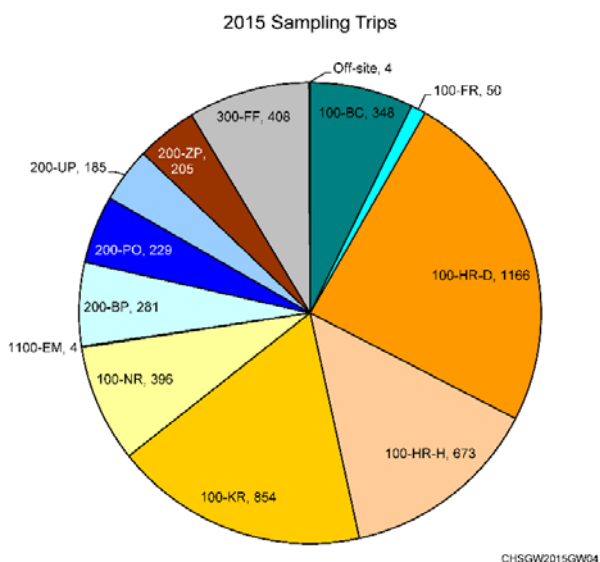
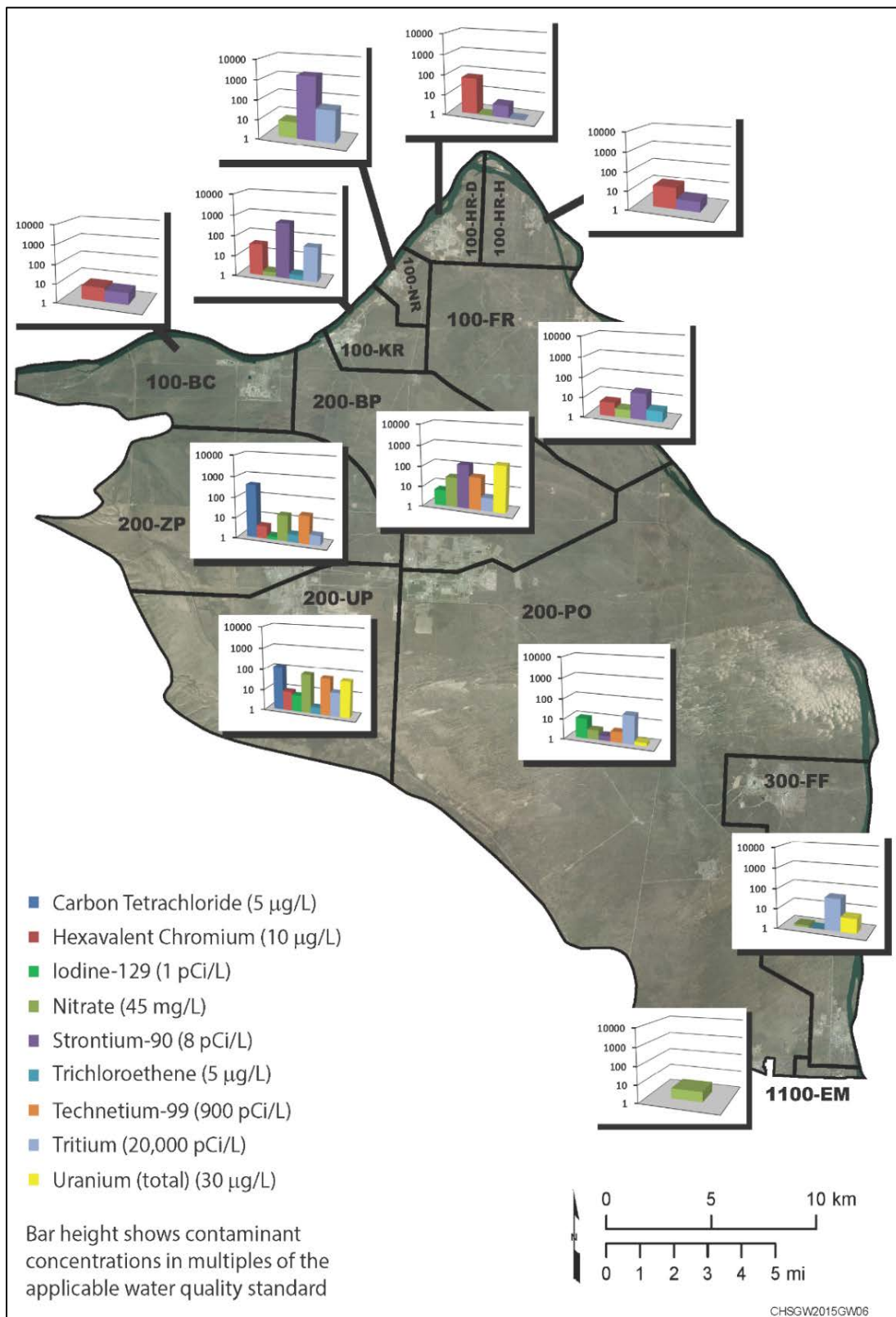


Figure 8.4. 2015 Sampling Events (Wells and Aquifer Tubes)

hundreds of sampling points near the Columbia River, known as aquifer tubes, for general information about groundwater approaching the river.

Figure 8.5 compares maximum concentrations of the major groundwater contaminants in various parts of the Site in 2015. These contaminants are discussed further in the following sections. This chapter is organized by geographic regions known as “groundwater interest areas” (Figure 8.5) within the River Corridor (100 and 300 areas) and Central Plateau (200 Areas).



8.1 River Corridor

Since the 1990s, DOE has been remediating waste sites and groundwater in the River Corridor under interim action RODs. Removal of contaminated soil has reduced the potential for exposure to contaminants, including future groundwater impacts. As of the end of 2015, 92% of the waste sites in the River Corridor had been remediated or were classified as not needing remediation under interim action RODs. Cleanup of the remaining sites is underway.

Table 8.1 provides a summary of the River Corridor groundwater interest areas and associated contamination plumes. In the 100 Area, groundwater contamination is related to past disposal of waste associated with water-cooled nuclear reactors. The primary groundwater contaminants of concern (COC) in the 100 Area are hexavalent chromium, strontium-90, nitrate, trichloroethene, and tritium (Figure 8.6). Sources of hexavalent chromium contamination included the routine disposal of reactor cooling water, which contained the corrosion inhibitor sodium dichromate, and unplanned spills and leaks of the high-concentration sodium dichromate stock solution. In the 300 Area, the groundwater COCs are uranium, tritium, nitrate, gross alpha, trichloroethene and cis-1,2-dichloroethene.

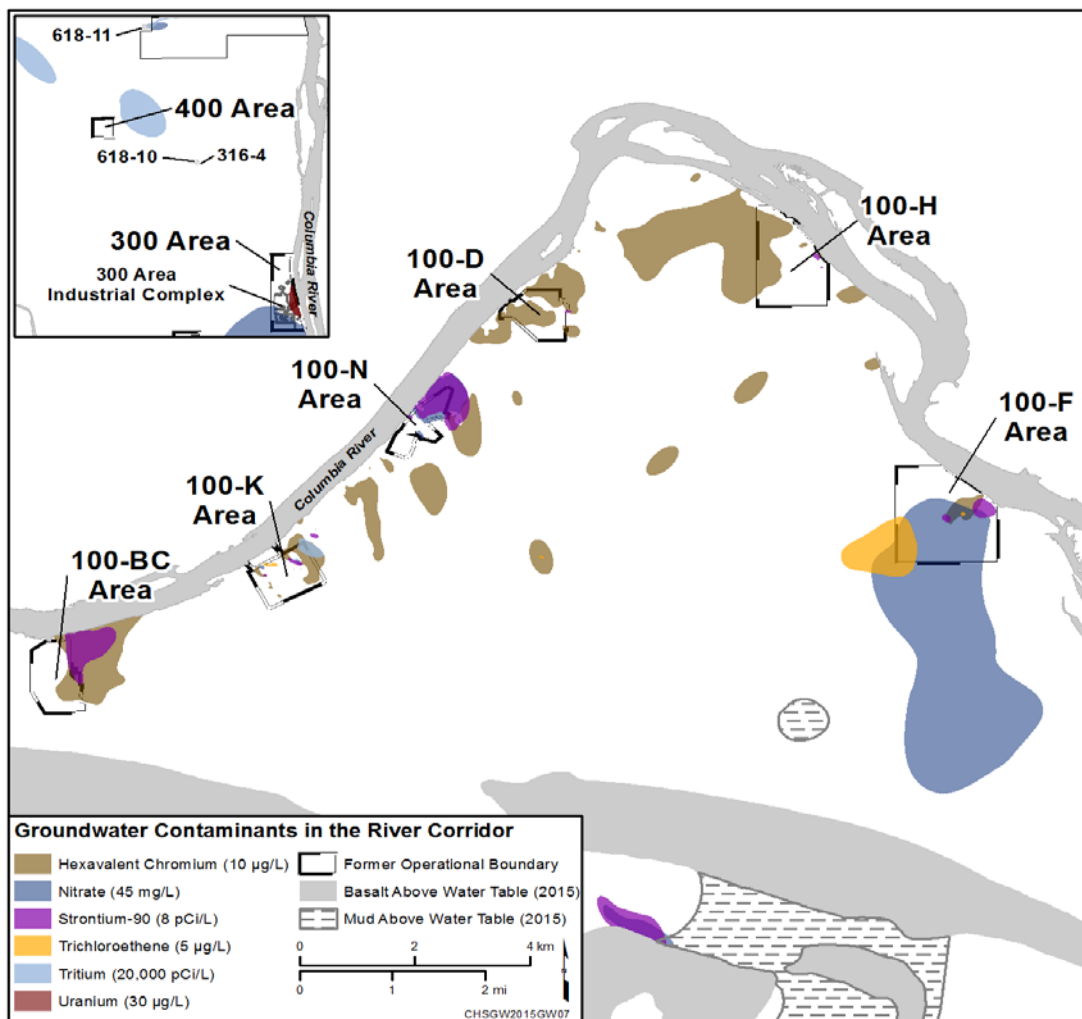


Figure 8.6. Maximum Concentrations of Groundwater Contaminants in Each Groundwater Interest Area in 2015 Expressed as Multiples of Water Quality Standards

Under interim action RODs, groundwater remediation systems in the 100-HR-3 and 100-KR-4 operable units (OUs) are limiting the amount of contamination reaching the Columbia River and reducing the mass of contaminants. The primary contaminant addressed is hexavalent chromium and the remedial action goal is 20 µg/L. Similar to other River Corridor decisions (e.g., 100-FR-3), the cleanup level for groundwater discharges to the river for the final action ROD for 100-HR-3 and 100-KR-4 is expected to be 10 µg/L when they are completed.

Final action RODs have been signed for 100-FR-3, 300-FF-5, and 1100-EM-1 OUs. Final action RODs for the other portions of the River Corridor are expected to be developed in the next few years.

8.1.1 100-BC

Groundwater contaminants of potential concern in 100-BC include hexavalent chromium, strontium 90, and tritium. Hexavalent chromium concentrations and the size of the plume declined between 2014 and 2015. The strontium 90 plume remained stable and tritium concentrations remained below the DWS in 2015. Sampling of water in the shallow river bed showed that Cr(VI) concentrations exceed the aquatic standard in pore water of the river bed.

DOE has completed interim action remediation of 100-BC waste sites. Vadose zone sampling indicated that at most sites, no substantive quantities of residual contaminant mass remain in the vadose zone. However, at a few sites, data from deep vadose soils and the rewetted zone, and the presence of persistent groundwater contamination, suggest that minor quantities of residual contamination may remain.

Remedial investigation studies continued in 100-BC in 2015, with additional sampling of wells and river shoreline sampling points installed in 2013. Data from the studies that concluded in January 2016 are being incorporated into a remedial investigation/feasibility study report to support remedy decisions for groundwater cleanup.

8.1.2 100-FR

Groundwater contamination in 100-FR originated from disposal of solid and liquid waste associated with operation of the water-cooled F Reactor and biological experiments. DOE has completed remediation of 100-FR waste sites, and sampling indicated that no substantive quantities of residual contaminant mass remain in the vadose zone.

Under a 2014 ROD, the groundwater remedy is monitored natural attenuation (MNA) of nitrate, trichloroethene, strontium 90, and hexavalent chromium. Contaminant concentrations are below cleanup standards near the river and are declining.

8.1.3 100-HR

The 100-HR-3 Groundwater OU in the northern part of the Hanford Site includes the 100-HR-D and 100-HR-H groundwater interest areas. Hexavalent chromium is the primary COC. Additional groundwater contaminants in 100-HR include strontium 90 and nitrate (Figure 8.6).

About 97% of the former waste sites have been remediated or were determined not to require remediation under an interim action ROD. At the 100-D-100 waste site, once a major source of hexavalent chromium contamination, efforts to excavate contaminated sediment down into the top portion of the aquifer were successfully completed in 2015. Remediation of other waste sites continued in 2015.

Two P&T systems continued to operate in 2015 under an interim action ROD to remove hexavalent chromium from groundwater. In 2015, 688 million gal (2.6 billion L) of groundwater were pumped from 80 extraction wells. Since 1997, the P&T systems have removed 5,211 lbs (2,364 kg) of hexavalent chromium. The overall areal extent of the plumes and the length of affected shoreline have declined between 1999 and 2015 (Figure 8.7). The changes are a result of groundwater contaminant removal, remediation of sources, hydraulic control, and natural processes.

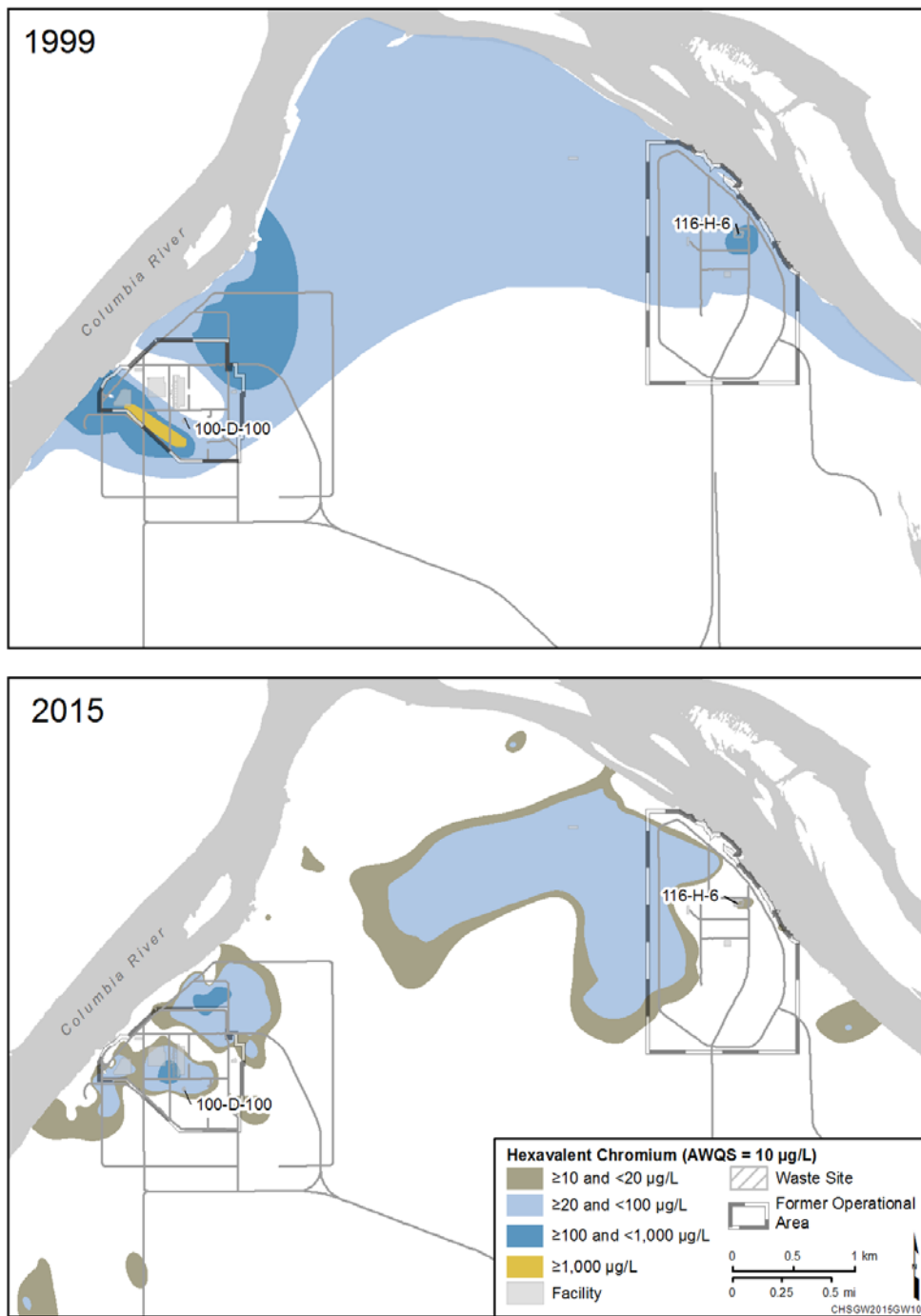


Figure 8.7. 100-HR Hexavalent Chromium Plume in 1999 (early in interim action period) and 2015 (during interim action)

The CERCLA process is underway to make final cleanup decisions for 100-HR. The proposed plan for remediation is expected to be available for public comment in 2016. A ROD will then be issued that identifies the final remedial alternatives. DOE has proposed ongoing P&T as the preferred alternative for remediating hexavalent chromium in groundwater.

The former 183-H Solar Evaporation Basins (waste site 116-H-6) constitute the only RCRA unit in 100-HR. The unit is monitored in accordance with RCRA corrective action requirements during the post-closure period to track contaminant trends during operation of the CERCLA P&T interim action for hexavalent chromium.

8.1.4 100-KR

Hexavalent chromium is the primary contaminant in 100-KR groundwater. Smaller plumes of carbon-14, tritium, strontium-90, nitrate, and trichloroethene also are present. About 51% of the waste sites in 100-KR have been remediated or were determined not to require remediation under an interim action ROD. Waste site cleanup continued in 2015.

Three P&T systems continued to operate in 100-KR in 2015, removing hexavalent chromium from groundwater. In 2015, over 764 million gal (2.89 billion L) of groundwater were pumped from 42 extraction wells. A total of 1,843 lbs (836 kg) of hexavalent chromium have been removed from 100-KR groundwater to date.

The hexavalent chromium plume area (greater than 20 µg/L) was estimated to be 0.23 mi² (0.59 km²) in 2015, a decrease of 29% from 2014. Since 2007, the plume area above 20 µg/L has decreased by 70%, and the length of shoreline that the plume intersects has decreased from 7,200 ft (2,200 m) to less than 330 ft (100 m; Figure 8.8).

In addition to hexavalent chromium, smaller plumes of carbon 14, tritium, strontium 90, nitrate, and trichloroethene also are present (Figure 8.6). Cleanup actions for these other contaminants will be defined in an upcoming ROD. DOE has proposed additional P&T for hexavalent chromium as part of a preferred alternative for groundwater remediation. In 2015, two boreholes were drilled near the KE fuel storage basins and 116-KE-3 Crib and reverse well in support of source characterization activities. The results will be incorporated into the RI/FS and proposed plan, which will be revised in 2017.

For AEA purposes, DOE monitors groundwater near the KW and former KE fuel storage basins, which were integral parts of each reactor building. Until 2004, the concrete water-filled basins were used to store irradiated fuel from the last run of N Reactor as well as miscellaneous fuel fragments recovered during remedial actions at other reactor areas. The KE Basin was demolished. The KW Basin has been emptied of fuel rods but remains a depository for contaminated sludge from the KE and KW Basins. Groundwater monitoring in 2015 did not show new groundwater impacts from the basins.



Figure 8.8. 100-KR Hexavalent Chromium Plume in 1996 (before interim action) and 2015 (during interim action)

8.1.5 100-NR

Principal groundwater activities for 100-NR include RCRA monitoring and remediation of strontium-90 and total petroleum hydrocarbons. Other groundwater contaminants include nitrate, total chromium, hexavalent chromium, and tritium. About 93% of the waste sites in 100-NR have been remediated. Remedial action and planning are expected to continue in 2016.

Originating at the 116-N-1 and 116-N-3 waste sites, strontium-90 is the primary COC. Strontium (including the strontium-90 isotope) substitutes for calcium in the sediment, reducing the mobility of this contaminant in the vadose zone and groundwater. As a result, the shape and size of the plume has not changed significantly since 1996. P&T technology, which operated from 1995 to 2006, was found to be ineffective in cleaning up strontium-90. Under an interim action ROD, a 900 ft (170 m) section of a permeable reactive barrier is in place along the shoreline to reduce the amount of strontium-90 migrating from groundwater into the river (Figure 8.9). Expansion of the barrier to its full 2,500 ft (760 m) length is pending.

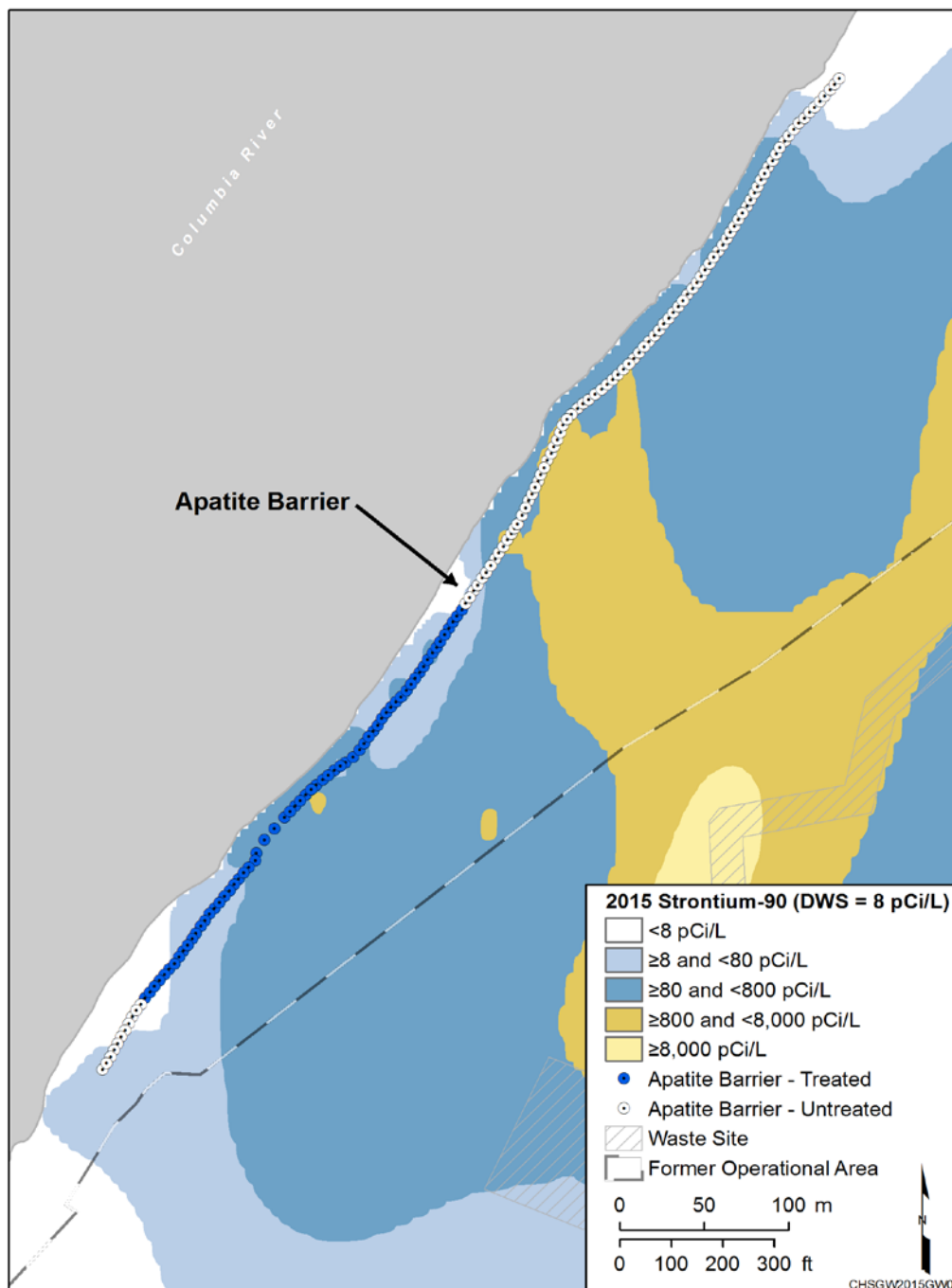


Figure 8.9. 100-NR 2015 Strontium-90 Plume and Apatite Barrier

DOE submitted a draft RI/FS report and proposed plan to Ecology for review in 2013. In 2015, DOE continued to respond to Ecology's comments on the documents. When finalized, these documents will be used to develop a ROD documenting remediation of waste sites and groundwater.

In 2015, RCRA monitoring continued under final status detection programs at the 1301-N, 1324-N/NA, and 1325-N facilities (waste sites 116-N-1, 120-N-1, 120-N-2, and 116-N-3). Results indicated no releases of dangerous waste constituents from the RCRA units.

8.1.6 300-FF

Three geographic regions comprise 300-FF: the 300 Area Industrial Complex; the 618-11 Burial Ground region; and a region including the 618-10 Burial Ground and 316-4 Cribbs (inset map on Figure 8.6). About 95% of the waste sites have been remediated or classified as not requiring remediation. Remediation is continuing at the remaining sites.

EPA and DOE signed a ROD in 2013. The remedial action of groundwater includes enhanced attenuation of uranium using sequestration by phosphate application. The first stage of enhanced attenuation was completed in 2015. MNA is the selected remedy for other COCs: Trichloroethene and cis-1,2-dichloroethene at the 300 Area Industrial Complex, and tritium and nitrate at the 618-11 Burial Ground.

Uranium concentrations remain above the cleanup level (30 µg/L) in groundwater in the 300 Area Industrial Complex (Figure 8.10). Uranium and chromium from the 618-7 Burial Ground was mobilized by waste site remediation activities in recent years, with some contamination reaching groundwater.

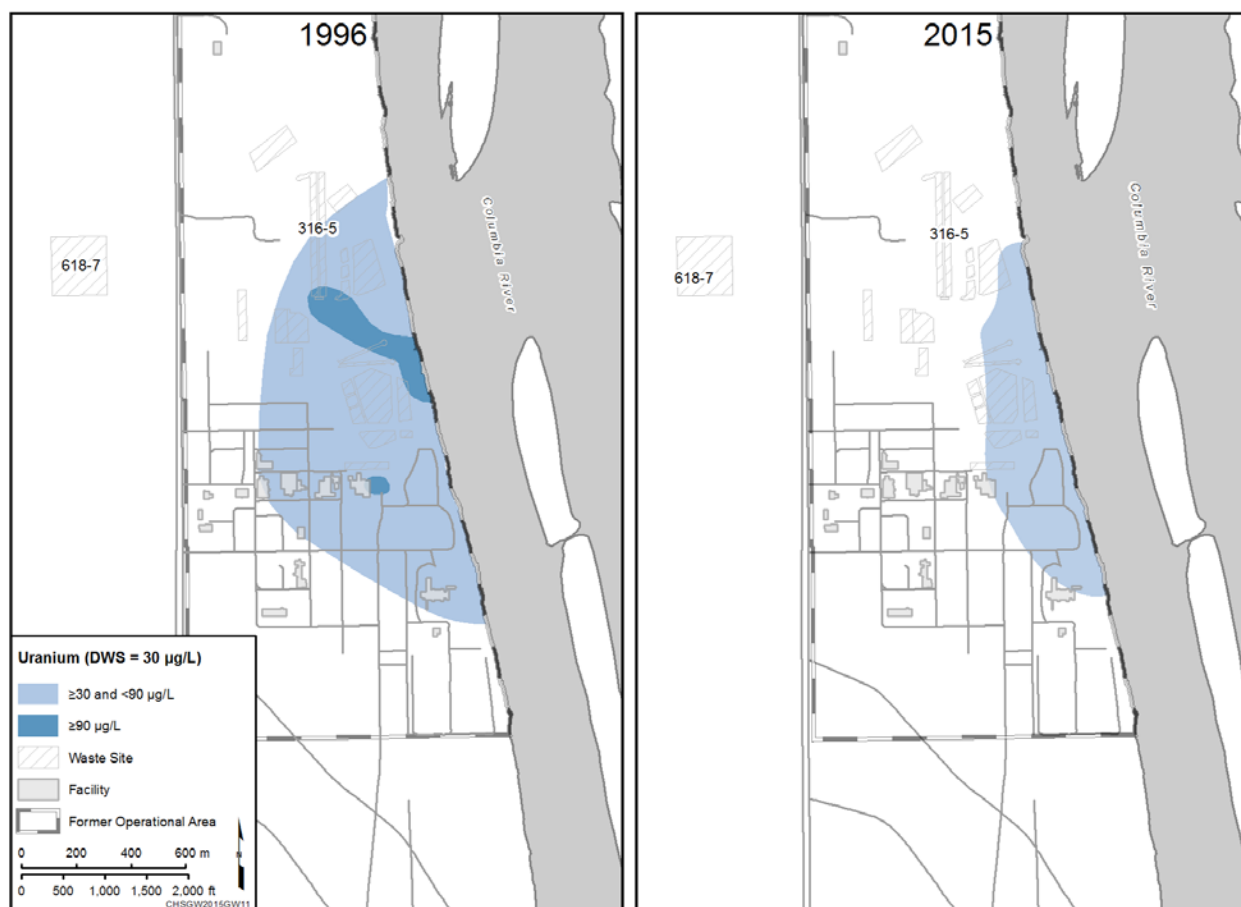


Figure 8.10. 300-FF Uranium Plume in 1996 and 2015

Trichloroethene concentrations were below the cleanup level (4 µg/L) in 300-FF monitoring wells in 2015. Cis-1,2-dichloroethene continued to exceed the cleanup level (16 µg/L) in one well. Concentrations of nitrate above 45 mg/L are present in groundwater beneath part of the 300 Area Industrial Complex, but these originated from offsite sources; nitrate in the 300 Area Industrial Complex is not a COC for the 300-FF-5 OU.

Groundwater associated with the 618-11 Burial Ground north of the 300 Area Industrial Complex contains a high-concentration tritium plume originating from irradiated material; the waste site has not yet been remediated. Nitrate concentrations near the 618-11 Burial Ground also continued to exceed 45 mg/L.

RCRA groundwater monitoring continued at the 300 Area Process Trenches (Waste Site 316-5). The unit is monitored in accordance with post-closure corrective action requirements. Uranium and cis-1,2-dichloroethene continued to exceed Permit limits in 2015. Remediation will be coordinated under the 300-FF-5 Groundwater OU.

8.1.7 1100-EM and Richland North

The 1100-EM-1 Groundwater OU was removed from the National Priorities List ([40 CFR 300](#), Appendix B) in 1996. The selected remedy was MNA for volatile organic compounds, with institutional controls preventing drilling of new water supply wells. Trichloroethene was the primary COC, but concentrations have remained below the cleanup level since 2001 and CERCLA groundwater monitoring ceased in 2015.

DOE monitors wells in and near the North Richland well field, which is part of the municipal water supply system. Groundwater in this region has not been impacted by Hanford Site contamination.

Uranium concentrations in Hanford Site wells near the DOE inactive Horn Rapids Landfill have increased gradually since 1996, exceeding the DWS in 2015. The presence of uranium at these locations is attributed to a plume moving northeast from a former surface impoundment at AREVA NP, Inc., an off-site nuclear fuel production facility that has been remediated.

8.2 Central Plateau

When the Hanford Site was operating as a plutonium-production facility, irradiated fuel reprocessing, isotope recovery, and associated waste management activities occurred in the 200 Areas in the Central Plateau portion of the Site. Ponds, cribs, and ditches used for liquid waste disposal were primary sources of groundwater contamination. There are also seven single shell tank WMAs in the 200 Areas. Some of these tanks have leaked, contaminating the vadose zone and groundwater.

Contamination is still present in many parts of the thick Central Plateau vadose zone and may continue to drain into the groundwater. DOE will shift its focus to the Central Plateau waste sites and the vadose zone after River Corridor remediation is complete. Meanwhile, DOE has been remediating groundwater and testing methods to remediate the deep vadose zone.

Large groundwater contaminant plumes of tritium, nitrate, and iodine-129 formed when the waste discharged to ponds and cribs in the Central Plateau reached the aquifer. Plume sizes have decreased over the years because of dispersion and, in the case of tritium, radioactive decay. A large carbon tetrachloride plume originated in the Plutonium Finishing Plant area of the 200 West Area. Other groundwater contaminants in the Central Plateau include technetium-99, uranium, strontium-90, trichloroethene, hexavalent chromium, cyanide, and other dangerous waste constituents (Table 8.2; Figure 8.11).

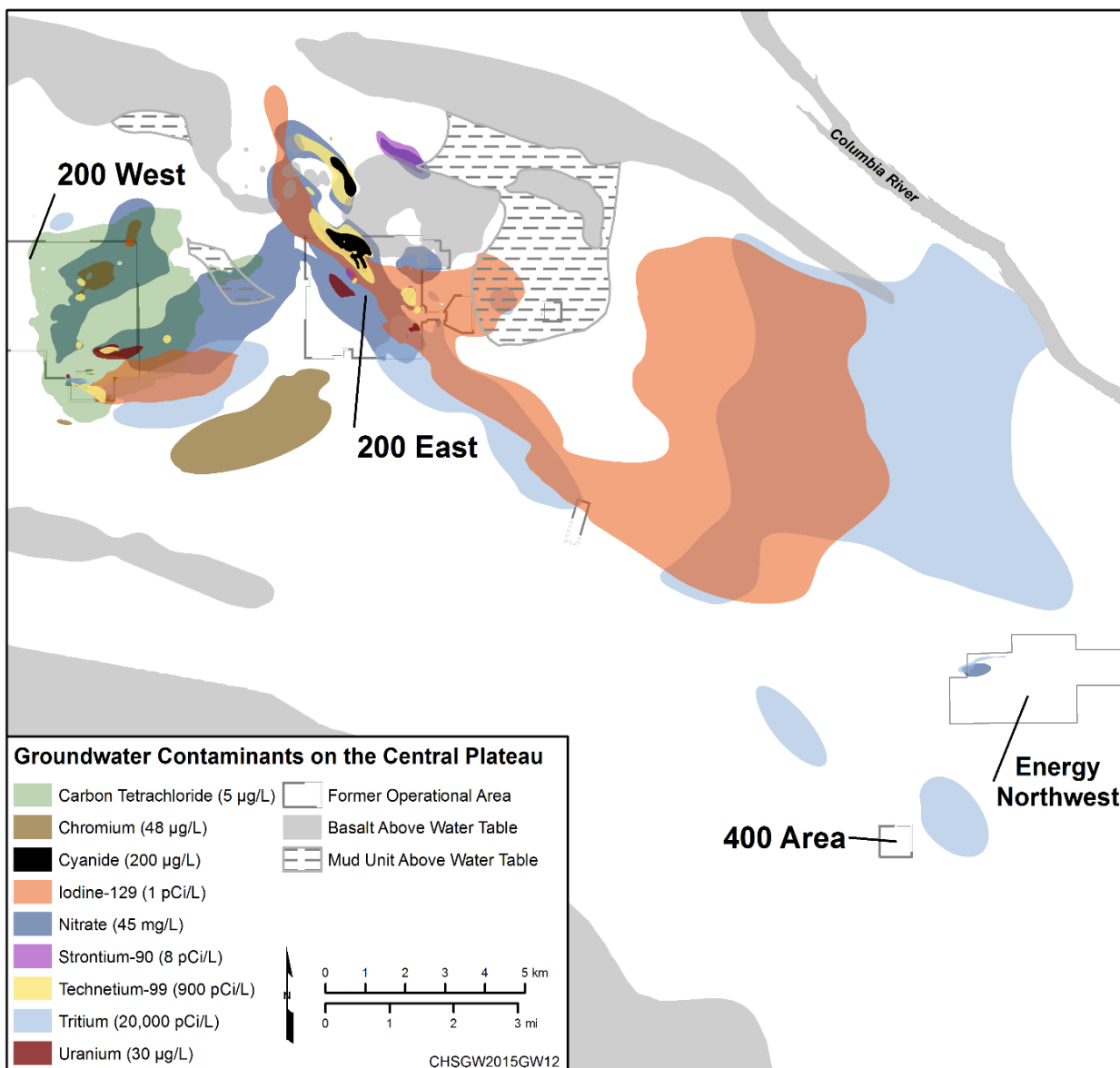


Figure 8.11. Groundwater Contaminants in the Central Plateau

8.2.1 200-BP

The 200-BP groundwater interest area includes the northern 200 East Area and the region to the northwest where mobile contaminants have migrated between Gable Mountain and Gable Butte. Most of the groundwater contamination is beneath waste sites in the northwestern portion of the 200 East Area. Nitrate, iodine-129, and technetium-99 exceed DWSs and form the largest contaminant plumes. The high concentration cores of these plumes have grown in size since 2007 due to continued drainage of contaminated water from the vadose zone into the aquifer (Figure 8.12). Smaller plumes of uranium, cyanide, strontium-90, and tritium also exceed their respective DWSs. Cesium-137 and plutonium-239/-240 contamination is limited to only one or two wells adjacent to the 116-B-5 injection well, where effluent was historically discharged into the aquifer. DOE drilled two deep investigation wells near B Plant in 2015 to evaluate concentrations of nitrate, tritium, and uranium with depth.

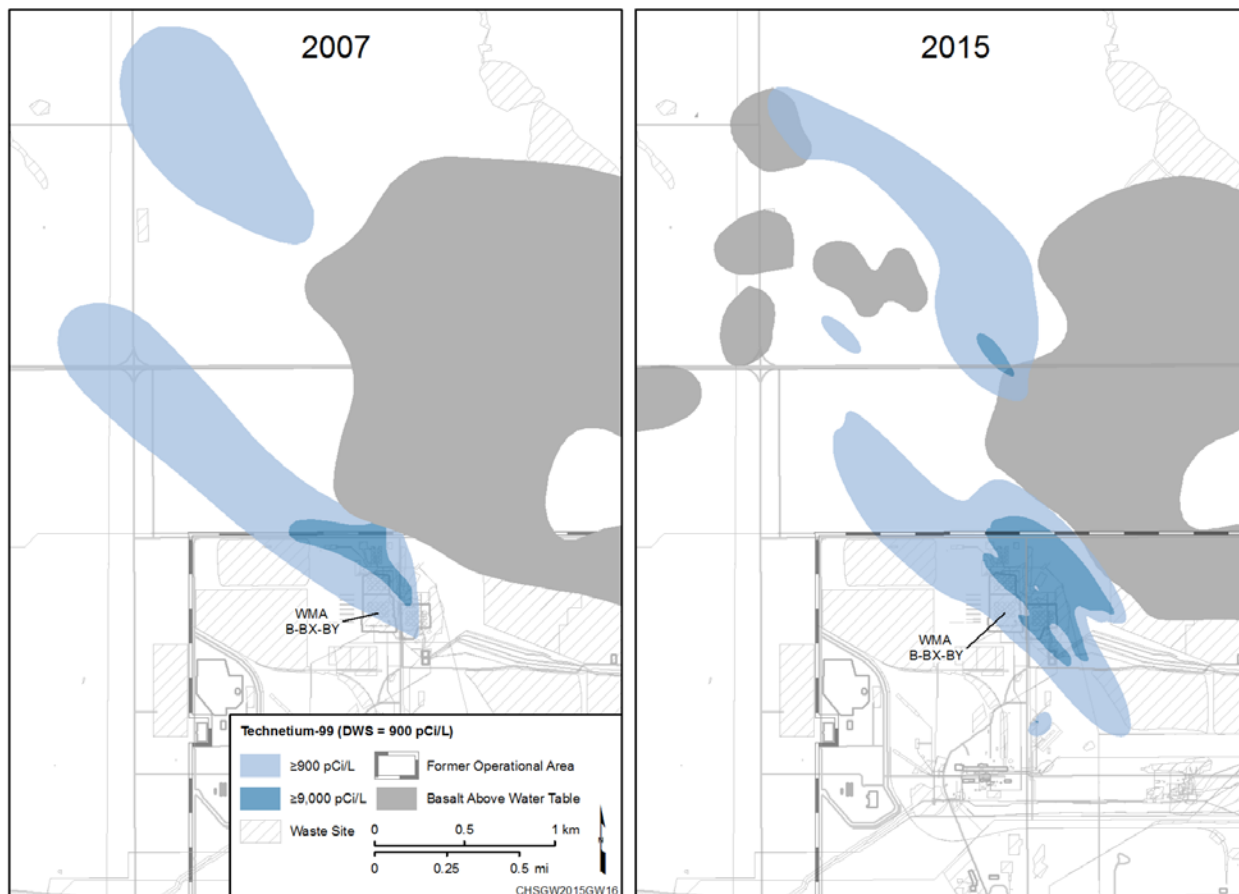


Figure 8.12. 200-BP Technetium-99 Plume in 2007 and 2015

Beneath WMA B-BX-BY, a zone of perched water lies above the water table with high concentrations of uranium and other contaminants (200-CV-1 OU). Water is pumped from this perched zone to prevent more from draining to the underlying aquifer, and approximately 37 lbs (17 kg) of uranium was removed in 2015.

DOE conducted a treatability test that involved long-term groundwater extraction in 2015. Results indicated that pumping rates greater than 155 gal (586 L) per minute can be sustained in the unconfined aquifer at B Complex; therefore, P&T may be a plausible alternative in the 200-BP-5 OU FS.

DOE submitted a draft remedial investigation report for the 200-BP-5 OU to Ecology in 2015, describing the nature and extent of contamination and identifying contaminants of potential concern to support a future feasibility study.

Six RCRA WMAs with groundwater monitoring requirements are located in 200-BP. RCRA groundwater quality assessment monitoring at WMA B-BX-BY and WMA C indicates that the dangerous waste constituent cyanide originated in the WMAs. In 2015, RCRA contamination indicator evaluation monitoring continued at the 216-B-63 Trench and two low-level waste management areas (LLWMA): LLWMA-1 and LLWMA-2. Results continued to show that these units have not impacted groundwater quality. DOE monitors the Liquid Effluent Retention Facility (LERF) under a RCRA final status detection program and results showed no indication that the site has affected groundwater. DOE installed one RCRA monitoring well for LERF in 2015.

8.2.2 200-PO

The southern portion of the 200 East Area and a large region of the Hanford Site to the east and southeast comprise 200-PO. Disposal of large volumes of liquid waste created regional groundwater plumes of tritium, iodine-129, and nitrate. The tritium plume had an area of 26.6 mi² (69 km²) above the 20,000 pCi/L DWS in 2015, a 14% decrease from 2014. Concentrations of tritium are declining as the groundwater plume attenuates naturally from radioactive decay and dispersion. The area of the iodine-129 plume above the 1 pCi/L contour has decreased slightly over the past decade, and maximum concentrations have declined because of dispersion. Radioactive decay has not decreased the level of iodine-129 contamination noticeably because this isotope has a half-life of 15.7 million years. The nitrate plume covers a large area with concentrations above background, but mostly below 45 mg/L. Other 200-PO contaminants include strontium-90, technetium-99, and uranium in smaller areas near their discharge sources (Figure 8.11).

The size of the regional tritium plume (Figure 8.13) from 200-PO has decreased by 63% since 1980 (from 71.4 to 26.6 mi² [185 to 69 km²]). The maximum concentration has declined from over 6 million pCi/L in the 1980s to 525,000 pCi/L in 2015.

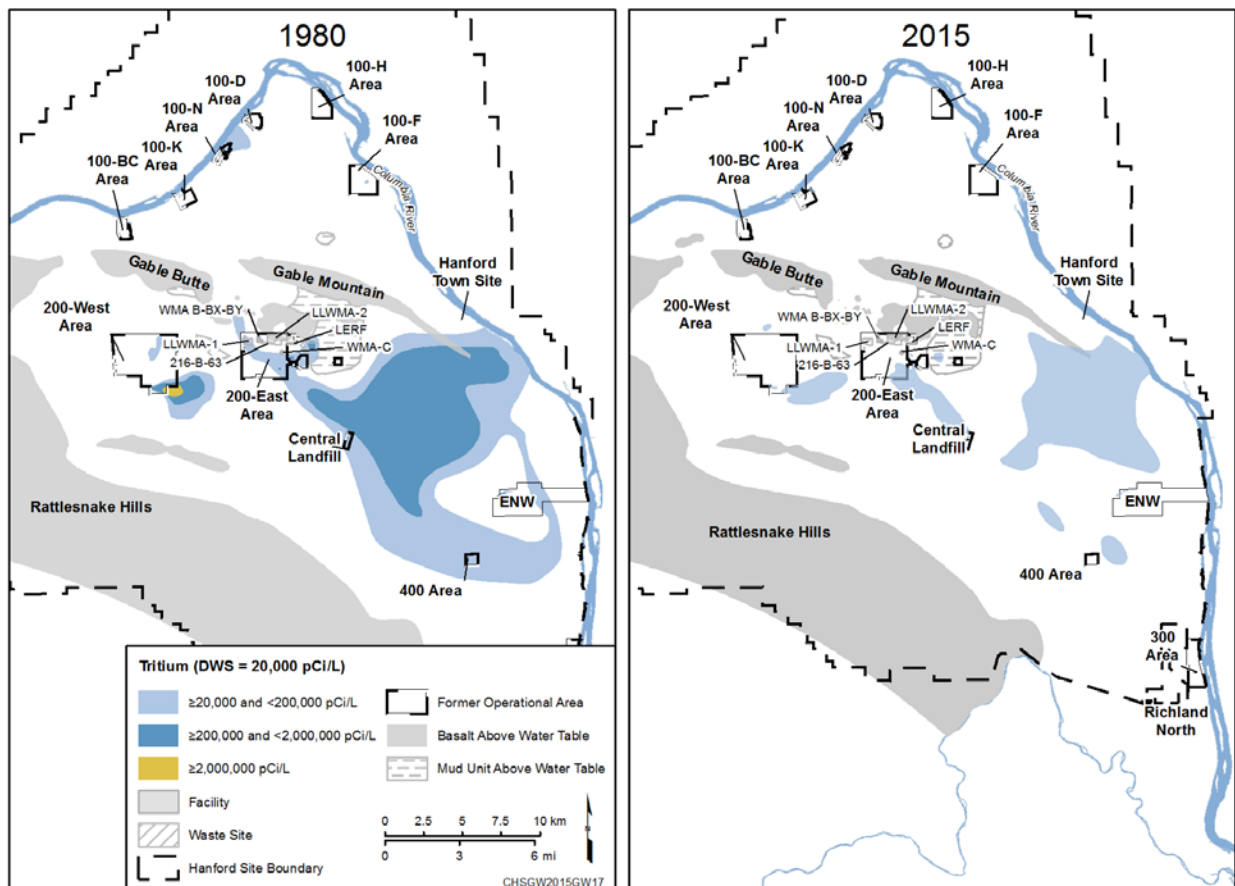


Figure 8.13. Hanford Site Tritium Plumes in 1980 and 2015

DOE provided Draft A of a remedial investigation addendum to Ecology in 2015. The addendum updates the risk assessment for the 200-PO-1 OU based on additional groundwater data collected since the remedial investigation was completed in 2009.

RCRA groundwater monitoring continued in 2015. Revised monitoring plans for WMA A-AX, 216-A-36B Crib, 216-A-37-1 Crib, 216-B-3 Pond, and the Nonradioactive Dangerous Waste Landfill were drafted in 2015 and are expected to be implemented in 2016. Specific conductance continued to exceed the critical mean value in three downgradient wells at the 216-A-29 Ditch. As agreed to with Ecology, an assessment program will be implemented in 2016 based on the current exceedances of the specific conductance critical mean. The Integrated Disposal Facility is an expandable, double-lined landfill that is regulated under RCRA and the AEA. It is not yet in use, and current groundwater monitoring is directed at obtaining baseline data.

Other groundwater monitoring in 200-PO includes the Solid Waste Landfill, regulated under Washington State solid waste handling regulations, and three on-site water supply wells that provide drinking water and serve as an emergency water supply for the 400 Area. Because the 400 Area is in the path of the Hanford Site-wide tritium plume, DOE routinely monitors the wells for tritium. Concentrations remained below the DWS in 2015.

8.2.3 200-UP

The southern portion of the 200 West Area and adjacent areas to the east and south comprise 200-UP. Contaminant sources included cribs, ponds, and single shell tanks. Carbon tetrachloride, technetium-99, uranium, tritium, iodine-129, nitrate, and chromium plumes are present. Carbon tetrachloride in this region originated from sources in 200-ZP.

An interim action ROD addressing all of the major contaminant plumes in the 200-UP-1 Groundwater OU was published in 2012. The selected remedy in the ROD is a combination of P&T, MNA, hydraulic containment, and institutional controls. Portions of this selected remedy began in 2015. The U Plant uranium/technetium-99 groundwater extraction system began operating two extraction wells in September. Comprising three injection wells east of 200 West Area, the iodine-129 hydraulic containment system began operating in October.

Wells near WMA S-SX monitor the highest technetium-99 activities on the Hanford Site, and the plume has grown in recent years (Figure 8.14). A P&T system at WMA S-SX continued to operate in 2015, and concentrations began to decline. From 2012 to 2015, the system removed 2.18 Ci of technetium-99, 50,000 lbs (22,600 kg) of nitrate, 79.6 lbs (36.1 kg) of chromium, and 87.1 lbs (39.5 kg) of carbon tetrachloride from groundwater.

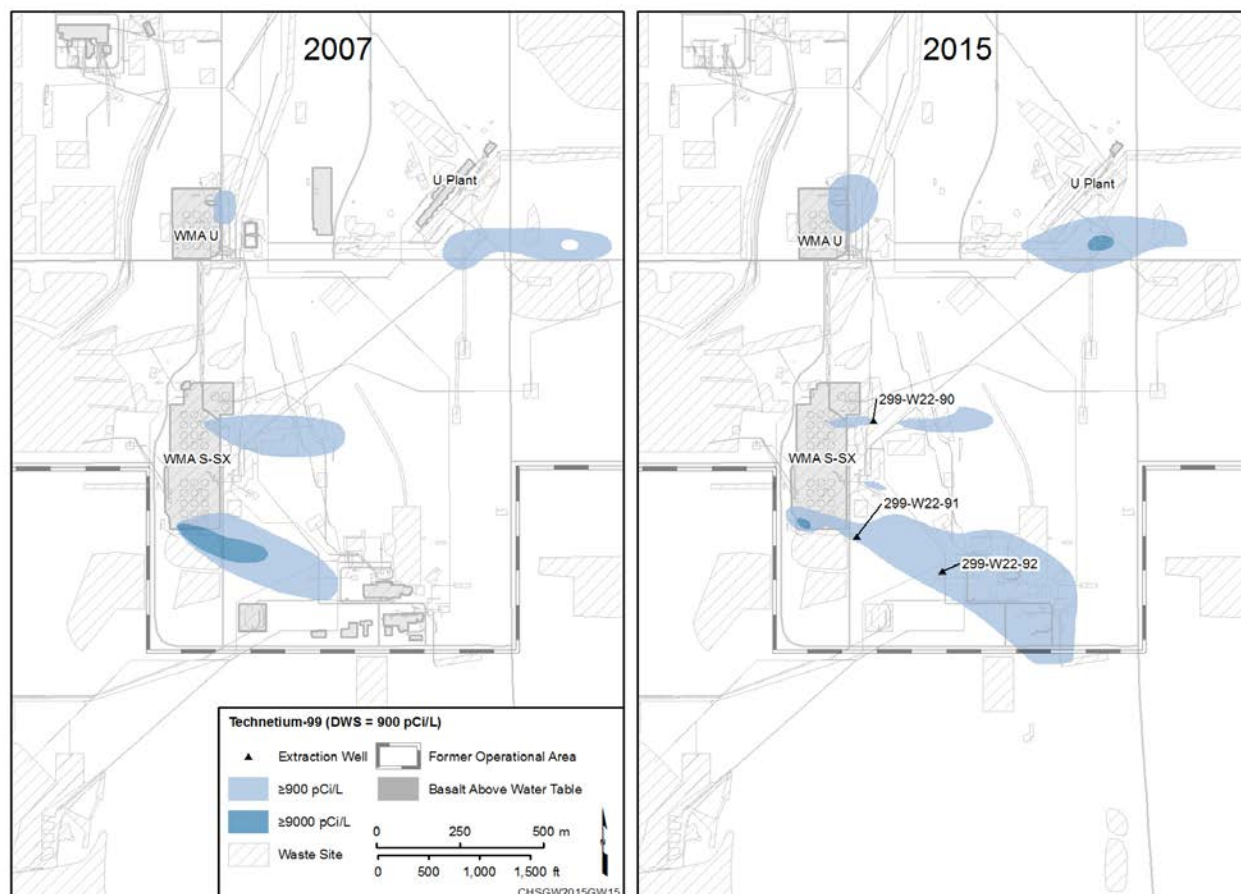


Figure 8.14. WMA S-SX Technetium-99 Plume in 2007 and 2015

RCRA monitoring in 200-UP includes interim status groundwater quality assessment monitoring at WMA S-SX and WMA U, and interim status indicator evaluation monitoring at the 216-S-10 Pond and Ditch. WMA S-SX has contaminated groundwater with chromium, nitrate, and the non-RCRA constituent technetium-99. Water levels have declined at WMA S-SX due to groundwater extraction, causing some monitoring wells to go dry. Three replacement wells were drilled and put into service in 2015, and a fourth well will begin operating in 2016. Sources within WMA U have contaminated groundwater with nitrate, chromium, and the non-RCRA constituent technetium-99. The groundwater beneath this tank farm is within the capture zone of a nearby extraction well. One new well was added to the network in 2015 to replace a dry well. Indicator parameters did not exceed statistical comparison values at the 216-S-10 Pond and Ditch during 2015.

The Environmental Restoration Disposal Facility is a CERCLA disposal facility used for disposal of low-level radioactive mixed waste generated by remedial actions. The results of 2015 groundwater monitoring continued to indicate that the facility has not impacted groundwater.

8.2.4 200-ZP

Contaminant sources in 200-ZP, located in the 200 West Area, included cribs, ponds, and single shell storage tanks. A final action ROD for the 200-ZP-1 OU groundwater identified carbon tetrachloride as the primary COC. Other COCs are trichloroethene, iodine-129, technetium-99, nitrate, chromium, and tritium.

A P&T system has reduced the area of the carbon tetrachloride plume with concentrations greater than 2,000 µg/L from 0.20 mi² (0.53 km²) in 1996 to zero in 2014 and 2015 (Figure 8.15). The interpreted plume area above 5 µg/L increased from 5.1 to 6.8 mi² (13 to 18 km²) between 2014 and 2015 as a result of a reinterpretation based on data collected during drilling of new wells and a model update.

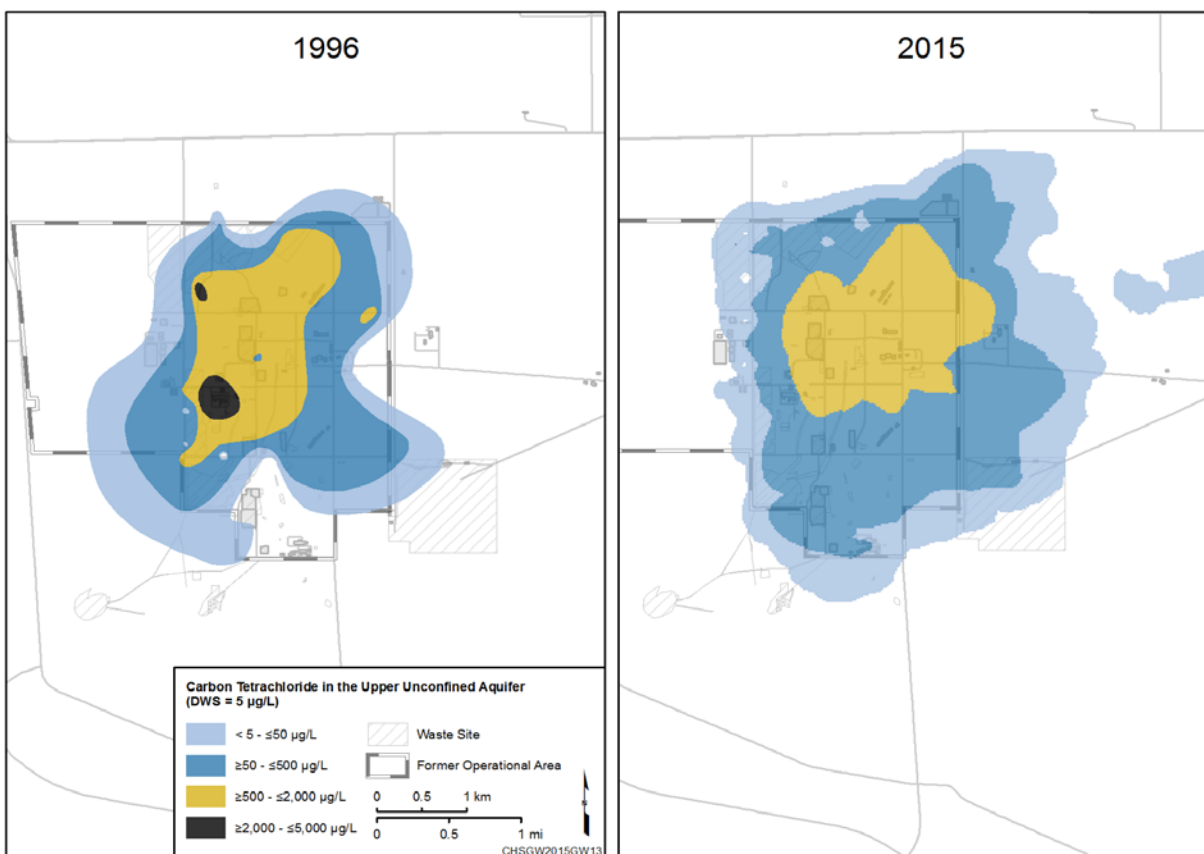


Figure 8.15. 200 West Carbon Tetrachloride Plume in 1996 (upper part of confined aquifer) and 2015 (including available vertical interval data)

In 2015, 26 extraction wells and 26 injection wells were in use, and the system processed 1.0 billion gal (3.8 billion L) of groundwater, removing 6,142 lbs (2,786 kg) of carbon tetrachloride, 768,159 lbs (348,431 kg) of nitrate, and other contaminants from groundwater. Combined, the final, interim, and soil vapor extraction systems have removed 227,698 lbs (103,282 kg) of carbon tetrachloride from the subsurface.

Four RCRA units were monitored in 200-ZP in 2015. LLWMA-3 and LLWMA-4 are monitored under interim status contaminant indicator evaluation programs. Monitoring results showed no indication that these LLWMAs are contaminating groundwater. RCRA assessment monitoring continued at WMA T and

WMA TX TY to track hexavalent chromium from the WMAs in groundwater. Groundwater beneath both WMAs is affected by CERCLA remediation activities (i.e., operation of the 200 West P&T system).

The State-Approved Land Disposal Site receives treated water from the Hanford Site Effluent Treatment Facility. It is regulated under a State Waste Discharge Permit and has created a local tritium plume. The Permit was renewed effective January 1, 2015 for 5 years. All groundwater sampling results from the proximal wells were within Permit compliance limits during 2015.

8.3 Confined Aquifers

Most Hanford Site groundwater contamination is found in the unconfined aquifer, but DOE monitors wells in deeper aquifers because of potential downward movement of contamination.

One confined aquifer occurs within sand and gravel at the base of the Ringold Formation. Carbon tetrachloride, chromium, and nitrate have entered this unit in a portion of the 200 West Area (200-ZP) where the upper confining unit is absent. Newer wells have been installed to monitor and remediate this contamination. The Ringold confined aquifer is the uppermost aquifer in a region east of the 200 East Area (within portions of 200-BP and 200-PO). Iodine-129 and tritium are detected in wells at this location, but the contamination has not migrated farther to the east or southeast.

In the northern Hanford Site, fine-grained sedimentary units, informally called the Ringold upper mud unit, confine deeper sediments in the Ringold Formation. In some parts of 100-HR, this unit is contaminated with hexavalent chromium at concentrations over 100 µg/L and is being remediated by a P&T system.

Groundwater within basalt fractures and joints, interflow contacts, and sedimentary interbeds make up the upper basalt-confined aquifer system. Groundwater monitoring data do not indicate that contamination has migrated into the upper basalt-confined aquifer.

8.4 Wells

Over the lifetime of the Hanford Site, DOE has installed thousands of wells to monitor and remediate groundwater and provide geologic data. During 2015, DOE installed 76 new wells, mostly to support groundwater remediation.

DOE identifies wells, boreholes, or other subsurface installations for decommissioning when they are no longer needed. This involves sealing the wells in compliance with Washington State standards for construction and maintenance of wells. In 2015, 38 borings and wells were decommissioned.

8.5 Additional Information

The data presented in this chapter and additional groundwater monitoring details are available in the *Hanford Site Groundwater Monitoring Report for 2015* (DOE/RL-2016-09) which, along with previous groundwater annual and related reports, is or will soon be available at <http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports>.

Additional information including environmental data, monitoring well locations, construction details, and screened intervals, can be found through the DOE Environmental Dashboard Application at <https://ehs.hanford.gov/eda/> or on the PNNL-Hanford Online ENvironmental Information eXchange (PHOENIX) website at <http://phoenix.pnnl.gov>.

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9.0 Soil Monitoring

JW Wilde, KR Turner

Radiological monitoring of soil is conducted at a variety of locations: on site near Hanford Site facilities and operations, on site away from facilities and operations, and off site at perimeter and distant locations and in nearby communities. Contaminant concentration data are used for the following:

- Determine the effectiveness of effluent monitoring and controls within facilities
- Assess the adequacy of containment at waste disposal sites
- Detect and monitor unusual conditions
- Provide information on long-term radionuclide contamination trends in soil at undisturbed locations.

Data obtained from on-site soil samples is used as a qualitative indicator and verification of ambient air sampling results per WDOH Radioactive Emissions License for the Hanford Site (FF-01).

Soil samples have been collected on and around the Hanford Site for more than 50 years; consequently, a large amount of data exist that document on- and off-site levels of manmade radionuclides in Hanford Site soils. These data provide a baseline to which unplanned releases are compared. The *Hanford Site Environmental Surveillance Master Sampling Schedule* is available for both CY 2015 ([DOE/RL-2013-53, Rev. 1](#)) and CY 2016 ([DOE/RL-2013-53, Rev. 2](#)).

9.1 Monitoring Results

Soil monitoring provides information about long-term contamination trends and baseline environmental radionuclide activities at undisturbed locations both on and off the Hanford Site according to the latest version of the *Hanford Site Environmental Monitoring Plan* ([DOE/RL-91-50](#)).

9.2 Sampling Results

Soil samples are collected near facilities and operations on the Hanford Site to detect potential migration and deposition of facility emissions and evaluate long-term trends in the environmental accumulation of radioactive materials. 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 groundwater or below ground waste, or translocation of buried waste by intruding animals.

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 in 2015 are summarized in Table 9.1. Only radionuclides with concentrations consistently above analytical detection limits are discussed in this section. Soil samples from off-site locations were collected in 2015.

Table 9.1. Soil Sample Locations

Number of Samples Analyzed	Operational Area (discrete samples analyzed)								ERDF
	ETF	100D	100H	200-West*	200-East*	300*	400	600*	
79	3	4	4	25	15	8	1	18	1

*Number of samples includes one or more duplicate samples.

Individual soil samples are 2.2 lbs (1.0 kg), which consist of five plugs of soil; each sample is approximately 1.0 in. (2.5 cm) deep and 4 in. (10 cm) in diameter. Soil samples were sieved in the field to remove potential sample intrusions such as rocks and plant debris, and then dried in the laboratory prior to analysis to remove residual moisture. Some soil samples were analyzed as a single sample (discrete code).

Soil samples were analyzed for radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides, strontium-90, uranium isotopes, and/or plutonium isotopes). The analytical results from Hanford Site soil samples were compared with concentrations of radionuclides measured in samples collected off site at various locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin counties in 2015 (Section 9.3). These comparisons were used to differentiate concentrations of Hanford Site-produced contaminants from levels resulting from natural sources and worldwide fallout.

On-site soil sampling results can be compared to the accessible soil concentrations ([WHC-SD-EN-TI-070](#), *Soil Concentration Limits for Accessible and Inaccessible Areas*) 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 hrs/yr in direct contact with the contaminated soil. The conservatism inherent in pathway modeling ensures the required degrees of protection are in place. These concentrations apply specifically to the Hanford Site with respect to onsite waste disposal operations, cleanup, and decontamination and decommissioning activities. A partial list of these values is provided in Table 9.2.

Table 9.2. Accessible Soil Concentration Limits for Selected Radionuclides*

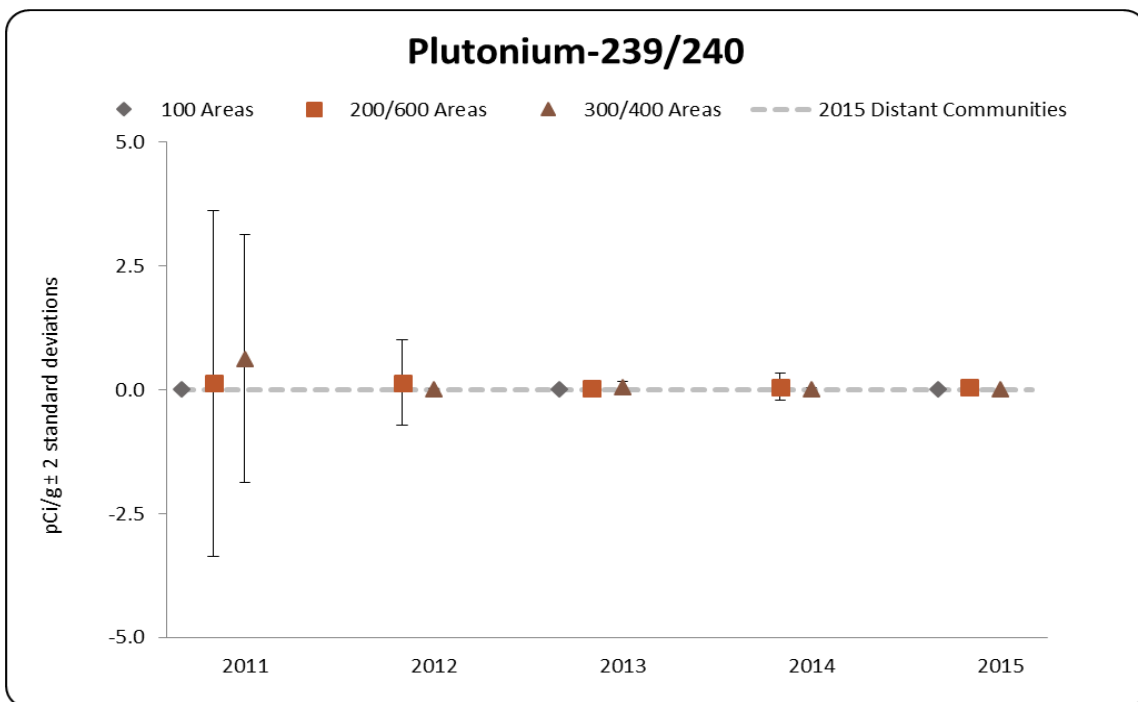
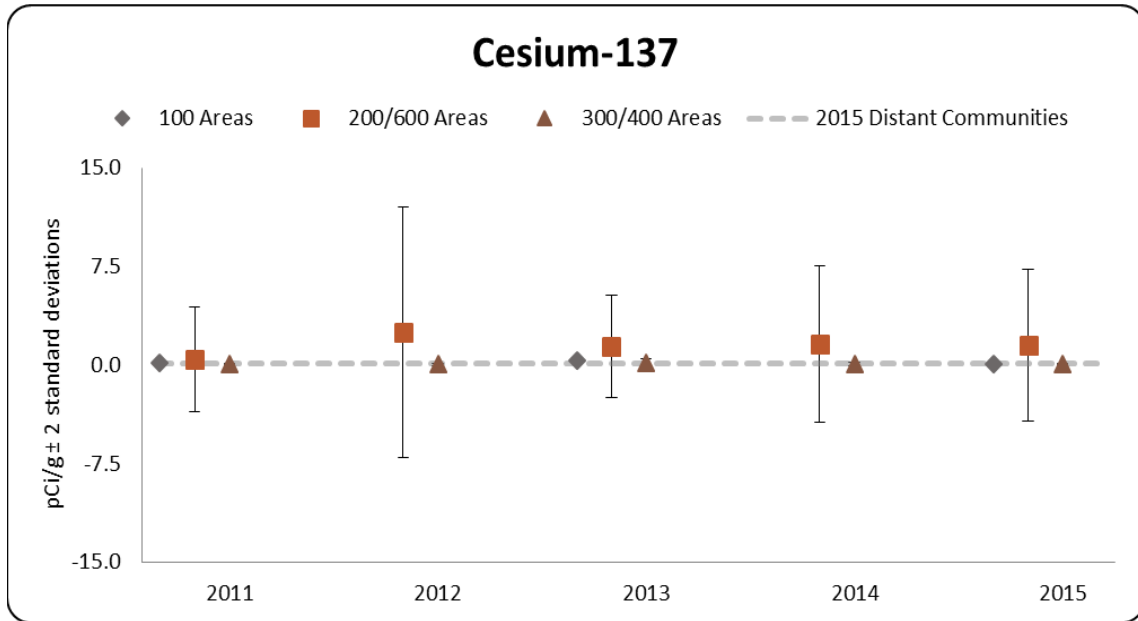
Category	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-235	Uranium-238	Plutonium-239/-240
Accessible soil concentration limits†	7.1	2,800	30	630	170	370	190

*pCi/g dry weight. To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

†Hanford Site soil that is not behind security fences; refer to [WHC-SD-EN-TI-070](#).

Some degree of variability is always associated with collecting and analyzing 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 2015 were higher than the concentrations in samples collected farther away. As expected, data also showed that concentrations of certain radionuclides in 2015 were higher in different operational areas when compared to concentrations measured in distant communities in previous years. Historically, the predominant radionuclides detected were activation and fission products in the 100 Areas, fission products in the 200 and 600 areas, and uranium in the 300 and 400 areas.

Cesium-137, strontium-90, plutonium-239/-240, and uranium were detected consistently in 2015 soil samples. Concentrations of these radionuclides were similar or slightly elevated near and within facility boundaries when compared to concentrations measured offsite at distant communities. Figure 9.1 shows the average concentrations of selected radionuclides in soil samples collected during 2015 and the preceding 4 years. Some individual levels demonstrate a high degree of variability, although overall trends are stable.



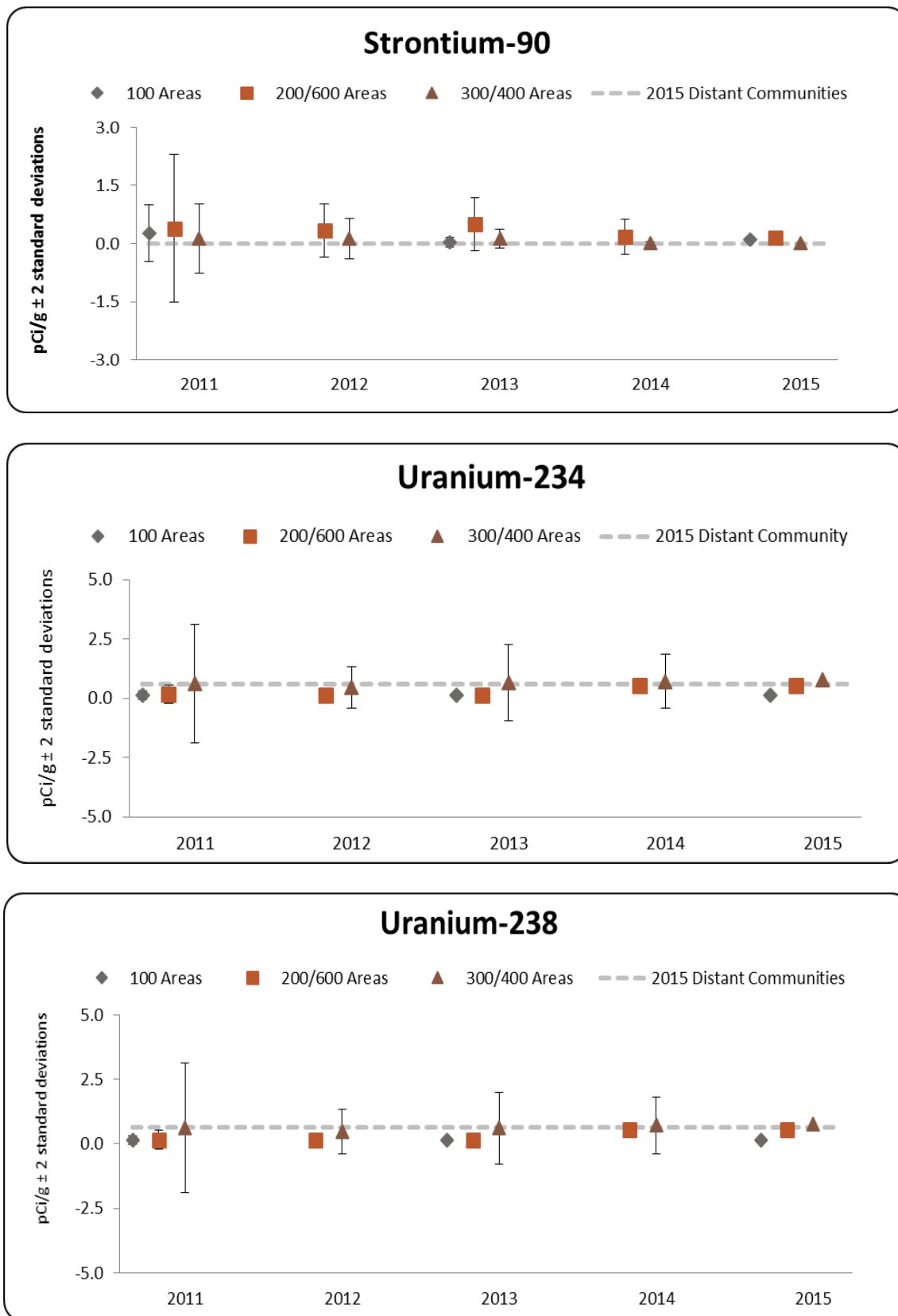


Figure 9.1. Hanford Site Soil Samples Average Concentrations of Selected Radionuclides, 2011–2015
As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol

Table 9.3 provides a summary of selected analytical results for near-facility soil samples collected and analyzed. The average and maximum results were reported for the major operational areas, along with comparative data for the preceding 5 years. Complete lists of radionuclide concentrations for all soil samples collected during 2015 as well as sampling location maps, are available upon request.

Results for soil samples collected in 2015 at locations in the 100, 200-East, 200-West, 300, and 600 areas were comparable to previous years. Soil samples collected in the 300 Area showed concentrations of uranium-234 and uranium-238 that were comparable to historical data, but remained higher than those measured in the 200 Area. The higher uranium levels in the 300 Area were expected because of uranium releases to the environment during past fuel-fabrication operations. Plutonium-239/-240 was detected in a number of soil samples in the 200, 300, and 600 areas. Strontium-90 was detected in the 200 and 600 areas and were within historical concentration ranges. Cesium-137 was detected consistently at levels comparable to historical levels over the past 5 years.

To comply with WDOH Notice of Construction requirements, special soil deposition sampling was collected during 2015 around the 200 Effluent Treatment Facility and Trench 94 of the 218-E-12B waste site in the 200-East Area. Sample results from both sites showed cesium-137 concentrations comparable to values from other sample areas. Table 9.4 provides a summary of selected analytical results for samples from these sites.

A soil sample is collected annually at ERDF from a predominantly downwind sampling location. The 2015 soil sample showed slightly elevated concentrations of uranium, however, detections were comparable to levels observed in previous years at other near-facility sampling locations on the Hanford Site.

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](#)). Soil samples collected on and around the Hanford Site for more than 50 years have been added to a large database documenting on- and off-site 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. Soil at site-wide (on-site away from facilities and operations) and off-site locations was last routinely monitored for radiation in 2004 (Section 8.9.2 in [PNNL-15222](#)).

Table 9.3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples*

Isotope	Hanford Area	2015		Maximum [‡] (pCi/gm)	2010 to 2014		Maximum [‡] (pCi/gm)
		Number of Samples	Detects	Average [†] (pCi/gm)	Number of Samples	Detects	Average [†] (pCi/gm)
Cobalt-60	100	8	0	N/A	41	4	6.5E-03 ± 4.0E-02
	200-East	15	0	1.1E-04 ± 2.4E-02	53	0	-5.6E-04 ± 1.4E-02
	200-West	25	0	-3.1E-03 ± 3.4E-02	85	0	-7.1E-04 ± 1.1E-02
	300	8	0	2.8E-03 ± 6.8E-03	56	0	3.8E-04 ± 1.2E-02
	400	1	0	-2.8E-03**	5	0	4.6E-03 ± 2.1E-02
	600	18	0	-2.6E-03 ± 4.7E-02	52	0	-4.6E-05 ± 1.3E-02
Cesium-137	100	8	0	N/A	41	40	2.0E-01 ± 3.7E-01
	200-East	15	15	3.4E+00 ± 1.0E+01	53	53	2.6E+00 ± 8.5E+00
	200-West	25	24	1.1E+00 ± 1.6E+00	85	83	1.2E+00 ± 2.5E+00
	300	8	4	4.0E-02 ± 5.5E-02	56	39	5.3E-02 ± 1.3E-01
	400	1	1	2.8E-02**	5	5	5.6E-02 ± 7.3E-02
	600	18	17	4.8E-01 ± 1.0E+00	52	52	9.5E-01 ± 7.3E+00
Plutonium-238	100	8	0	N/A	41	1	1.9E-03 ± 3.3E-02
	200-East	15	12	9.4E-04 ± 9.1E-04	53	2	3.1E-04 ± 2.7E-02
	200-West	25	19	9.0E-03 ± 5.5E-02	85	9	4.0E-03 ± 3.4E-02
	300	8	1	5.3E-05 ± 7.1E-04	56	2	1.2E-03 ± 2.2E-02
	400	1	0	1.4E-04**	5	0	-6.9E-03 ± 4.3E-02
	600	18	12	1.5E-03 ± 5.1E-03	52	3	9.4E-03 ± 1.0E-01
Plutonium-239/-240	100	8	0	N/A	41	13	1.2E-02 ± 1.6E-02
	200-East	15	15	1.6E-02 ± 2.7E-02	53	29	8.1E-02 ± 9.5E-01
	200-West	25	24	7.1E-02 ± 3.0E-01	85	71	1.4E-01 ± 6.6E-01
	300	8	7	3.8E-03 ± 1.0E-02	56	12	9.5E-03 ± 3.3E-02
	400	1	1	1.6E-03**	5	1	7.3E-03 ± 2.1E-02
	600	18	17	7.7E-02 ± 3.8E-01	52	26	1.3E-01 ± 1.4E+00
Strontium-90	100	8	0	N/A	41	1	-4.1E-01 ± 1.0E+00
	200-East	15	9	1.2E-01 ± 2.5E-01	53	22	4.5E-01 ± 4.7E+00
	200-West	25	22	1.7E-01 ± 2.6E-01	84	32	2.1E-01 ± 2.9E+00
	300	8	0	5.5E-03 ± 3.7E-02	56	1	-1.5E-01 ± 1.0E+00
	400	1	0	-4.4E-03**	5	0	-2.6E-01 ± 1.3E+00
	600	18	11	1.2E-01 ± 4.6E-01	52	14	-3.1E-02 ± 1.0E+00
Uranium-234	100	8	0	N/A	41	41	1.5E-01 ± 1.2E-01
	200-East	15	15	5.9E-01 ± 1.9E-01	53	52	2.1E-01 ± 3.6E-01
	200-West	25	25	5.1E-01 ± 2.0E-01	85	80	2.0E-01 ± 2.8E-01

Table 9.3. Concentrations of Selected Radionuclides in Hanford Site Soil Samples*

Isotope	Hanford Area	2015		Maximum‡ (pCi/gm)	2010 to 2014		Maximum‡ (pCi/gm)
		Number of Samples	Detects	Average† (pCi/gm)	Number of Samples	Detects	Average† (pCi/gm)
Uranium -235	300	8	8	8.3E-01 ± 1.2E+00	56	56	6.8E-01 ± 1.4E+00
	400	1	1	4.1E-01**	5	5	3.0E-01 ± 4.9E-01
	600	18	18	5.4E-01 ± 1.8E-01	52	51	2.0E-01 ± 2.9E-01
	100	8	0	N/A	41	20	1.2E-02 ± 1.5E-02
	200-East	15	14	7.5E-02 ± 5.2E-02	53	33	1.6E-02 ± 2.4E-02
	200-West	25	22	5.1E-02 ± 3.4E-02	78	43	1.6E-02 ± 2.5E-02
	300	8	8	6.8E-02 ± 9.6E-02	56	46	4.5E-02 ± 9.2E-02
	400	1	1	3.4E-02**	5	4	2.4E-02 ± 3.6E-02
	600	18	16	5.9E-02 ± 4.3E-02	42	21	1.6E-02 ± 2.4E-02
	100	8	0	N/A	41	41	1.5E-01 ± 1.2E-01
Uranium -238	200-East	15	15	5.8E-01 ± 1.8E-01	53	52	2.0E-01 ± 3.6E-01
	200-West	25	25	5.0E-01 ± 1.9E-01	85	80	2.0E-01 ± 2.7E-01
	300	8	8	8.2E-01 ± 1.1E+00	56	55	6.7E-01 ± 1.4E+00
	400	1	0	4.2E-01**	5	5	3.4E-01 ± 6.2E-01
	600	18	18	5.7E-01 ± 1.3E-01	52	51	2.0E-01 ± 2.7E-01
*pCi/g dry weight †Average ± two standard deviations ‡Maximum ± analytical uncertainty §Maximum value reported is a non-detect **Standard deviation cannot be calculated for one sample							

Table 9.4. Radionuclide Concentrations in Other Contractor Project Soil Samples*

Project/ Facility	Location†	Date	Cobalt-60	Strontium-90	Cesium-137	Uranium-234	Uranium-238	Plutonium-239/-240
Trench 94	D458	8/18/2015	-2.40E-04±2.40E-03	1.000E-01±3.50E-02	1.80E-01±2.30E-02	5.40E-01±1.20E-01	4.70E-01±1.10E-01	2.10E-03±5.90E-04
	D460	8/18/2015	-1.20E-02±2.20E-02	2.90E-02±2.70E-02	2.30E-01±3.50E-02	4.00E-01±1.10E-01	5.50E-01±1.30E-01	2.90E-03±5.90E-04
	D461	8/18/2015	-1.90E-03±9.30E-03	5.30E-01±1.10E-01	2.50E+00±2.20E-01	5.00E-01±1.20E-01	5.40E-01±1.20E-01	6.30E-03±9.30E-04
Effluent Treatment Facility	D457	11/12/2015	-8.80E-03±1.70E-02	1.50E+00±2.80E-01	9.40E+00±7.70E-01	5.70E-01±9.60E-02	6.20E-01±1.00E-01	1.90E-03±6.30E-04
	D458	11/12/2015	-1.40E-03±1.20E-02	4.70E-02±3.20E-02	2.00E-01±2.30E-02	4.70E-01±8.10E-02	4.80E-01±8.10E-02	1.50E-03±9.20E-04
	D459	11/12/2015	2.70E-03±9.50E-03	8.30E-02±3.80E-02	5.40E-01±4.80E-02	4.90E-01±8.90E-02	4.90E-01±8.70E-02	1.80E-03±8.40E-04
ERDF	D146	6/8/2015	8.40E-03±1.50E-02	1.20E-01±1.90E-01	1.5E-02±1.40E-02	8.6E-02±7.50E-02	1.1E-01±8.70E-02	-4.3E-03±3.60E-02
	D147	7/20/2015	-3.00E-02±2.20E-02	1.80E-01±1.60E-01	2.60E-01±5.00E-02	9.00E-02±6.90E-02	2.20E-01±1.10E-01	-1.40E-03±1.40E-02
	D171	7/20/2015	-2.00E-04±2.00E-03	8.10E-02±1.50E-01	4.30E-01±6.80E-02	3.30E-02±7.30E-02	1.20E-01±1.10E-01	3.10E-02±4.70E-02
100D	D172	7/20/2015	5.30E-03±1.50E-02	-9.40E-02±1.40E-01	1.20E-01±3.00E-02	1.10E-01±7.50E-02	1.00E-01±7.10E-02	-3.30E-03±2.80E-02
	D173	7/20/2015	6.30E-03±1.30E-02	3.00E-02±1.60E-01	1.50E-02±1.40E-02	4.60E-02±4.80E-02	5.40E-02	-2.80E-03±2.80E-02
	D152	10/12/2015	N/A	2.30E-01±1.70E-01	N/A	1.10E-01±9.40E-02	1.80E-01±1.20E-01	1.10E-01±1.70E-01
100H	D176	10/12/2015	-1.60E-03±1.30E-02	6.40E-02±1.50E-01	1.40E-01±3.20E-02	1.70E-01±1.10E-01	2.00E-01±1.20E-01	-3.90E-03±3.90E-02
	D177	10/12/2015	-4.90E-03±1.30E-02	1.30E-01±1.60E-01	1.40E-01±3.20E-02	2.50E-01±1.40E-01	1.90E-01±1.20E-01	-4.50E-03±4.50E-02
	D178	10/12/2015	-3.70E-03±1.60E-02	1.30E-01±1.60E-01	1.30E-01±3.30E-02	1.70E-01±9.90E-02	7.50E-02±7.00E-02	3.10E-02±6.80E-02
Accessible soil concentration‡			7.1	2,800	30	630	370	190

*pCi/g dry weight: 1 pCi = 0.037 Bq. Dry weight ± total analytical uncertainty.
†Sampling location code.
‡Hanford soils that are not behind security fences.

9.3 Soil Sampling at Hanford Off-site Locations

Soil samples were collected at 18 locations around the Hanford Site during 2015. Off-site samples were collected around the perimeter of the Hanford Site, George, McNary Dam, Othello, Sunnyside, Toppenish, Walla Walla, Wanapum, and Washtucna, WA.

All samples were analyzed for gamma-emitting radionuclides; strontium-90; uranium-234, -235, and -238; and plutonium-238 and -239/-240. Selected samples were also analyzed for americium-241. The 2015 radiological analytical results were compared to results from 1998, 2001, 2004, and 2008 (Table 9.5).

Table 9.5. Concentrations of Selected Radionuclides in Hanford Site Soil Samples Collected Off Site*

Isotope	Number of Samples Detects		2015		1998, 2001, 2004, and 2008			
			Average [†] (pCi/gm)	Maximum [‡] (pCi/gm)	Number of Samples Detects		Average [†] (pCi/gm)	Maximum [‡] (pCi/gm)
Cobalt-60	18	0	4.8E-03 ± 4.1E-02	6.1E-02 ± 7.0E-02§	0	0	N/A	N/A
Cesium-137	18	18	1.3E-01 ± 2.5E-01	4.4E-01 ± 1.0E-01	25	11	1.5E-01 ± 3.5E-01	4.8E-01 ± 5.3E-02
Plutonium-238	18	7	4.3E-04 ± 8.1E-04	1.6E-03 ± 4.7E-04	25	11	2.7E-04 ± 2.0E-03	7.0E-04 ± 2.4E-03
Plutonium-239/-240	18	18	4.9E-03 ± 1.2E-02	2.3E-02 ± 2.4E-03	25	20	4.8E-03 ± 9.0E-03	1.6E-02 ± 2.2E-03
Strontium-90	18	1	3.0E-04 ± 4.9E-02	5.3E-02 ± 3.3E-02	25	7	4.1E-02 ± 8.1E-02	1.4E-01 ± 4.6E-02
Uranium-234	18	18	6.1E-01 ± 2.6E-01	1.1E+00 ± 1.8E-01	0	0	N/A	N/A
Uranium-235	18	15	6.6E-02 ± 4.4E-02	1.1E-01 ± 4.7E-02	0	0	N/A	N/A
Uranium-238	18	18	6.3E-01 ± 3.2E-01	1.3E+00 ± 2.0E-01	25	23	5.7E-01 ± 1.5E-01	7.1E-01 ± 1.2E-01
Americium-241	0	0	N/A	N/A	4	3	4.1E-03 ± 7.6E-04	7.9E-03 ± 8.1E-03

*pCi/g dry weight, 1 pCi=0.037 Bq; [†]Average ± 2 standard deviations; [‡]Maximum ± analytical uncertainty; [§]Maximum value reported is non-detect

In 2015, observed mean radionuclide activities in soil samples for all isotopes off site were generally similar to their respective averages from 1998, 2001, 2004, and 2008 (Table 9.5). Plutonium-239/-240 concentrations appeared to be higher in 2015 than in previous years. The maximum detectable concentrations for cesium-137 and uranium-238 were also higher than maximum concentrations observed in 1998, 2001, 2004, and 2008, and the remaining radionuclides tested were similar to the maximum concentrations observed during those same years. The Hanford Site-wide average soil concentrations in 2015 were higher than at off-site locations for the radionuclides measured, consistent with historical data and reflecting the higher site-wide soil concentrations associated with years of nuclear materials production.

9.4 Radiological Contamination Investigations

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 Area and 200 Areas were strontium-90, cesium-137, and plutonium-239/-240. Uranium-234, uranium 235, and uranium 238 were routinely found in 300 Area samples.

There were 20 instances of radiological contamination in soil discovered during 2015 site investigations. Of the 20, eight were cleaned up and disposed of on site in licensed burial grounds, and the other 12 were posted as contamination areas. None of the soil samples was submitted for radioisotopic analysis. The number of soil investigation contamination incidents in 2015 were generally within historical values. Table 9.6 summarizes the number and general locations of soil contamination incidents investigated during 2015, and provides the number of contamination incidents investigated from 2000 through 2015.

Table 9.6. Soil Contamination Incidents Investigated

Location	2015 Incidents	Year	Incidents
100 Area	1	2000	25
200-East Area		2001	20
Tank farms	1	2002	22
Burial grounds	1	2003	30
Cribs, ponds, and ditches	0	2004	19
Fence lines	0	2005	20
Roads and railroads	0	2006	25
Unplanned release sites	0	2007	17
Underground pipelines	1	2008	16
LERF/ETF	0	2009	28
Miscellaneous	8	2010	22
200-West Area		2011	10
Tank farms	2	2012	10
Burial grounds	1	2013	21
Cribs, ponds, and ditches	0	2014	22
Fence lines	0	2015	20
Roads and railroads	0		
Unplanned release sites	1		
Underground pipelines	0		
Miscellaneous	1		
Cross-site transfer line	0		
200-BC cribs and trenches	0		
200-North Area	0		
300 Area	0		
400 Area	0		
600 Area	3		
Total	20		

10.0 Biota Monitoring

10.1 Agricultural Monitoring

ME Hoefler

Food and farm products (cherries, leafy vegetables, milk, potatoes, and tomatoes) were collected in 2015 at locations near the Hanford Site (Figure 10.1; note not all agricultural monitoring locations shown are sampled each year due to program efficiencies, budgetary restrictions and historical trending purposes). These products are used to determine pathway-specific exposure assumptions by way of annual dose calculations based on a 1 mrem/yr (10 mSv/yr) threshold and ingestion pathways for annual intake, assuming 100% of each food originated in the affected area.

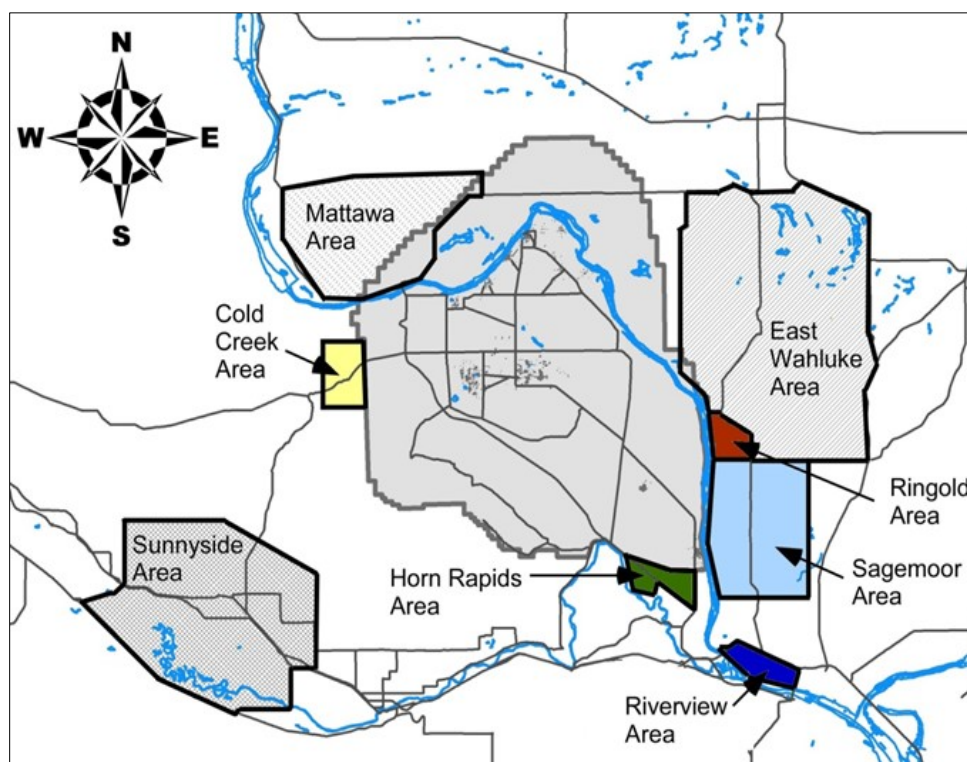


Figure 10.1. Agricultural Monitoring Locations

Samples analyzed to determine radiological contaminant concentrations were obtained from the following locations:

- generally downwind (east and southeast) of the Hanford Site where airborne emissions or contaminated dust from the site potentially would be deposited
- generally upwind of and distant from the Hanford Site to provide information about reference (background) contaminant levels
- from farms irrigated with water taken from the Columbia River downstream of the Hanford Site.

Sample analyses are used to assess the amounts of Hanford Site-origin contaminants in food and farm products by comparing analytical results obtained from similar samples collected from the same regions

over long periods of time; from samples collected at downwind locations to results from samples obtained from generally upwind or distant locations; and from samples collected in areas irrigated with water withdrawn from the Columbia River downstream of the Hanford Site to analytical results from samples obtained from locations irrigated with water from other regional sources.

Radionuclide concentrations in most food and farm product samples in 2015 were below the analytical laboratory detection levels; however, some potential Hanford Site-produced contaminants (e.g., strontium-90, tritium) were found at low levels in some samples. Data for potassium-40 are included to show the natural radioactive elements that exist in food products relative to concentrations of potential Hanford Site-produced contaminants. Radiological doses associated with potential Hanford Site-produced contaminants are discussed in Section 4.0. Where possible, the measured concentrations are compared to the applicable unusual concentration reporting levels. Unusual concentration reporting levels have been established based on environmental concentrations that would result in a dose of 1 mrem (10 mSv)/yr ([DOE/RL-91-50](#)). Agricultural products sampled in 2015 are listed in Table 10.1 and described in the following sections.

Table 10.1. Agricultural Monitoring Location

Product	Sampling Locations	Analytes
Alfalfa	Horn Rapids, Riverview, Sagemoor, Sunnyside	¹⁴ C, Gamma, Sr-90
Apples	Mattawa, Riverview, Sagemoor, Sunnyside	Gamma, Sr-90
Corn	East Wahluke, Riverview, Sagemoor, Sunnyside	¹⁴ C, Gamma, Sr-90
Leafy vegetables	East Wahluke, Riverview, Sagemoor, Sunnyside	Gamma, Sr-90
Melons	East Wahluke, Riverview, Sagemoor, Sunnyside	¹⁴ C, Gamma, Sr-90
Milk	East Wahluke, Sagemoor, Sunnyside	Gamma, Sr-90, Tritium
Potatoes	East Wahluke, Horn Rapids, Riverview, Sagemoor, Sunnyside	Gamma, Sr-90
Tomatoes	Riverview, Sunnyside	Gamma, Sr-90, Tritium
Wine	Columbia Basin, Mattawa, Yakima Valley	Low-level Tritium, Gamma

10.1.1 Milk

Milk samples were obtained quarterly in 2015 from several dairies in the East Wahluke and Sagemoor sampling areas and one dairy in Sunnyside. The Sunnyside dairy closed during the third quarter of 2015, so no data were available for the late summer and fall collections in relation to Sunnyside area milk. Another dairy is currently being sought to return to quarterly collections in all three areas in CY 2016.

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 Hanford Site. If milk were obtained from more than one dairy within a sampling area, the milk samples were combined, and the composite sample was analyzed. All samples were analyzed for gamma-emitting radionuclides, tritium, and Sr-90. 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 food chains to humans. In recent years, levels of Hanford Site-produced radiological contaminants in milk samples have diminished in conjunction with facility shutdowns and remedial efforts. Concentrations in samples obtained from dairies downwind of the Hanford Site are now similar to levels measured in samples obtained from the dairies generally upwind of the Hanford Site.

Tritium. Tritium was detected in all milk samples collected in 2015. Overall concentrations ranged from a maximum of 44 pCi/L (1.6 Bq/L) in a Sagemoor-area sample to a minimum of 12 pCi/L (0.44 Bq/L) in a Sunnyside-area sample. Annual average concentrations for the three sampling areas were 28 pCi/L (1.0 Bq/L). Specific location average was 35 pCi/L (1.3 Bq/L) for Sagemoor (n=4); 26 pCi/L (0.96 Bq/L) for East Wahluke (n=5); and 19 pCi/L (0.70 Bq/L) for Sunnyside (n=2). Maximum and average concentrations were less than those historically measured at these locations.

Strontium-90. No detectable concentrations were found in 2015 milk samples.

Cesium-137. No synthetic gamma emitters were detected in milk samples collected and analyzed in 2015.

Potassium-40. Naturally occurring potassium-40 was detected in all milk samples collected in 2015. Concentrations ranged from a maximum of 1,600 pCi/L (59 Bq/L) in a Sagemoor area sample to a minimum of 1,370 pCi/L (51 Bq/L) in an East Wahluke sample. The Sunnyside area had a maximum of 1,500 pCi/L (56 Bq/L), and the overall average was 1,476 pCi/L (55 Bq/L) for all results.

10.1.2 Fruit, Vegetables, and Farm Products

Alfalfa, apple, corn, leafy vegetable (e.g., lettuce), melon, potato, and tomato samples were collected from upwind and downwind sampling areas during the 2015 growing season (Figure 10.1; Table 10.1). All samples were analyzed for gamma-emitting radionuclides and Sr-90. Corn, leafy vegetables, and melons were also analyzed for carbon-14 for additional monitoring due to increased concentrations in the 100K area and to further support VIT plant-monitoring. Tomato samples were also monitored for tritium (Table 10.1) and showed no detectable concentrations during 2015.

Three of four leafy vegetable samples collected from the East Wahluke, Sagemoor, and Sunnyside areas had detectable Sr-90 with a maximum concentration of 0.006 pCi/L (2.2E-04 Bq/L), with results falling well within historical levels. All fruit and vegetable concentrations of cesium-137, cobalt-60, and tritium were reported as non-detects and were well within the historical 5-year range. All apple, cherry, corn, leafy vegetable, melon, potato, and tomato samples had detectable concentration levels of naturally occurring potassium-40.

Alfalfa (or similar foraging grass, e.g., Timothy, Orchard, etc.) samples were collected in the Horn Rapids, Riverview, Sagemoor, and Sunnyside areas in 2015. Analyses included gamma-emitting radionuclides and strontium-90. All samples had detectable concentrations of naturally occurring potassium-40, and a single sample from the Riverview area had a maximum detectable concentration of strontium-90 (0.098 pCi/L), similar to the maximum concentration reported in the previous 10 years (0.0975 pCi/L).

10.1.3 Wine

Wine samples were collected from the Columbia Basin, Mattawa area, and the Yakima Valley. All samples were analyzed for gamma-emitting radionuclides and tritium. Average concentrations (26 pCi/L) of vintage 2015 wine fell below historical averages (51 pCi/L) and maximum concentrations (39 pCi/L) found in 2015 also fell well below the 10-year maximum (447 pCi/L). Wine samples had detectable concentration levels of naturally occurring potassium-40 as well.

10.2 Fish and Wildlife Monitoring

JW Wilde

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during the 2015 calendar year were mountain whitefish (*Prosopium williamsoni*), white sturgeon (*Acipenser transmontanus*), Nuttall's cottontail rabbit (*Sylvilagus nuttallii*), and Canada goose (*Branta canadensis*). Monitoring fish and wildlife for uptake and exposure to Hanford Site operations-produced contaminants ensures that consumption of fish and wildlife obtained from Hanford Site environs does not pose a threat to human health and provides long-term contamination trends. These species were selected and monitored because they provide a potential pathway for off-site human consumption. Figure 10.2 shows locations on and around the Hanford Site where fish and wildlife were collected in 2015. Samples of fish and wildlife were analyzed for selected (suspected or known to be present) radionuclides and metals (Table 10.2). In addition, samples were collected from locations distant from the Hanford Site to obtain reference (background) contaminant measurements. All fish and wildlife samples were monitored for strontium-90 contamination and analyzed by gamma spectrometry to detect a number of 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.

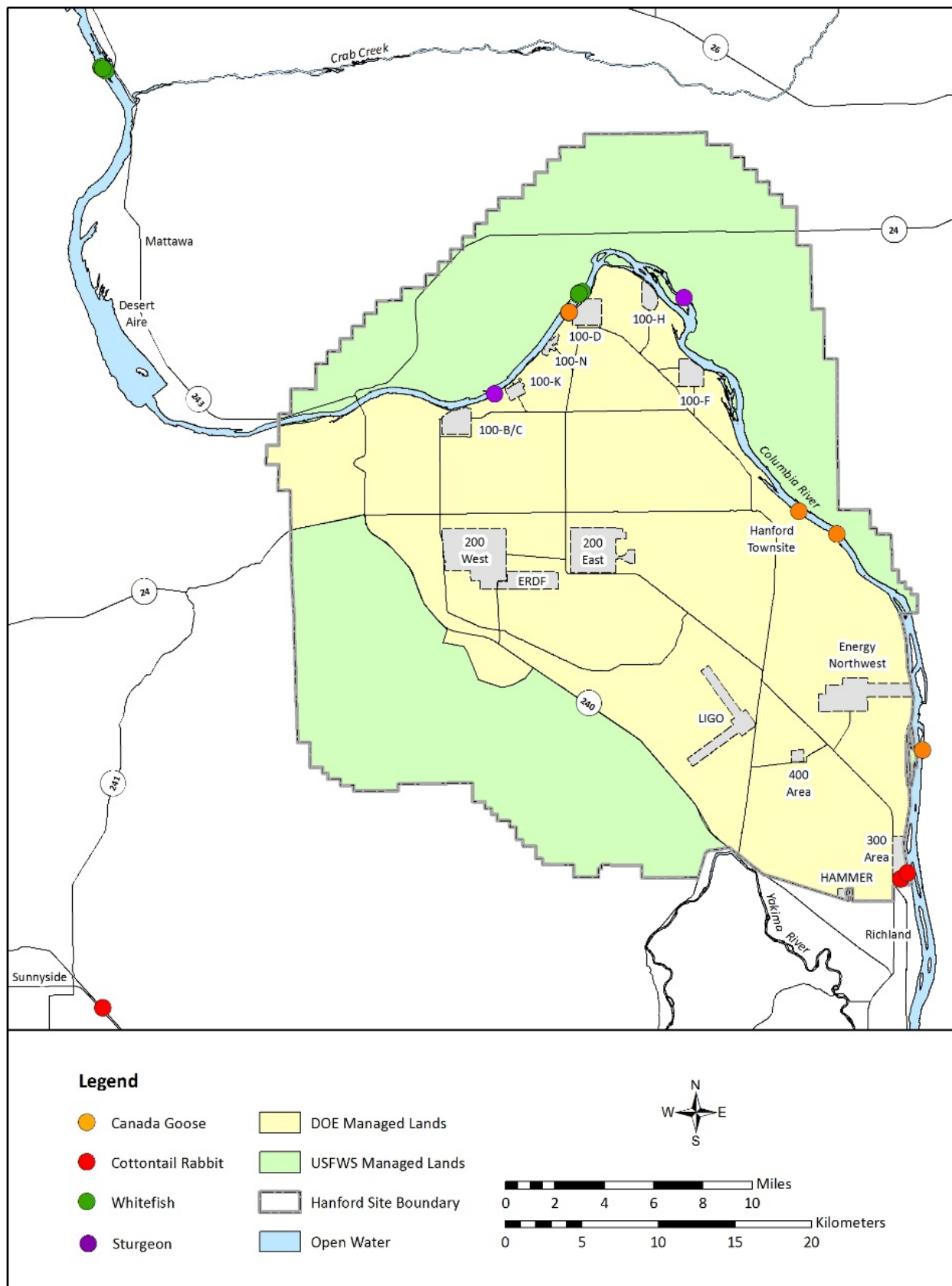
Table 10.2. Animal Monitoring Analysis

Biota	Off-site Locations	On-site Locations	Gamma	Strontium-90	Trace Metals
Fish (mountain whitefish)	1	3	18	18	4
Fish (white sturgeon)	0	5	10	20	9
Mammals (cottontail)	1	2	14	7	6
Waterfowl (Canada goose)	1	2	9	9	0

Most fish and wildlife samples are collected on and around the Hanford Site and analyzed for human-pathway exposure every 2 to 3 years, with samples obtained at locations determined not to be affected by Hanford Site effluents and emissions approximately every 5 years.

Strontium-90 is present in Hanford Site environments because of past Hanford Site operations and waste disposal practices. Contaminated groundwater entering the Columbia River through shoreline springs in the 100-N and 100-H areas is the primary source of measurable Hanford Site-produced strontium-90 in the Columbia River. Chemically similar to calcium, strontium-90 consequently accumulates in hard tissues rich in calcium such as bones, antlers, and eggshells. In addition, Sr-90 has a biological half-life in hard tissue from 14 to 600 days ([PNL-9394](#), *Ecotoxicity Literature Review of Selected Hanford Site Contaminants*). Hard-tissue concentrations may profile an organism's lifetime exposure to strontium-90; however, because strontium-90 does not accumulate in edible portions of fish and wildlife, it generally does not contribute much to the human dose ([NCRP 2009](#)).

Cesium-137 is present in Hanford Site environments because of past Hanford Site operations, waste disposal practices, and from historical worldwide fallout resulting from nuclear weapons testing. Cesium-137 is particularly important to the human food chain because the isotope is chemically similar to potassium and is found in the muscle tissues of fish and wildlife. Cesium-137 is an indicator of recent exposure to radioactive materials because it has a relatively short biological half-life (less than 200 days in muscle and less than 20 days in the gastrointestinal tract [[PNL-9394](#)]).

**Figure 10.2. Animal Monitoring Locations**

Gamma spectrometry results for most radionuclides generally are too low to measure or the concentrations measured are 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 analytical laboratory detection levels.

A number of trace metals associated with Hanford Site operations have a potential to accumulate in certain fish and wildlife tissues. These metals are contaminants of potential concern (e.g., copper, lead, and mercury), particularly along the Hanford Site Columbia River shoreline where contaminated groundwater flows into the river. Hanford Site historical operations have resulted in the production of both radiological and non-radiological wastes, including trace-metal emissions in a variety of forms. Liquid and solid wastes that were placed in disposal sites (trenches, cribs, ditches, ponds, and underground storage tanks), and fly ash (produced from burning coal in coal-fired steam/power plants associated with some Hanford Site reactors) released to the atmosphere. The fly ash contains trace metals and natural radionuclides that may have deposited on soil surfaces around the 100 Area reactors.

10.2.1 Mountain Whitefish

In 2015, mountain whitefish were sampled and analyzed for radiological contaminants, since whitefish are sometimes harvested for food along the Hanford Reach of the Columbia River, which could potentially contribute to human exposure through digestion. Many sportsmen have found that the flesh of the whitefish is of good quality, being firm, palatable, and tasty with a bony structure similar to trout.

Sixteen mountain whitefish were collected from three locations along the Hanford Reach, including a reference area (along the 100D shoreline and eight from the reference location at Priest Rapids Lake above Priest Rapids Dam). One whole fish from the 100 Areas and one whole fish from the reference area were sent to the WDOH. Three composite samples including one duplicate were used to achieve sample mass for larger suite of analyses including trace metals. Four fish from the 100 Areas created one composite, and four fish from the reference area made up the other. An additional two composites including a duplicate were comprised of two whitefish to meet mass for the standard Gamma Emitting Analysis and strontium-90 analysis. The following are the radiological results for the 10 mountain whitefish samples analyzed.

Cesium-137. Manmade gamma-emitting radionuclides including cesium-137 were not detected above the reporting limit (0.03 pCi/g [0.001 Bq/g] wet weight) in any of the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

Strontium-90. Strontium-90 was not above the required limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in whitefish samples collected from the reference area and the two Hanford Reach locations.

Uranium. Uranium isotopes were detected in three samples submitted. Two samples were from the reference area above Priest Rapids Dam and a single sample from the Hanford Reach, the detections of which were lower than samples from the reference area. Uranium-234 was reported at 5.50E-04 pCi/g in the 100 Area sample with an average of 6.77E-04 pCi/g in the two reference area samples. Uranium-238 was also lower in the 100 Area sample (4.22E-04 pCi/g) than the average of the reference area samples (7.64E-04 pCi/g).

Trace Metals. Two whitefish samples were analyzed for 18 different trace metal concentrations. Only seven trace metals were detected in samples that were above the analytical detection limit at any location. Table 10.3 provides a summary of the 2015 metal analyses for the whitefish samples.

Table 10.3. Metals Analyses for the Mountain Whitefish Samples

Isotope	Samples	Detects
Aluminum	3	0
Antimony	3	0
Arsenic	3	0
Barium	3	1
Beryllium	3	0
Cadmium	3	0
Chromium	3	0
Copper	3	3
Lead	3	0
Manganese	3	2
Mercury	3	0
Nickel	3	0
Selenium	3	2
Silver	3	0
Thallium	3	0
Thorium	3	2
Uranium	3	1
Zinc	3	3

Surveillance data sets for trace-metal concentrations in fish both on and near the Hanford Site are relatively small with variable results. At this time, no established federal or state adverse-effects values (i.e., benchmark criteria) are available for trace-metal concentrations in fish tissue. Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about contribution effects are limited by the factors above. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site will continue to provide important information for tracking the extent and long-term trends of contamination in the Hanford Reach environment.

10.2.2 White Sturgeon

During the week of July 16, 2015, a sudden die-off of large white sturgeon (*Acipenser transmontanus*) occurred in the Columbia River extending from Priest Rapids Dam through the lower Columbia River. The die-off provided an opportunity to collect tissue samples from white sturgeon not normally available. The collection activities took place from the Vernita Bridge down through the 300 Area. All white sturgeon found during the survey were reported to the WDFW with location information and requested measurements. A total of six white sturgeon were found dead within the Hanford Reach. All of the deceased fish ranged from 7 to over 9 feet in length, suggesting that most were at least over 40 years in age. Two of the six white sturgeon found were in a condition acceptable for representative tissue samples to be harvested and submitted for analytical evaluation. Eight samples (four muscles and four carcasses) were processed from the harvested fish tissue (including two duplicates of each tissue type) and sent to the analytical laboratory for analysis.

Cesium-137. Manmade gamma-emitting radionuclides, including cesium-137, were found in all three filet samples analyzed. Average tissue concentrations of cesium-137 were 1.168E-02 pCi/g.

Strontium-90. Strontium-90 was not found above the reporting limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in sturgeon samples collected from the Hanford Reach.

Uranium and Plutonium. Isotopic analysis for uranium and plutonium was performed on all samples. There was no detection of uranium and plutonium above detection limits in any sturgeon samples.

Trace Metals. Seven of the 18 different trace metal analyzed were detected in sturgeon samples above detection limits. Trace metal detections are presented in Table 10.4. Mercury was detected in all samples.

Table 10.4. White Sturgeon Metals Analyses

Isotope	Samples	Detects	Isotope	Samples	Detects
Aluminum	4	0	Manganese	4	2
Antimony	4	0	Mercury	4	4
Arsenic	4	0	Nickel	4	0
Barium	4	4	Selenium	4	2
Beryllium	4	0	Silver	4	0
Cadmium	4	0	Thallium	4	0
Chromium	4	0	Thorium	4	2
Copper	4	4	Uranium	4	0
Lead	4	0	Zinc	4	4

Surveillance data sets for trace-metal concentrations in fish on and near the Hanford Site are relatively small with variable results. At this time, no established federal or state adverse effects values (i.e., benchmark criteria) are available for trace-metal concentrations in fish tissue. Identifying Hanford Site contributions to trace-metal concentrations or drawing conclusions about the effects of this contribution are limited by the factors above. Monitoring fish for uptake and exposure to radionuclides and metals at locations near to and distant from the Hanford Site will continue to provide important information for tracking the extent and long-term trends of contamination in the Hanford Reach environment.

10.2.3 Cottontail Rabbit

Cottontail rabbits are useful for detecting localized radioactive contamination because they have relatively small home ranges, forage or live in potentially contaminated soil, and can enter fenced restricted areas that contain radioactive waste materials. They also may be useful as sentinel organisms both on and off the Hanford Site. In 2015, Nuttall's cottontail were sampled from the 300 Area. Public access to cottontails exposed to Hanford Site environs is limited due to the range size of the animal. The 300 Area poses the largest probability for public contact with rabbits from Hanford environs.

Five cottontail rabbits were collected from the 300 Area, including one from the reference area. A single rabbit from the 300 Area was sent to DOH. The following data are from the remaining four samples analyzed. Results from rabbits collected in 2015 were compared to samples collected in previous years.

Cesium-137. Cesium-137 was not found above detection limits (0.03 pCi/g [0.001 Bq/g] wet weight) in cottontail rabbit samples submitted for analysis in 2015. These results are consistent with a decline in cesium-137 levels in wildlife examined from the preceding years.

Strontium-90. Three rabbit bone samples collected at the Hanford Site in 2015 contained strontium-90 concentrations with an average detection at 0.107 pCi/g (0.0039 Bq/g) wet weight. All strontium detects were from rabbits collected in the 300 Area; the single reference area rabbit had undetectable strontium-90 concentrations. Figure 10.3 shows the historical median (shows average when only two samples are present) and maximum strontium-90 concentrations (pCi/g wet weight) in rabbit bone samples collected

near the Hanford Site and from reference locations from historical sampling events. It should be noted that the Figure 10.3 y-axis is on a log scale, suggesting that 2015 strontium levels are substantially lower than results seen historically in other areas of the site. In addition, maximum concentrations in the figure are represented by the upper bar.

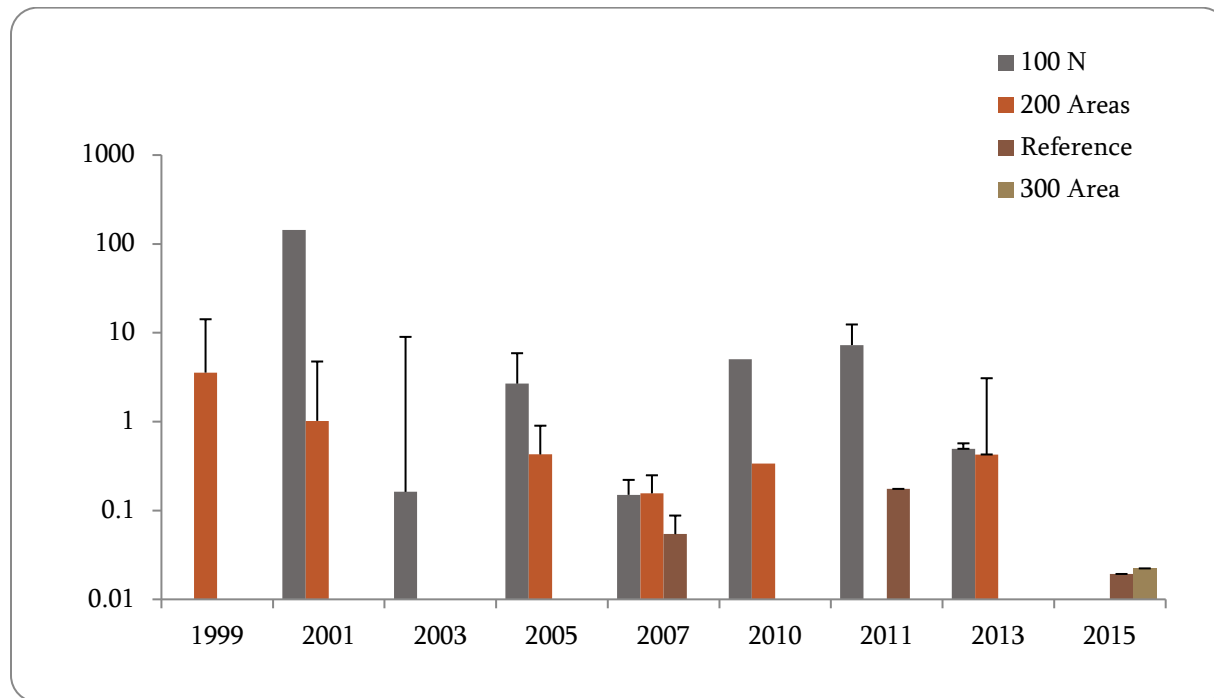


Figure 10.3. Strontium-90 Concentrations in Cottontail Bone Samples

10.2.4 Waterfowl

During 2015, six Canada geese were collected along the Hanford Reach of the Columbia River: three between the Hanford Townsite and the 300 Area, and three near the 100 Areas. Attempts to collect a reference sample goose from the Priest Rapids Lake area were unsuccessful. Sampling efforts focused on young of the year birds whose entire life cycle before collection would have occurred on the Hanford Site. All six geese were monitored for cesium-137 in muscle and strontium-90 in bone. Radionuclide levels found in muscle and bone samples analyzed during 2015 were compared with levels measured in waterfowl samples collected at the Hanford Site over the past eight sample evolutions and with samples collected from reference locations, where available.

Cesium-137. Manmade gamma-emitting radionuclides including cesium-137 were below the detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) for all Canada goose muscle samples analyzed in 2015. These results are consistent with those reported over the past 15 years, illustrating 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. Strontium-90 concentrations were below the analytical detection limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in all Canada goose bone samples collected in 2015. Comparisons of the maximum and median strontium-90 concentrations reported for waterfowl bone samples (collected at the

Hanford Site since 1997) and reference locations are consistent with these results, which do not indicate elevated strontium-90 levels. Figure 10.4 shows the median and maximum strontium-90 concentrations (pCi/g wet weight) and reference waterfowl samples for 2015 compared to previous years. Note that maximum concentrations in the figure are represented by the upper bar.

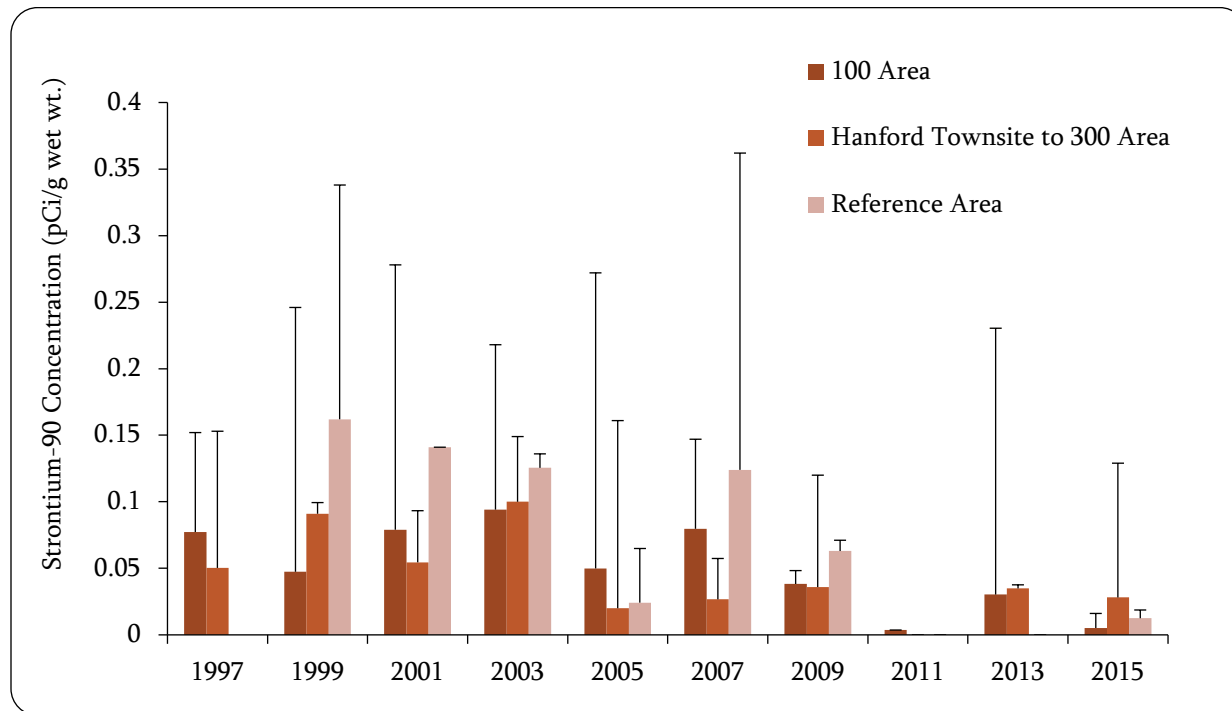


Figure 10.4. Strontium-90 Concentrations in Canada Goose Bone Samples

10.3 Vegetation Monitoring

JW Wilde, KR Turner

Vegetation monitoring conducted on and around the Hanford Site is summarized in this section. Included are discussions of surveying and monitoring of Hanford Site plant populations, monitoring contaminants in perennial vegetation growing near facilities and operations, and controlling contaminated or unwanted vegetation.

Plant populations and habitats that occur on the Hanford Site are surveyed and monitored 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. Vegetation near on-site facilities and operations is monitored for radiation to determine the effectiveness of effluent monitoring and controls within facilities, assess the adequacy of containment at waste disposal sites, and detect and monitor unusual conditions. Hanford Site and historical off-site vegetation samples are analyzed for information about atmospheric deposition of contaminants in and around operational areas on site and in uncultivated areas off site. These data provide a baseline against which unplanned releases can be compared. Vegetation management activities help prevent, limit, or remove contaminated plants or undesirable plant species. For further information about monitoring and control efforts, purpose, and programs that support them, refer to Section 10.3.3 or [DOE/RL-91-50](#).

Monitoring rabbitbrush and sagebrush leaves and stems provides information about atmospheric deposition of radioactive materials in uncultivated areas and at Hanford Site locations that potentially could be affected by contaminants from Hanford Site operations. Collected on and around the Hanford Site for over 50 years, vegetation samples are maintained in a database to document on- and off-site levels of synthetic radionuclides in vegetation at specific locations. This database contains baseline data against which statistics from unplanned releases from the Hanford Site can be compared.

Vegetation 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. 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 or by absorption of radionuclides through the roots of vegetation growing on or near former waste disposal sites.

The number and location of Hanford Site vegetation samples collected are summarized in Table 10.5. Only those radionuclides with concentrations consistently above analytical detection limits are discussed in this section. Data obtained from on-site vegetation samples is used as a qualitative indicator and verification of ambient air sampling results per FF-01. Vegetation samples from off-site locations were collected in 2015 and are discussed in Section 10.3.2.

Table 10.5. Vegetation Monitoring Locations

Samples Analyzed	Operational Area (discrete samples analyzed)					
	100-N	200-East Area	200-West Area*	300 Area*	400 Area	600 Area*
44	2	9	17	1	1	14

*Sample numbers include one or more duplicates

Individual vegetation samples (approximately 17.6 oz [500 g]) consisted of new-growth leaf cuttings taken from the available brushy, deep-rooted species (e.g., sagebrush and/or rabbitbrush). To avoid decimation of any individual plant through overharvesting, samples may consist of mixed biota representing several like members of the sampling-site plant community. Vegetation samples were dried prior to analyses, and analytical results were reported on a dry weight basis.

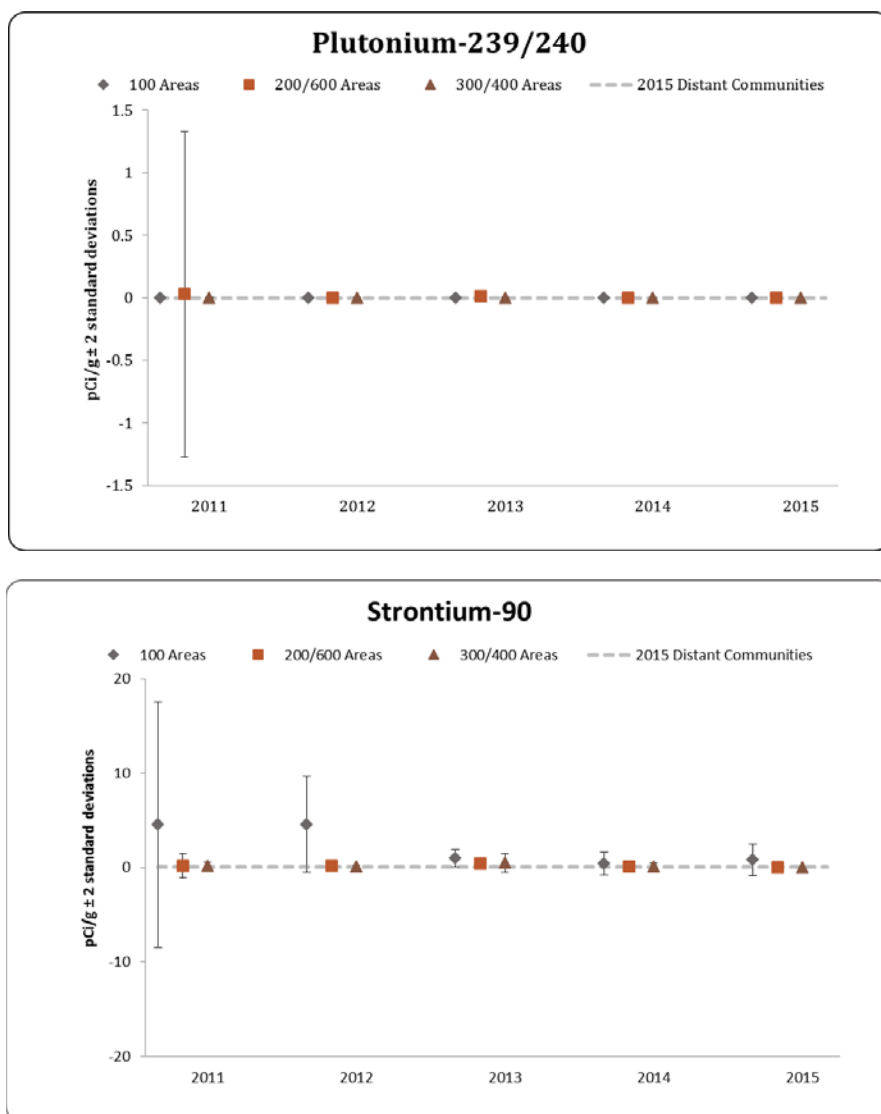
Some vegetation samples were analyzed as single-parent samples (discrete data points), while others were composited with a multi-incremental sampling approach, used when collecting samples from a large given area (i.e., decision unit). Individual samples are processed using a gridded pattern approach and combined with other samples from the decision unit to create a composite sample that represents the decision unit as a whole. This compositing limits the variability of selected environmental contaminant concentrations in a given area and reduces the amount of sampling error due to heterogeneity while allowing for a reproducible mean concentration for the decision unit.

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 2015 at off-site sampling locations in Yakima, Grant, and Franklin counties. 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.

10.3.1.1 Vegetation Monitoring Results

Some degree of variability is always associated with collecting and analyzing environmental samples; therefore, variations in sample concentrations annually are expected. In general, radionuclide concentrations in vegetation samples collected from or adjacent to waste disposal facilities in 2015 were higher than concentrations in samples collected farther away, including concentrations measured off site. Generally, the predominant radionuclides were activation and fission products in the 100 Areas, fission products in the 200 Areas and 600 Area, and uranium in the 300 Area and 400 Area.

Uranium-234, uranium-235, and/or uranium-238 were detected in 95 of the 2015 samples. Three samples showed detectable concentrations of cesium-137 and 12 samples showed detectable strontium-90 levels. Concentrations of detected radionuclides were elevated near and within facility boundaries compared to historic concentrations measured at distant communities; however, they remained within the historical range of those collected within facility boundaries. Figure 10.5 shows the Hanford Site average concentration of selected radionuclides for vegetation samples.



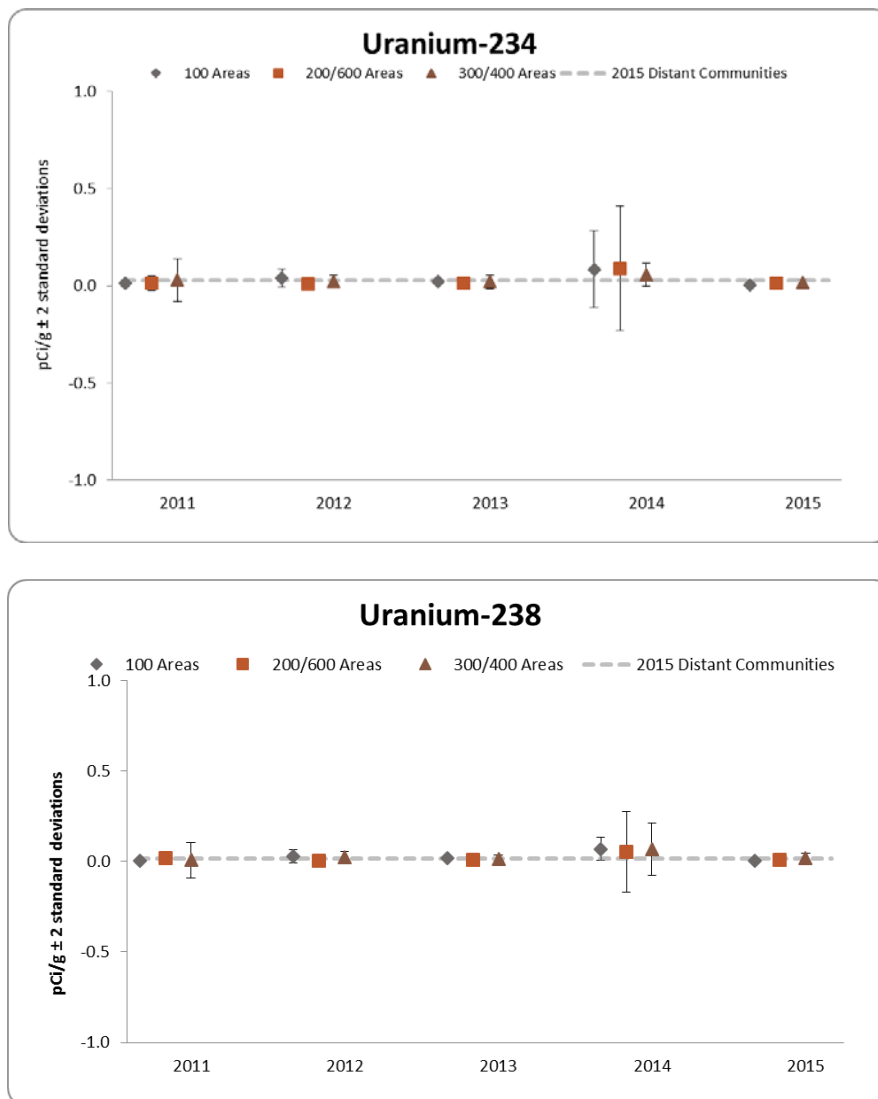


Figure 10.5. Hanford Site Vegetation Average Concentrations of Select Radionuclides

Table 10.6 provides a summary of selected radionuclides detected in vegetation samples collected and analyzed in 2015 and previous years. The average and maximum results are reported for the six primary waste facility/operational areas of interest, including comparative data for the preceding 5 years. Vegetation samples collected in 2015 at locations in the 100-N Area, 200-East Area, 200-West Area, 400 Area, and 600 Area were comparable to those collected in previous years. Vegetation samples collected in the 200 Areas and 600 Area showed concentrations of uranium-234, uranium-235, and uranium-238 that were comparable to historical data. The uranium levels are a result of uranium releases to the environment during past fuel-fabrication operations in that area. The range of strontium-90 concentrations was comparable to historical levels.

Table 10.6. Hanford Site Vegetation Concentrations of Select Radionuclides

Isotope	Hanford Area	2015				2010–2014			
		Number of Samples	Detects	Average* (pCi/gm)	Maximum† (pCi/gm)	Number of Samples	Detects	Average* (pCi/gm)	Maximum† (pCi/gm)
Cobalt-60	100	2	0	1.1E-02 ± 9.4E-03	1.6E-02 ± 4.0E-02‡	13	0	4.8E-03 ± 3.6E-02	3.6E-02 ± 8.8E-02‡
	200-East	9	0	1.23E-02 ± 4.3E-02	5.1E-02 ± 5.7E-02‡	39	0	-4.2E-03 ± 5.4E-02	5.4E-02 ± 1.1E-01‡
	200-West	17	0	3.5E-03 ± 4.1E-02	6.4E-02 ± 4.7E-02‡	71	0	-5.1E-03 ± 5.0E-02	5.4E-02 ± 8.6E-02‡
	300	1	0	-6.5E-02§	-6.5E-02 ± 6.1E-02‡	36	0	-2.9E-03 ± 6.7E-02	7.4E-02 ± 1.0E-01‡
	400	1	0	2.1E-02§	2.1E-02 ± 5.2E-02‡	4	0	-2.1E-02 ± 2.6E-02	-5.0E-03 ± 1.4E-02‡
	600	14	0	1.4E-02 ± 4.0E-02	6.7E-02 ± 6.5E-02‡	47	1	9.6E-03 ± 9.1E-02	2.6E-01 ± 1.3E-01
Cesium-137	100	2	0	-1.1E-02 ± 9.1E-03	-6.5E-03 ± 3.6E-02‡	13	1	2.2E-02 ± 5.7E-02	8.7E-02 ± 8.5E-02‡
	200-East	9	2	3.7E-02 ± 8.1E-02	1.2E-01 ± 4.3E-02	39	16	7.5E-02 ± 1.4E-01	3.3E-01 ± 1.4E-01
	200-West	17	1	1.9E-02 ± 2.7E-02	4.2E-02 ± 3.7E-02	71	19	6.5E-02 ± 1.3E-01	3.2E-01 ± 1.2E-01
	300	1	0	-6.3E-03§	-6.3E-03 ± 3.6E-02‡	36	9	5.7E-02 ± 1.8E-01	3.6E-01 ± 9.7E-02
	400	1	0	7.7E-02§	7.7E-02 ± 5.9E-02‡	4	0	1.2E-02 ± 2.9E-02	2.8E-02 ± 3.8E-02‡
	600	14	0	9.4E-03 ± 3.4E-02	4.6E-02 ± 3.6E-02‡	47	12	4.7E-02 ± 1.2E-01	2.0E-01 ± 8.6E-02
Plutonium-238	100	1	0	7.9E-04§	7.9E-04 ± 6.7E-04‡	13	0	-1.4E-03 ± 1.4E-02	6.4E-03 ± 1.4E-02‡
	200-East	9	1	5.0E-05 ± 1.1E-03	1.4E-03 ± 4.6E-04	39	1	1.4E-03 ± 1.2E-02	1.6E-02 ± 1.9E-02‡
	200-West	17	2	9.9E-05 ± 4.1E-04	3.9E-04 ± 3.8E-04	71	2	2.0E-04 ± 1.3E-02	2.7E-02 ± 1.2E-02
	300	1	0	1.8E-04§	1.8E-04 ± 3.3E-04‡	36	1	1.5E-03 ± 1.1E-02	1.9E-02 ± 2.1E-02‡
	400	1	0	-2.4E-05§	-2.4E-05 ± 2.4E-04‡	4	0	-1.4E-03 ± 5.1E-03	8.1E-04 ± 5.4E-03‡
	600	14	0	1.4E-05 ± 3.8E-04	4.2E-04 ± 4.9E-04‡	46	0	2.4E-03 ± 1.6E-02	3.2E-02 ± 2.3E-02‡
Plutonium-239/-240	100	2	1	1.4E-03 ± 1.3E-03	2.1E-03 ± 1.0E-03‡	13	2	1.9E-03 ± 7.2E-03	9.2E-03 ± 7.3E-03
	200-East	7	1	5.6E-04 ± 5.2E-04	9.2E-04 ± 5.3E-04	40	0	1.4E-03 ± 3.7E-03	5.7E-03 ± 5.6E-03‡
	200-West	17	13	1.2E-03 ± 1.5E-03	3.3E-03 ± 9.8E-04	71	34	3.2E-02 ± 3.2E-01	1.3E+00 ± 2.8E-01
	300	1	0	4.0E-04§	4.0E-04 ± 6.1E-04‡	36	0	1.2E-03 ± 3.6E-03	5.8E-03 ± 5.7E-03‡
	400	1	0	-1.3E-04§	-1.3E-04 ± 4.5E-04‡	4	0	5.6E-04 ± 3.8E-03	3.7E-03 ± 4.3E-03‡
	600	14	4	4.4E-04 ± 1.2E-03	1.9E-03 ± 7.1E-04	47	6	1.9E-03 ± 7.6E-03	1.3E-02 ± 6.8E-03
Strontium-90	100	2	2	7.9E-01 ± 1.1E+00	1.4E+00 ± 2.8E-01	13	10	2.2E+00 ± 7.4E+00	1.3E+01 ± 1.7E+00
	200-East	9	6	1.5E-01 ± 3.2E-01	5.0E-01 ± 1.2E-01	39	19	1.0E-01 ± 1.3E+00	1.0E+00 ± 2.8E-01
	200-West	17	4	3.1E-02 ± 1.1E-01	1.6E-01 ± 4.9E-02	17	14	2.73E-02 ± 5.6E-01	7.4E-01 ± 2.0E-01
	300	1	0	1.7E-02§	1.7E-02 ± 2.9E-02‡	36	10	6.6E-02 ± 5.0E-01	8.4E-01 ± 1.9E-01
	400	1	0	-2.2E-03§	-2.2E-03 ± 2.1E-02‡	4	0	-2.4E-02 ± 3.0E-01	1.5E-01 ± 1.7E-01‡
	600	14	0	1.6E-02 ± 4.5E-02	4.3E-02 ± 3.0E-02‡	47	9	-4.4E-02 ± 9.0E-01	1.3E+00 ± 3.4E-01
Uranium-234	100	2	1	6.5E-03 ± 4.1E-03	8.6E-03 ± 4.5E-03	13	11	3.5E-02 ± 9.7E-02	1.8E-01 ± 1.4E-01
	200-East	9	8	9.4E-03 ± 5.6E-03	1.5E-02 ± 5.6E-03	39	27	4.2E-02 ± 1.8E-01	3.6E-01 ± 1.8E-01
	200-West	17	13	1.5E-02 ± 1.4E-02	3.5E-02 ± 9.9E-03	71	58	2.9E-02 ± 1.3E-01	3.4E-01 ± 1.7E-01
	300	1	1	2.2E-02§	2.2E-02 ± 8.6E-03	36	31	3.1E-02 ± 5.9E-02	1.1E-01 ± 3.5E-02
	400	1	1	1.1E-02§	1.1E-02 ± 5.7E-03	4	2	1.9E-02 ± 2.1E-02	3.6E-02 ± 1.2E-01‡
	600	14	12	1.1E-02 ± 8.5E-03	2.1E-02 ± 7.5E-03	47	29	1.3E-02 ± 7.7E-02	1.3E-01 ± 1.3E-01‡
Uranium-235	100	2	1	3.6E-03 ± 3.5E-03	5.3E-03 ± 3.2E-03	13	2	9.3E-03 ± 2.4E-02	4.4E-02 ± 1.1E-01
	200-East	9	4	4.8E-03 ± 5.3E-03	9.5E-03 ± 4.9E-03	39	5	4.1E-02 ± 3.2E-01	0.0E+00‡
	200-West	17	11	4.9E-03 ± 2.9E-03	7.9E-03 ± 5.5E-03	71	17	7.2E-03 ± 9.2E-02	1.6E-01 ± 1.2E-01
	300	1	0	2.8E-03§	2.8E-03 ± 3.9E-03‡	36	9	3.6E-03 ± 1.1E-02	9.6E-03 ± 6.5E-03‡
	400	1	0	2.4E-03§	2.4E-03 ± 4.1E-03‡	4	1	2.6E-02 ± 7.3E-02	8.9E-02 ± 1.1E-01‡
	600	14	6	4.1E-03 ± 3.3E-03	8.4E-03 ± 4.4E-03	46	4	-7.0E-04 ± 5.7E-02	5.8E-02 ± 1.0E-01‡
Uranium-238	100	2	1	3.3E-03 ± 7.0E-04	3.7E-03 ± 2.7E-03	13	9	2.8E-02 ± 5.9E-02	1.0E-01 ± 1.2E-01‡
	200-East	9	8	8.0E-03 ± 3.6E-03	1.1E-02 ± 4.9E-03	39	21	2.6E-02 ± 7.6E-02	1.4E-01 ± 1.3E-01‡
	200-West	17	14	1.1E-02 ± 7.8E-03	2.0E-02 ± 7.1E-03	71	49	1.7E-02 ± 7.1E-02	1.4E-01 ± 1.1E-01
	300	1	1	2.7E-02§	2.7E-02 ± 9.2E-03	36	34	3.0E-02 ± 5.6E-02	1.2E-01 ± 1.1E-01
	400	1	1	6.9E-03§	6.9E-03 ± 4.4E-03	4	3	1.1E-02 ± 9.4E-03	1.8E-02 ± 7.9E-02‡
	600	14	12	7.8E-03 ± 4.4E-03	1.2E-02 ± 4.9E-03	47	33	1.2E-02 ± 9.8E-02	1.6E-01 ± 2.5E-01‡
*Average ± two standard deviations; †Maximum ± analytical uncertainty; ‡Maximum value reported is a non-detect; §Standard deviation cannot be calculated for one sample.									

*Average ± two standard deviations; †Maximum ± analytical uncertainty; ‡Maximum value reported is a non-detect; §Standard deviation cannot be calculated for one sample.

10.3.1.2 Vegetation Sampling at Hanford Off-site Locations

Vegetation samples were collected at six off-site locations around the Hanford Site in 2015. Off-site samples were collected around the perimeter of the Hanford Site, Sunnyside, George, and Wanapum, WA.

Vegetation samples consisted of the current year's growth of leaves, stems, and new branches from sagebrush and rabbitbrush. Samples were dried before analyses, and analytical results were reported on a dry weight basis. Shoreline samples were usually taken from a predominant species at the sampling location. A contaminant was detected if the analytical result was greater than the minimum detectable activity and was larger than the total analytical error. All six samples collected in 2015 were analyzed for gamma-emitting radionuclides, strontium-90, uranium isotopes (uranium-234, uranium-235, and uranium-238), and plutonium isotopes (plutonium-238 and plutonium-239/-40).

10.3.1.3 Analytical Results for Vegetation Samples Collected at Hanford Off-site Locations

Vegetation sampling results in 2015 generally confirmed observations from past sampling efforts. Strontium-90, cesium-137, plutonium-238, and plutonium-239/-240 concentrations were generally below nominal detection limits at off-site locations (Table 10.7). Uranium-238 was detected in two vegetation samples collected off site in 2015, and plutonium-239/-240 was detected in two of the off-site samples. The maximum uranium-238 concentration measured in vegetation during 2015 was collected at Sunnyside (0.036 ± 0.038 pCi/g [1.3 ± 1.4 mBq/g]). This result was higher than the maximum uranium-238 concentration measured at Hanford off-site locations between 1998 and 2008. The highest measured plutonium-239/-240 concentration (0.00075 ± 0.00042 pCi/g [0.028 ± 0.016 mBq/g]) was from a vegetation sample collected at Sunnyside. This concentration was higher than the maximum plutonium-239/-240 concentration measured at Hanford off-site locations between 1998 and 2008.

Table 10.7. Hanford Site Concentrations of Select Radionuclides in Off-site Soil Samples*

Isotope	Number of Samples Detects	2015	1998, 2001, 2004, and 2008					
			Average [†] (pCi/gm)	Maximum [‡] (pCi/gm)	Number of Samples	Detects	Average [†] (pCi/gm)	Maximum [‡] (pCi/gm)
Cobalt-60	6	0	$-1.4\text{E-}02 \pm 6.3\text{E-}02$	$9.0\text{E-}03 \pm 2.3\text{E-}02$ §	0	0	N/A	N/A
Cesium-137	6	0	$-3.9\text{E-}03 \pm 2.5\text{E-}02$	$8.3\text{E-}03 \pm 2.0\text{E-}04$ §	12	0	$7.4\text{E-}03 \pm 2.4\text{E-}02$	$3.0\text{E-}02 \pm 1.4\text{E-}02$
Plutonium-238	6	2	$2.2\text{E-}04 \pm 3.1\text{E-}04$	$5.0\text{E-}04 \pm 2.8\text{E-}04$	12	0	$2.6\text{E-}05 \pm 1.1\text{E-}04$	$1.1\text{E-}04 \pm 2.3\text{E-}04$
Plutonium-239/-240	6	2	$4.5\text{E-}04 \pm 4.8\text{E-}04$	$7.5\text{E-}04 \pm 4.2\text{E-}04$	12	5	$6.0\text{E-}04 \pm 2.0\text{E-}03$	$3.1\text{E-}03 \pm 7.3\text{E-}04$
Strontium-90	6	1	$2.8\text{E-}02 \pm 1.5\text{E-}01$	$2.0\text{E-}01 \pm 4.4\text{E-}02$	12	2	$2.5\text{E-}02 \pm 2.9\text{E-}02$	$8.7\text{E-}02 \pm 1.0\text{E-}01$
Uranium-234	5	2	$3.6\text{E-}02 \pm 5.9\text{E-}02$	$8.9\text{E-}02 \pm 5.6\text{E-}02$	0	0	N/A	N/A
Uranium-235	5	1	$1.5\text{E-}02 \pm 3.7\text{E-}02$	$5.1\text{E-}02 \pm 4.8\text{E-}02$ §	0	0	N/A	N/A
Uranium-238	6	2	$1.6\text{E-}02 \pm 2.3\text{E-}02$	$3.6\text{E-}02 \pm 3.8\text{E-}02$ §	12	3	$1.8\text{E-}02 \pm 1.5\text{E-}02$	$2.6\text{E-}02 \pm 1.3\text{E-}02$

*2015 compared with select previous years; pCi/g dry weight, where 1 pCi = 0.037 Bq; [†]Average \pm two standard deviations; [‡]Maximum \pm analytical uncertainty; §Maximum value reported is a non-detect

10.3.2 Radiological Contamination

JW Wilde, RC Roos

Investigations of 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 radiological conditions at specific project sites. All samples collected during investigations were field-surveyed for alpha- and beta-gamma radiation.

Radiological contamination was found in 48 vegetation samples surveyed during the 2015 investigations. Forty-seven of the samples were Russian thistle (*Salsola tragus*) or fragments, and one sample was

unidentified. No samples were analyzed for specific radionuclides. Tumbleweed surveys resulted in 8 locations posted as contamination areas; 40 samples were disposed at a licensed facility.

Section 10.3.1 provided a discussion of the vegetation control on the Hanford Site. Table 10.8 summarizes the number and general locations of vegetation contamination incidents investigated from 2000 to 2015.

Table 10.8. Hanford Site Vegetation Contamination Incidents Investigated

Location	2015 Incidents	Year	Incidents
100 Area	1	2000	66
200-East Area		2001	20
Tank farms	8	2002	16
Burial grounds	4	2003	32
Cribs, ponds, and ditches	3	2004	60
Fence lines	2	2005	66
Roads and railroads	1	2006	75
Unplanned release sites	0	2007	62
Underground pipelines	0	2008	127
LERF/ETF	4	2009	109
Miscellaneous	5	2010	36
200-West Area		2011	10
Tank farms	5	2012	18
Burial grounds	1	2013	35
Cribs, ponds, and ditches	7	2014	50
Fence lines	4	2015	48
Roads and railroads	0		
Unplanned release sites	0		
Underground pipelines	0		
Miscellaneous	0		
Cross-site transfer line	0		
600 Area burial grounds	1		
200-North Area	0		
300 Area	0		
400 Area	0		
600 Area	1		
1100 Area	1		
Total	48		

10.3.3 Vegetation Control

JM Rodriguez, RC Roos

The purpose of vegetation control at the Hanford Site is effective control and minimization of noxious weeds, industrial weeds, and other vegetation to ensure protection of Hanford Site workers, the public, facilities, property, and the site's cultural and environmental (including biological) resources. Risks that are mitigated through effective vegetation control are the spread of contamination, wildfire fuel loading, harborage of vermin and insect pests around facilities, damage and destruction of native plant communities, damage to facilities and interference with work and transportation.

Approximately 5,164 ac (2,090 ha) were treated with herbicides in 2015 on radiological waste sites, around operations areas, and along roadways to keep areas free of deep-rooted vegetation (e.g., Russian thistle, also known as tumbleweed). Follow-up treatments are included in the total treated acres; several areas received more than one herbicide application.

Noxious Weeds

Noxious weeds are controlled at the Hanford Site 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., the U.S. Department of Agriculture or Washington State Department of Agriculture). Noxious weeds are non-native, aggressively invasive, and hard to control. Noxious weed plant communities degrade ecosystems unless control measures are taken. Control measures can be mechanical, chemical, cultural, or biological. Approximately 94 ac (38 ha) of noxious weeds on the Hanford Site were treated with herbicides in 2015 along roadways. The *Environmental Assessment: Integrated Vegetation Management on the Hanford Site, Richland, Washington* ([DOE/EA-1728-F](#)) was completed in 2012. The FONSI clears the way to develop an appropriate process for NEPA clearance of noxious weed control.

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 2015 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 it 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 yellow starthistle have included spot treatments and broadcast applications by ground equipment and aerial sprayers, biological control, and hand weeding in critical locations. Major populations near the Hanford Townsite have been reduced to scattered individual plants, mostly near live trees where aerial herbicide applications were not made. Control of yellow starthistle in 2015 consisted of hand pulling individual plants as they were identified and spot treatment with herbicides on roadways and in areas of the Hanford Townsite.

Yellow starthistle seeds are known to remain viable for 10 years in the soil. The small number of seedlings found over much of the area of infestation indicates the seed bank is being exhausted. Careful control efforts over the next few years should result in the yellow starthistle changing from a major infestation to a monitoring and eradication effort.

Biological control agents for yellow starthistle are widely distributed across the infested area and have been highly effective during the early part of the flowering season. However, the adult phase of the control agent's annual lifecycle is completed before the end of the flowering season. Consequently, flowers opening late in the season are largely spared the effects of insect predation.

Successful control of yellow starthistle in the past has substantially reduced populations in both area and density. The biological control organisms require yellow starthistle in order to complete their lifecycle. The reduced plant population can no longer sustain a robust population of biological control organisms. As the population of bio controls fails, greater emphasis needs to be placed on effective monitoring and control of the plants to continue toward eradication of yellow starthistle at Hanford.

Rush Skeletonweed (*Chondrilla juncea*). Rush skeletonweed is a challenging species to control because their seeds are spread by the wind, allowing seedlings to germinate and begin new populations miles away from other plants. The deep and extensive root system of rush skeletonweed makes it extremely difficult to control using herbicides. Herbicide application may kill the main plant, but roots deep in the soil or far from the green portion of the plant often avoid the effects of herbicide. Those roots can remain living in

the soil for several years, eventually sending sprouts to the surface to begin new plants long after the effects of herbicide application have ended.

Rush skeletonweed is scattered over large areas of the Hanford Site. Areas of dense rush skeletonweed infestation north of the Wye Barricade largely have been eliminated. Nevertheless, considerable rush skeletonweed remains as scattered individual plants. Populations of rush skeletonweed have increased in some areas burned by past wildfires. Reduction in active control efforts over the past few years, while NEPA requirements have been evaluated, has allowed populations of skeletonweed to increase in both aerial extent and density. Rush skeletonweed has become the most challenging noxious weed to control on the Hanford Site due to the large aerial extent of infestation, density of infestation, and sustained effort required to eliminate individual plants and populations.

Biological control agents commonly applied to rush skeletonweed at the Hanford Site have not significantly reduced plant populations or seed production.

Babysbreath (*Gypsophila paniculata*). Babysbreath is generally resistant to control by herbicides; however, the above-ground portion of the plant can be destroyed by some herbicides that can prevent flowering and seed production. The plants should be eradicated by continually removing the top portions through herbicide use. By removing the green portions of the plants, the energy reserves in the roots will eventually be depleted, killing the plant. Mainly found in the Hanford Townsite, babysbreath was aggressively controlled in 2015 using herbicide and hand pulling in sensitive areas.

Dalmatian Toadflax (*Linaria genistifolia* ssp. *dalmatica*). A small population of dalmatian toadflax is found near Energy Northwest on the Hanford Site. Sprouts and seedlings of the long-lived perennial plant will be eliminated as they are identified. The current population consists of plants widely scattered across the area of infestation. The low density population is not conducive to successful establishment of predatory species. Consequently, no biological controls have been released at the Hanford Site for dalmatian toadflax. Toadflax growing along road shoulders were controlled using herbicides.

Diffuse Knapweed (*Centaurea diffusa*). In 2015, control of diffuse knapweed was limited to herbicide application on roadways and hand pulling in critical areas. The population of this species near the Columbia River high watermark has not been actively controlled by herbicides because of the biological sensitivity of the area. Established biological controls assist staff members with monitoring and observing effectiveness in controlling the weed.

Tackweed (*Tribulus terrestris*). Tackweed has become increasingly common on the Hanford Site over the past several years. In 2015, a large population found at the Hanford Townsite was controlled aggressively using a combination of herbicide application and hand pulling. Other tackweed found across the Hanford Site as individual plants or small populations were also controlled.

Purple Loosestrife (*Lythrum salicaria*). The banks of the Columbia River bank and islands along the Hanford Site are monitored for purple loosestrife, as these locations in these areas are appropriate for this weed. Individual plants and small populations are found along the south and west bank of the river.

Under good ecological conditions, biological measures for controlling purple loosestrife are effective; however, widely fluctuating levels along the Columbia River destroy the biological control organisms as they attempt to over-winter soil at the plant bases. Winter mortality prevents effective population control agents from developing. No control measures were applied in 2015 for purple loosestrife.

Russian Knapweed (*Acroptilon repens*). Biological controls for Russian knapweed are limited, and their success has been poor in the semi-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 were found at the Hanford Site in years past. Most are the remainders 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 continue to be treated with herbicide and will be monitored until they are eradicated.

Saltcedar roots are very deep and store a great deal of energy, making control of the species difficult. A few trees that were treated with herbicide in 2014 began to show new green growth in 2015. Effective control of weeds often depends on the plant having sufficient green-leaf area for herbicide to enter the plant. The small amount of green growth found in 2015 was not sufficient for effective herbicide application. It is expected that these trees will be sprayed with herbicide in 2016.

Spotted Knapweed (*Centaurea maculosa*). Spotted knapweed at the Hanford Site has been controlled so that sprouts or seedlings are rare. In 2015, no sprouts or seedlings were found. The Hanford Site will continue to be monitored for several years to ensure 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. The root-feeding weevil *Cyphocleonus achates* has been released specifically to help eradicate spotted knapweed at Hanford, but it is expected that the population is too small and scattered to sustain a biological control population. *Cyphocleonus* is known to use diffuse knapweed, however, and it is hoped that this weevil will establish in diffuse knapweed and cross over to control spotted knapweed when it appears. Most biological controls for diffuse knapweed also are effective for spotted knapweed.

10.3.4 Mulberry Sampling at the 100N Shoreline

CJ Perkins, SE Johnson

In late May/early June 2015, leaf, bark, and fruit samples were collected from mulberry trees growing along the 100N Area shoreline (Figure 10.6) in an exploratory sampling effort to attain qualitative radio-inventory information. Three groups of 2 to 4 trees were collected to create composite samples, the most upstream (UR) of which was intentionally sited in a known strontium-90 groundwater/spring plume near outfall 100N-79.

Two additional groups of trees located approximately 60 m and 130 m downstream from the first group comprised a midriver and downriver composite sample, respectively. Reference samples of leaf, bark, and fruit were collected upstream of the Hanford Site near the Vernita Bridge rest area.

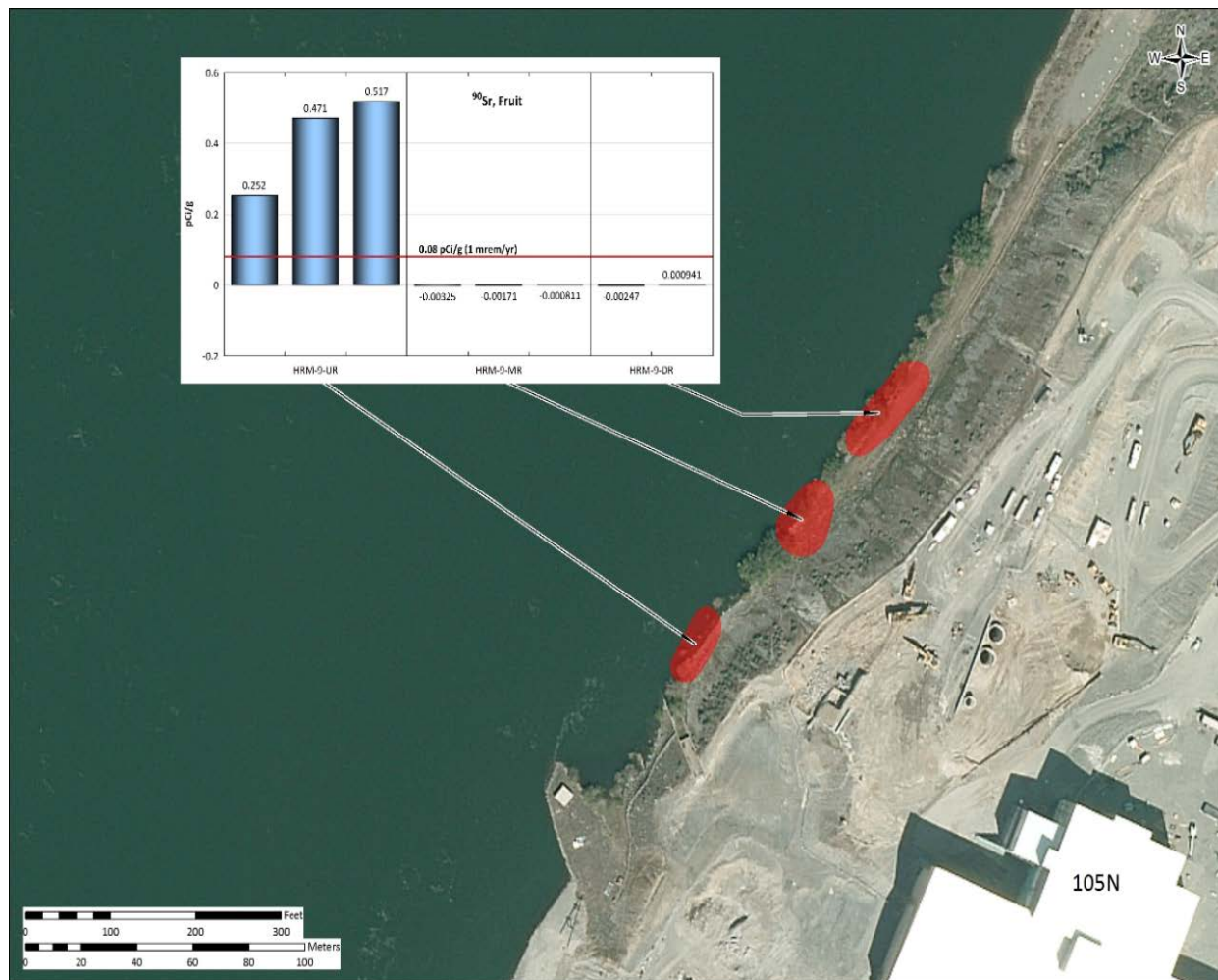


Figure 10.6. Mulberry Tree Sample Locations and Strontium-90 Concentrations (pCi/g) in Fruit Samples

Analytical data indicate that the strontium-90 concentration in fruit samples collected from the upriver group of trees were above the DOE 1 mrem/yr dose reporting threshold. The EPA's Ingestion Model assumes that a 170-lb (80-kg) individual would have to consume approximately 11 oz (311 g) of fruit with a strontium-90 concentration at 0.08 pCi/g every day for a year to receive the 1 mrem dose. The highest strontium-90 levels measured in 100N fruit at the UR location was approximately 0.52 pCi/g, about 6 times higher than the 0.08 pCi/g value, theoretically resulting in an annual dose of approximately 6 mrem to the mulberry consumer. This is an unlikely scenario, as the available quantity of fruit would limit the consumer's intake and therefore the dose. A person would ultimately need to ingest approximately 240 lbs of the fruit per year to receive a 1 mrem dose, while the typical fruit yield for this species of tree (white mulberry) ranges from 5–25 lbs/yr.

Strontium-90 was not detected in the fruit samples in any of the other locations, and no other radionuclides were detected above the 1 mrem/year dose-based reporting value (Table 10.9).

Table 10.9. Concentrations (pCi/g)* of Select Radionuclides in 100N Shoreline Mulberry Tree Samples

Radionuclide	Sample Type	Number of Samples	Detections†	Average‡	Maximum§	Maximum Location
Tritium	Fruit	6	4	7.8E-01 ± 2.4E+00	2.7E+00 ± 4.9E-01	HRM-9-UR
	Leaves	6	3	8.5E-01 ± 2.7E+00	3.5E+00 ± 4.9E-01	HRM-9-UR
	Bark	6	0	3.9E+00 ± 1.1E+01	1.3E+01 ± 1.0E+01	HRM-9-UR
Strontium-90	Fruit	10	3	1.2E-01 ± 4.2E-01	5.2E-01 ± 9.8E-02	HRM-9-UR
	Leaves	11	9	7.2E-01 ± 2.1E+00	3.2E+00 ± 6.0E-01	HRM-9-UR
	Bark	8	7	1.2E-01 ± 8.4E-01	3.2E+00 ± 6.0E-01	HRM-9-UR
Technetium-99	Fruit	6	0	-1.9E-02 ± 5.0E-01	3.9E-01 ± 4.4E-01	HRM-9-MR
	Leaves	6	0	3.5E-01 ± 8.2E-01	7.5E-01 ± 7.8E-01	HRM-9-MR
	Bark	6	0	-6.3E-02 ± 7.5E-01	3.2E-01 ± 8.2E-01	HRM-9-DR
Cesium-137	Fruit	6	0	1.2E-01 ± 1.7E+00	9.2E-03 ± 1.1E-02	HRM-9-UR
	Leaves	5	0	4.1E-03 ± 1.0E-02	1.1E-02 ± 1.3E-02	HRM-9-UR
	Bark	0				
Uranium-234	Fruit	6	5	7.2E-03 ± 8.4E-03	1.3E-02 ± 5.6E-03	HRM-9-MR
	Leaves	6	5	7.2E-03 ± 5.4E-03	1.0E-02 ± 3.8E-03	HRM-9-DR
	Bark	6	5	1.1E-02 ± 9.0E-03	1.9E-02 ± 6.0E-03	HRM-9-UR
Uranium-238	Fruit	6	5	5.3E-03 ± 4.8E-03	9.4E-03 ± 4.3E-03	HRM-9-MR
	Leaves	6	5	5.3E-03 ± 3.6E-03	7.6E-03 ± 3.2E-03	HRM-9-UR
	Bark	6	3	8.5E-03 ± 9.9E-03	1.4E-02 ± 5.1E-03	HRM-9-UR

*1 pCi = 0.037 Bq

†Number of samples with measurable concentrations of contaminant.

‡Average ± two standard deviations of all samples analyzed.

§Maximum ± analytical uncertainty.

10.4 Waste Site Remediation and Revegetation

RC Roos, JM Rodriguez

In 2015, 46 ac (18.6 ha) were planted with grass seed to stabilize areas where traffic and erosion had damaged the grass cover on waste sites. Waste sites in the 200 East and 200 West areas were designed and constructed with a cap of perennial grass essential to performance of engineered waste sites. However, soil used as backfill and cover on waste sites was often sandy, which provides a poor medium for growth of the grass. Over the years, poor soil combined with lack of maintenance has resulted in degradation and decreased function of the vegetative caps on many waste sites. Integrated Biological Control has been actively restoring vegetative caps on other waste sites.

Vegetative caps on waste sites perform three primary functions:

1. **Prevent Erosion.** A well-designed and maintained grass cap stabilizes soil on waste sites by physically covering the soil surface and serves as a windbreak, reducing wind velocity at the soil surface.
2. **Exclude Tumbleweed Growth.** Tumbleweeds are the main biological vector of contamination spread on the Hanford Site. They are deep-rooted annual plants that quickly invade and establish on disturbed soil. The deep roots readily absorb radionuclides buried in the soil and transport them to the aboveground portions of the plant. At the end of the 1-year lifecycle, dead tumbleweeds detach from the roots and become mobile, transporting radioactive contamination from posted and monitored disposal areas.

A well-designed and maintained grass cap excludes tumbleweeds by direct competition for space and nutrients (primarily water). Stabilized soil forms a crypto-biotic crust composed of moss, lichen, algae, and other organisms that provide a poor surface for germination of tumbleweed seeds. The combination of competition for resources and prevention of germination effectively excludes tumbleweeds from establishing on waste sites.

3. **Prevent Water Percolation through the Soil Column.** Waste sites were designed with vegetative caps to prevent natural precipitation moving through the soil column and washing radioactive or hazardous materials downward toward groundwater.

The 6- to 7-in (15- to 18-cm) average precipitation received at the Hanford Site typically percolates 2–4 ft (0.6–1.2 m) into the soil during the winter. Evaporation during summer months removes some moisture from the soil. However, as surface soil dries, it acts as a mulch, which inhibits further evaporation. Evaporation alone does not remove all the natural precipitation from the soil. Water remaining in the soil from the previous year has an additive effect during the subsequent wet season, allowing water to percolate to increasing depth.

Vegetative caps on waste sites were designed so that in addition to evaporation from the soil surface, plant roots would mine water from deeper in the soil profile, transporting it to leaves where it is lost through evaporation. The process of water moving from soil into plant roots, through the plant and out the leaves to the atmosphere is transpiration. The combination of evaporation and transpiration removes sufficient moisture from the soil so that precipitation during subsequent wet seasons falls on dry soil, yielding no net increase in depth of percolation. Effective containment of waste in burial grounds depends on the combination of evaporation and transpiration drying the soil, preventing additive percolation and transport of contaminants to groundwater.

11.0 Resource Protection

11.1 Ecological Protection

JW Wilde, KJ Cranna, JE Grzyb, JJ Nugent, JA Pottmeyer

Ecological monitoring is performed on the Hanford Site to collect and track data needed to ensure compliance with an array of environmental laws, regulations, and policies governing DOE activities. Ecological monitoring data provide baseline information about the plants, animals, and habitat under DOE stewardship at Hanford required for decision-making under NEPA and CERCLA.

The *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (CLUP; [DOE/EIS-0222-F](#)) evaluated the impacts associated with future land-use planning at the Hanford Site. The purpose of this land-use plan and its implementing procedures is to facilitate decision-making about the site's uses and facilities over at least the next 50 years. The DOE decision to adopt the CLUP seeks to balance continuing land-use needs at Hanford with the preservation of important ecological and cultural values of the site and supporting future access and economic development in the area.

The *Hanford Site Biological Resources Management Plan* (BRMP; [DOE/RL-96-32](#)) is identified by the CLUP as the primary implementation control for managing and protecting natural resources on the Hanford Site. According to the CLUP, the BRMP:

provides a mechanism for ensuring compliance with laws protecting biological resources; provides a framework for ensuring that appropriate biological resource goals, objectives, and tools are in place to make DOE an effective steward of the Hanford biological resources; and implements an ecosystem management approach for biological resources on the Site. The [BRMP][†] provides a comprehensive direction that specifies DOE biological resource policies, goals, and objectives.

DOE places priority on monitoring those plant and animal species or habitats with specific regulatory protections or requirements; that are rare and/or declining (federal or state listed endangered, threatened, or sensitive species); or are of significant interest to federal, state, or tribal governments or the public. The BRMP ranks wildlife species and habitats (Levels 0–5), providing a graded approach to monitoring biological resources based on the level of concern for each resource.

Ecological monitoring and ecological compliance support the Hanford Site's waste management and environmental restoration mission through the following activities:

- Ensuring the Hanford Site's operational compliance with laws and regulations including the Endangered Species Act of 1973 ([16 U.S.C. 1531](#)), *Bald and Golden Eagle Protection Act* ([16 U.S.C. 668–668c](#)), and MBTA of 1918 ([16 U.S.C. 703](#)) as well as compliance with executive orders, DOE orders, and DOE resource management guidance
- Providing data for environmental impact and ecological risk assessments

[†]The CLUP document uses a different acronym (BRMaP, in place of BRMP used here) for abbreviating the *Hanford Site Biological Resource Management Plan* document.

- Providing information and maps of the distribution and condition of biological resources at the Hanford Site
- Supporting Hanford Site land-use planning and stewardship.

Hanford Site ecological monitoring activities provide information useful to the Hanford Site natural resource stakeholders and the public on the status of some of the site's most highly valued biological resources. Population level surveys are conducted to monitor fish, wildlife, and plants and are used to develop baseline information and monitor any changes resulting from Hanford Site operations. Population data collection and analysis are integrated with data from environmental surveillance monitoring of biotic and abiotic media, and analytical results are used to characterize any potential risk or impact to the biota.

11.1.1 Rare Plants

Plant populations monitored at the Hanford Site include taxa classified by the Washington State Natural Heritage Program as endangered, threatened, or sensitive species and those listed as Review Group 1 (i.e., taxa in need of additional fieldwork before status can be determined). In 2015, two separate monitoring efforts occurred on the DOE managed portion of the Hanford Site. Upland plants of conservation concern were inventoried concurrently with an effort to map Hanford Site plant communities, and a focused survey of gray cryptantha (*Cryptantha leucophaea*) was led by Washington Rare Care and Conservation (Rare Care) with participation by botanists/ecologists representing Rare Care, the Washington State Natural Heritage Program, the U.S. Bureau of Land Management, and DOE.

Species canvassed as part of the study of rare upland plant species at Hanford included the following:

Cespitose evening primrose (*Oenothera cespitosa*), Washington (WA) State Sensitive
 Columbia milk-vetch (*Astragalus columbianus*), Federal Species of Concern, WA State Sensitive
 Dwarf evening-primrose (*Eremothera pygmaea*), WA State Sensitive
 Gray cryptantha (*Cryptantha leucophaea*), Federal Species of Concern, WA State Sensitive
 Great Basin gilia (*Aliciella leptomaria*), WA State Threatened
 Piper's daisy (*Erigeron piperianus*), WA State Sensitive
 Rosy pussypaws (*Calyptridium roseum*), WA State Threatened
 Small-flowered evening-primrose (*Eremothera minor*), WA State Sensitive
 Spreading pygmyleaf (*Loeflingia squarrosa* var. *squarrosa*), WA State Threatened
 Suksdorf's monkeyflower (*Erythranthe suksdorfii*), WA State Sensitive
 Thompson's sandwort (*Eremogone franklinii* var. *thompsonii*), WA State Sensitive
 Yellow or sand wildrye (*Leymus flavescens*), WA State Review Group 1

In May 2015, Rare Care partnered with the U.S. Bureau of Land Management to locate the remaining occurrences of gray cryptantha in Washington State that had not been monitored for the previous 5 years. This effort included the survey of gray cryptantha populations at Hanford described in this section. Rare Care found that 26% of the known population occurrences in Washington State could not be relocated and 26% had fewer than 50 individuals. In total, populations appear to have declined by 75% or more at 30% of the occurrences ([Rare Care 2015](#)). Overall, roughly 6,200 individual plants of gray cryptantha were observed at the Hanford site over the monitoring period. Of those plants, approximately 98% were in bloom and 2% were vegetative. Plant "skeletons" or senescing plants were not included in the tally and were seen infrequently. Because of the extent of the Hanford Dune fields (roughly 2,820 ac) and the scattered nature of the gray cryptantha populations, it is likely that not all populations within the dune fields were found.

Each year, seed collections are made from populations of rare native plants across Washington State. In June 2015, a month after completion of the survey described above, personnel from Rare Care and BLM returned to the Hanford Site to collect gray cryptantha seed following Rare Care protocols. The findings were also surveyed by MSA Radiological Control Technicians prior to being removed from the Hanford Site. Additional details from these surveys are included in the FY 2015 monitoring report currently or shortly available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.1.2 Fish and Wildlife Monitoring

This section provides inventory, monitoring, and survey information for fish and wildlife evaluated at the Hanford Site during 2015. This information is provided in context with historical data and trend information. Historically, three fish and wildlife species on the Hanford Site have been monitored annually: fall Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), and bald eagles (*Haliaeetus leucocephalus*). These species are either protected by federal or state laws and regulations or are of special interest to the public and stakeholders. Monitoring consisted of estimating numbers of fall Chinook salmon redds, surveying for steelhead redds, and assessing bald eagle nesting and night roosting activity because the species have the potential to be impacted by Hanford Site operations. Yearly monitoring provides occurrence and distribution data to ensure their protection from Hanford Site operations. Additional annual monitoring efforts included nesting raptors and migratory birds. Each calendar year, additional species specific monitoring are performed based on stakeholder interest, legal requirements, resource status, BRMP resource level and data needs. In addition to the aforementioned annual projects, CY 2015 monitoring also included Townsend's ground squirrel, burrowing owl, Hanford reptiles, black-tailed jackrabbits, and American badger. The sections below provide summaries of the monitoring results; the detailed monitoring reports are currently or shortly available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.1.2.1 Fall Chinook Salmon

Commonly referred to as king salmon, Chinook are the largest Pacific salmon ([Myers et al. 1998](#); Netboy 1958). Adult fall Chinook salmon destined for the Hanford Reach enter the Columbia River in late summer and spawn in the fall. Females fan out nests or redds in suitable gravel substrate and deposit eggs in a pocket while males simultaneously extrude milt to fertilize the eggs. Redds are readily identifiable during this time and appear as clean swept gravel patches amidst darker undisturbed substrate covered by algae (periphyton).

The population of fall Chinook salmon that spawns in the Hanford Reach of the Columbia River is the largest run remaining in the Pacific Northwest and has regional ecological and cultural significance, and economic importance that reaches areas downstream on the Columbia River and along the Pacific Ocean as far as southeast Alaska ([Dauble and Watson 1997](#)). These fall Chinook salmon have been vital in efforts to preserve and restore other depleted Chinook salmon stocks in the Columbia Basin ([Anglin et al. 2006](#)). Aerial counts of fall Chinook salmon redds have been conducted since 1948 at Hanford to provide an index of relative abundance among spawning areas and years ([Wagner, Lindsey, and Nugent 2012](#); [Wagner, Nugent, and Lindsey 2013](#); [Lindsey and Nugent 2014](#); [Nugent and Wilde 2015](#)). The counts are also used to document the onset of spawning, locate spawning areas, and determine intervals of peak spawning activity. These data also allow for planning to avoid impacts such as disturbance or siltation to redds from Hanford Site activities. Understanding the location and abundance of spawning is a critical part of the management of this important population. The information collected during the aerial surveys, which are the focus of this report,

is vitally important for the implementation of the Hanford Reach Fall Chinook Protection Program ([USACE 2006](#)). Prior to 2011, the Hanford Reach was divided into 11 sections that were maintained in the current monitoring campaign. In 2011, eight additional sections (100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, the dunes, and 300 Area) were defined to better monitor the abundance and distribution of fall Chinook redds in areas of potential upwelling of contaminated groundwater. The original 11 sections and the newer eight sections are not mutually exclusive areas; they simply represent different divisions of the Hanford Reach.

In 2015, three aerial surveys were completed along the length of the Hanford Reach (October 19, November 2, and November 16). Table 11.1 summarizes the results of visual aerial surveys for fall Chinook salmon redds in the originally defined 11 sections. The results for the same surveys, organized into the eight operational areas are shown in Table 11.2. The peak annual redd count for 2015 (20,678) was certainly the highest count since 1948 and well exceeds the previous 10-year average (8,813; Figure 11.1). Additional information detailing the 2015 monitoring effort is available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

Table 11.1. Summary of Fall Chinook Visual Aerial Redd Counts for CY 2015 Aerial Surveys in the Hanford Reach of the Columbia River

Area	Description	10/19/15	11/02/15	11/16/15	Maximum Count
0	Islands 17–21 (Richland)	0	0	0	0
1	Islands 11–16	4	581	1,193	1,193
1a	Savage Island/Hanford Slough	0	0	0	0
2	Islands 8–10	18	1,320	3,145	3,145
3	Near Island 7	1	535	800	800
4	Island 6 (lower half)	5	1,630	2,315	2,315
5	Island 4, 5, and upper 6	13	1,550	2,540	2,540
6	Near Island 3	5	320	1,100	1,100
7	Near Island 2	12	1,400	1,900	1,900
8	Near Island 1	0	400	1,000	1,000
8a	Upstream of Island 1 to Coyote Rapids	0	0	15	15
9	Near Coyote Rapids	15	215	750	750
9a	Upstream of Coyote Rapids to China Bar	0	71	230	230
China Bar	China Bar/Midway	3	400	1,500	1,500
10	Near Vernita Bar	10	3,250	4,175	4,175
11	Upstream of Vernita Bar to Priest Rapids Dam	0	10	15	15
Total		86	11,682	20,678	20,678

Table 11.2. Summary of Fall Chinook Visual Aerial Redd Counts for CY 2015 Aerial Surveys by Operational Area Sub-sections

Sub-area	10/19/15	11/02/15	11/16/15	Maximum Count
300 Area	0	0	0	0
Dunes	0	0	0	0
100F	1	535	800	800
100H	13	1,550	2,540	2,540
100D	0	400	1,000	1,000
100N	0	0	15	15
100K	0	0	0	0
100BC	15	215	750	750
Total	29	2,700	5,105	5,105

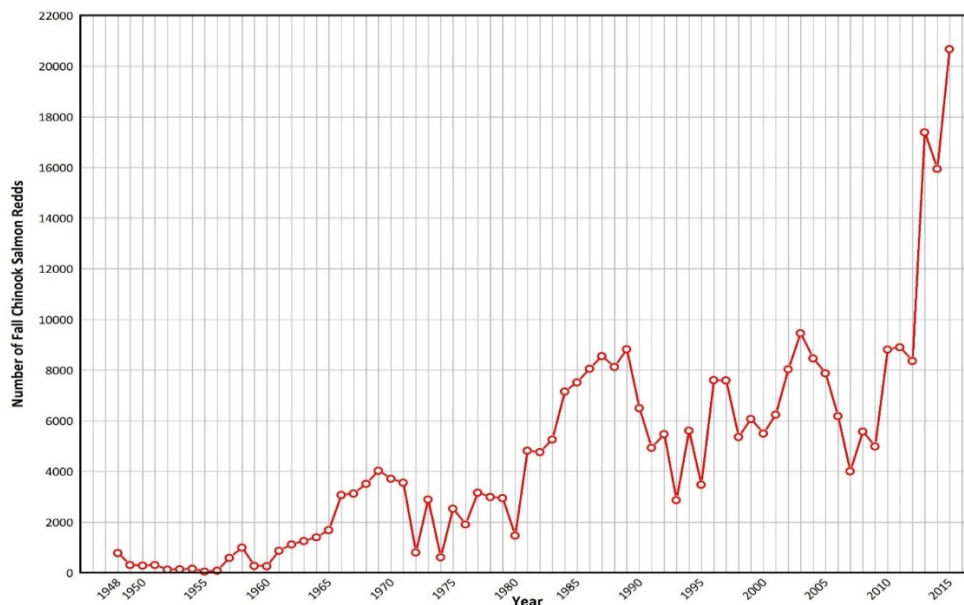


Figure 11.1. Visual Hanford Reach Fall Chinook Salmon Redd Counts 1948 to 2015

11.1.2.2 Steelhead

Steelhead use the Hanford Reach for rearing as juveniles, as a migratory corridor for juveniles and adults, and for spawning as adults. Currently, upper Columbia summer-run steelhead are federally listed as threatened under the *Endangered Species Act of 1973* in [16 U.S.C. 1531](#) and as a state candidate in Washington. Because of their listing status and importance to recreational and tribal fisheries, steelhead were selected for monitoring under this program.

Steelhead build nests termed “redds” in gravel or cobble substrate and spawn in the spring; the steelhead fry emerge from the gravel later that same spring. Adult steelhead generally use smaller tributary habitat and substrate; however, adult steelhead will spawn in larger mainstream rivers with suitable habitat, such as the Columbia River. Suitable spawning conditions within the Hanford Reach, occur between February and early June, with peak spawning in mid-May (Eldred 1970; Watson 1973; [PNL-5371](#)).

Aerial surveys for steelhead redds are conducted on the Hanford Reach in the spring of each year to identify potential spawning areas and timing as well as to provide an annual index of relative abundance among spawning areas. The surveys document any change in the status of steelhead spawning in the Hanford Reach and could help plan project activities to avoid redds, if any are identified. Similar to the methods used to document fall Chinook salmon spawning, the survey area is divided into 11 sections, with the number of redds being totaled by section. Eight additional sub-sections (100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, the dunes, and 300 Area) were added in 2012 to monitor the abundance and distribution of steelhead redds in areas of potential upwelling of contaminated groundwater. The original 11 sections and the newer 8 sections are not mutually exclusive areas; they simply represent different divisions of the Hanford Reach area. Because few redds have been counted in recent years, after the first aerial survey in which redds are observed, a follow-up boat survey is conducted to verify redds seen from the air.

Three steelhead aerial redd count surveys were completed along the length of the Hanford Reach during the 2015 spawning season. The first survey was performed on April 7, the second survey on May 6, and the third survey on May 21. No steelhead redds were observed on April 7 but were observed on May 6 and

May 21. A boat survey on May 11 confirmed redds seen from the air on May 6. A maximum count of 43 steelhead redds were recorded in 2015, the most redds recorded in the Hanford Reach of the Columbia River since 1998 when 75 redds were documented (Dauble 1998; [DOE/RL-2000-27](#)). Table 11.3 describes the counts performed by survey area for each flight. The maximum count describes the highest number of redds documented in a survey area within a single flight. Table 11.4 shows the number of redds occurring within the newer defined sub-sections, coinciding with areas of potential upwelling of contaminated groundwater.

Table 11.3. Summary of Steelhead Redd Counts for the 2015 Aerial Surveys in the Hanford Reach of the Columbia River

Area	Description	4/7/15	5/6/15	5/21/15	Maximum Count
0	Islands 17–21 (Richland)	0	0	0	0
1	Islands 11–16	0	15	7	15
1a	Savage Island/Hanford Slough	0	0	0	0
2	Islands 8–10	0	6	6	6
3	Near Island 7	0	0	0	0
4	Island 6 (lower half)	0	7	16	16
5	Island 4, 5, and upper 6	0	0	6	6
6	Near Island 3	0	0	0	0
7	Near Island 2	0	0	0	0
8	Near Island 1	0	0	0	0
8a	Upstream of Island 1 to Coyote Rapids	0	0	0	0
9	Near Coyote Rapids	0	0	0	0
9a	Upstream of Coyote Rapids to China Bar	0	0	0	0
China Bar	China Bar/Midway	0	0	0	0
10	Near Vernita Bar	0	0	0	0
11	Upstream of Vernita Bar to Priest Rapids Dam	0	0	0	0
Total		0	28	35	43

Table 11.4. Summary of Steelhead Redd Counts by Sub-areas Adjacent to Hanford Site Operations for the 2015 Aerial Surveys in the Hanford Reach of the Columbia River

Sub-area	4/7/15	5/6/15	5/21/15	Maximum Count
300 Area	0	0	0	0
Dunes	0	0	0	0
100F	0	0	0	0
100H	0	0	6	6
100D	0	0	0	0
100N	0	0	0	0
100K	0	0	0	0
100BC	0	0	0	0
Total	0	0	6	6

Lower than normal flows in late April and early May were likely the reason for the increase in steelhead redds detected. It is unclear whether the higher number of redds detected was due to increased spawning in the reach or to better conditions for observation during 2015. Past records of elevated numbers of steelhead redds in the Hanford Reach also coincided with low flow periods during the spawning season. It is assumed, although it has not been quantified, that more high-quality spawning habitat occurs at lower flow levels. Additional information detailing the 2015 monitoring effort is available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.1.2.3 Bald Eagle

Bald eagles were removed from the federal endangered and threatened species list in July 2007 and were down-listed by the WDFW from threatened to sensitive in January 2008. Federal laws, including the *Bald and Golden Eagle Protection Act of 1940* ([16 U.S.C. 668–668c](#)) and the *Migratory Bird Treaty Act of 1918*, still provide protection for eagles, their nest trees, and communal night roosts. [DOE/RL-94-150](#) sets temporal and spatial restrictions on Hanford Site work activities to protect eagles and their habitats in accordance with current federal and state guidelines. Under the plan, communal night roosts and nest sites are protected with a 0.25-mi (400-m) buffer zone. Night roost buffers are enforced from November 15 until March 15, and nest exclusion buffers are maintained until nest abandonment or fledging of young, whichever is later. Work-related access into roost areas is allowed between 10 a.m. and 2 p.m. after notification to Hanford Site Ecological Compliance staff members.

Monitoring bald eagles is essential to maintaining current biological information about their abundance and distribution on the Hanford Site, ensuring compliance with protection regulations and informing future protection and management efforts and decisions. As of early April 2016, 226 night roost, three boat, and eight nest surveys were conducted. WDFW defines a communal or night roost as “a tree or a group of trees in which at least three eagles roost for at least two nights and during more than one year.” Night roost surveys were conducted at dusk from 10 minutes prior to sunset until dark. Night roost surveys were conducted weekly at 12 locations between mid-November 2015 and mid-March 2016 with the exception of the week of December 21, 2015 when staff visited only the locations that had yet to qualify as a roost for the 2015-16 season under the WDFW definition described above.

As noted above, the entire Hanford Reach was surveyed by boat three times during the 2015-16 season (mid-December, mid-January, and late February). Boat surveys are used to determine the number, age class, and distribution of eagles present on the Hanford Reach (Figure 11.2). Boat surveys also are used to identify additional potential night roosts and nest sites and to identify the primary foraging areas along the Hanford Reach. The maximum count of 136 bald eagles on the Hanford Reach for the 2015-16 season (on December 15, 2015) was less than the record maximum count of 141 documented during the 2014-15 season, but remains much higher than the historic average maximum count of 25 eagles (1961 to 2013). This was most likely a result of the record number of adult fall Chinook salmon spawning in the Hanford Reach in recent years. Spawmed-out salmon carcasses that accumulate along the Hanford Reach provide bald eagles their primary food source. During 2015-16 boat surveys, adult eagles were observed sitting on nests at both the BPA sub-station tower location (near the Upstream of Wooded Island nest that was occupied during the 2012-13 to 2014-15 seasons) and the White Bluffs Peninsula (on February 16, 2016).

Nest site surveys were conducted in two locations: White Bluffs Peninsula and BPA sub-station utility tower. Sites were monitored for nesting activities (e.g., a pair defending the nest from other eagles, nest tending, and pair bonding behaviors). As of April 4, 2016, eagles appeared to be using both the peninsula and sub-station tower nests. The areas are posted with signs to ensure that no vehicular traffic approaches the nests within 0.25 mi (400 m) as required by [DOE/RL-94-150](#). MSA staff members will continue to monitor the nests to determine the outcome of the nesting attempts. Additional information detailing the 2015-16 monitoring effort is available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

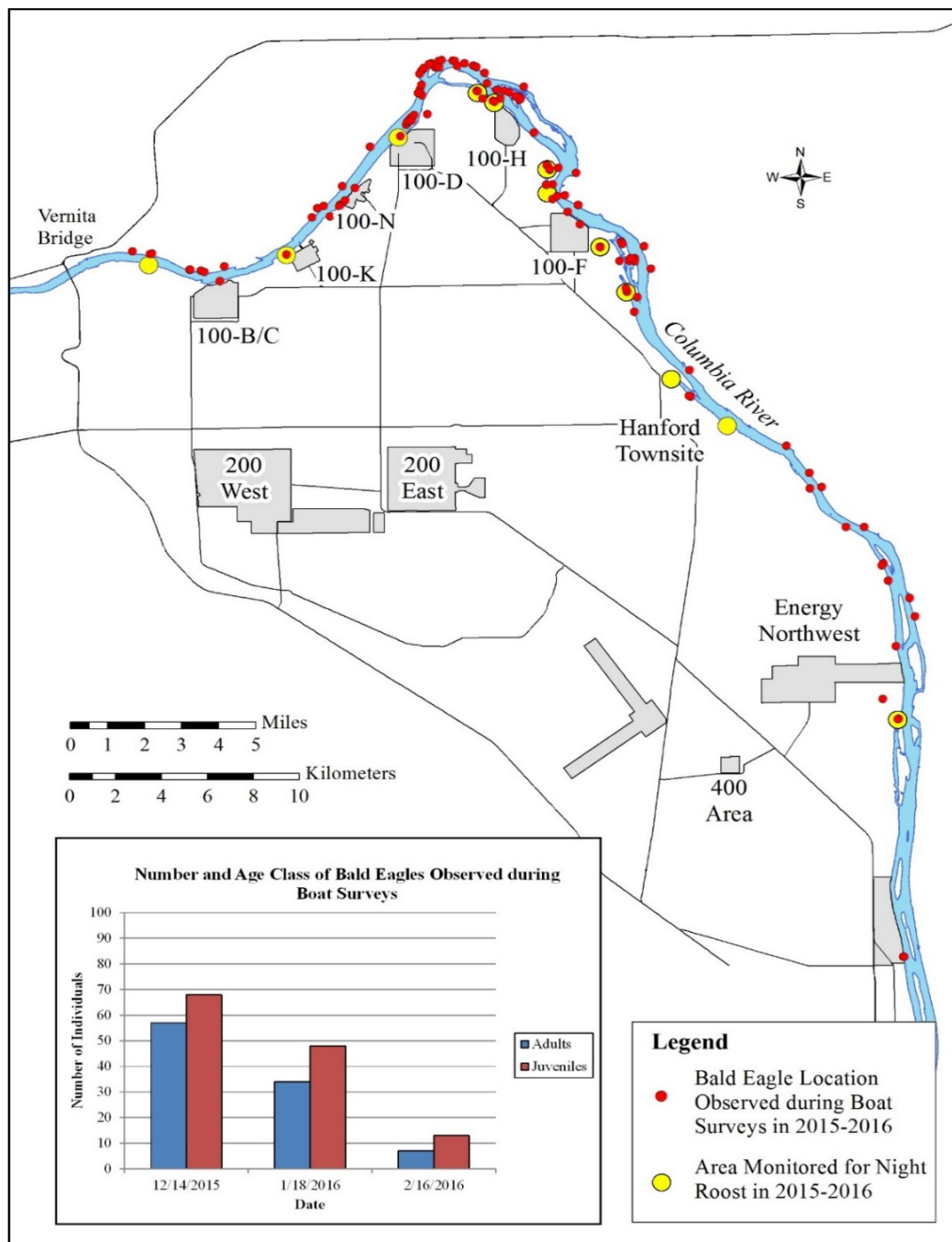


Figure 11.2. Bald Eagle Boat Survey Results for the 2015-16 Season

11.1.2.4 Raptor Nest Monitoring

The Hanford Site supports a large and diverse community of raptorial birds (PNL-3212), with 26 species of raptors observed on the Hanford Site. Thirteen raptor species have been recorded nesting on the Hanford Site, including eight species of diurnal raptors and five species of owls (Table 11.5), and several of which are on federal and state endangered and threatened species lists. The ferruginous hawk is a Washington state-listed threatened species, and the bald eagle is a Washington state sensitive species and a federal species of concern. The burrowing owl (*Athene cunicularia*) is a Washington state candidate species, and the Swainson's hawk (*Buteo swainsoni*), prairie falcon (*Falco mexicanus*), and osprey (*Pandion haliaetus*)

are all Washington state monitored species. Raptor species on the Hanford Site are also afforded protection under the MBTA ([16 U.S.C. 703](#)). Because of the status of these species and their protection under the MBTA, DOE-RL documents and protects nest locations to avoid disturbance during the nesting season and tracks populations over time to determine potential impacts of Hanford operations on these species. Common ravens also nest on the Hanford Site, and although they are not considered raptors, they perform a similar ecological role.

Table 11.5. Nest Substrates Used by Raptors and Ravens in 2015 on DOE-RL Managed Lands of the Hanford Site

Species	Tree	Cliff	Transmission Tower	Utility Pole	Electrical Substation	Nest Platform	Communications Tower	Building	Irrigation Pipe	Mammal Burrow	Artificial Burrow	Total
Ferruginous hawk			4									4
Swainson's hawk	19		1									20
Red-tailed hawk	3		3					1				7
Prairie falcon		3										3
American kestrel	4											4
Bald eagle	1											1
Osprey						3						3
Great horned owl	3							2				5
Long-eared owl	2											2
Burrowing owl*									3	3	5	11
Common raven†	14	1	37	7	1		1	1				62
Total	46	4	45	7	1	3	1	4	3	3	5	122

*Burrowing owls were recorded in separate monitoring effort (Wilde et al. 2016).
†Common ravens are technically not raptors but occupy a similar ecological niche and are protected under the MBTA.

Nest surveys for raptors and ravens were conducted on DOE-managed lands, including central Hanford, McGee Ranch/Riverlands, the dunes, and southern shoreline of the Columbia River. Nests were located using vehicular and foot surveys. Nest searches occurred in late May and early June when all species occupy nesting territories. Survey methods used in 2015 were consistent with the methods used in 2012 through 2014 ([Nugent, Lindsey, and Malin 2013](#); [Nugent, Lindsey, and Wilde 2014](#); [Nugent et al. 2015](#)).

A total of 122 nest sites were recorded in 2015 (Table 11.5). A second bald eagle nest was built on the White Bluffs peninsula, but its continued occupancy and success could not be determined. Of the 11 burrowing owl nests observed, 10 of these were found during a separate burrowing owl monitoring effort (Wilde, Granna, and Nugent 2016), and one nest site was detected during a vegetation mapping survey. From the 62 common raven nests observed, two of these were removed from utility poles by Integrated Biological Control because they were deemed fire hazards. Nest substrates used by raptors and ravens on DOE-RL managed lands are shown in Table 11.5. All raptor and raven nest sites located in 2015 are displayed in Figure 11.3. A comparison of the number of raptor and raven nest sites located during 2012 to 2015 is presented in Figure 11.4.

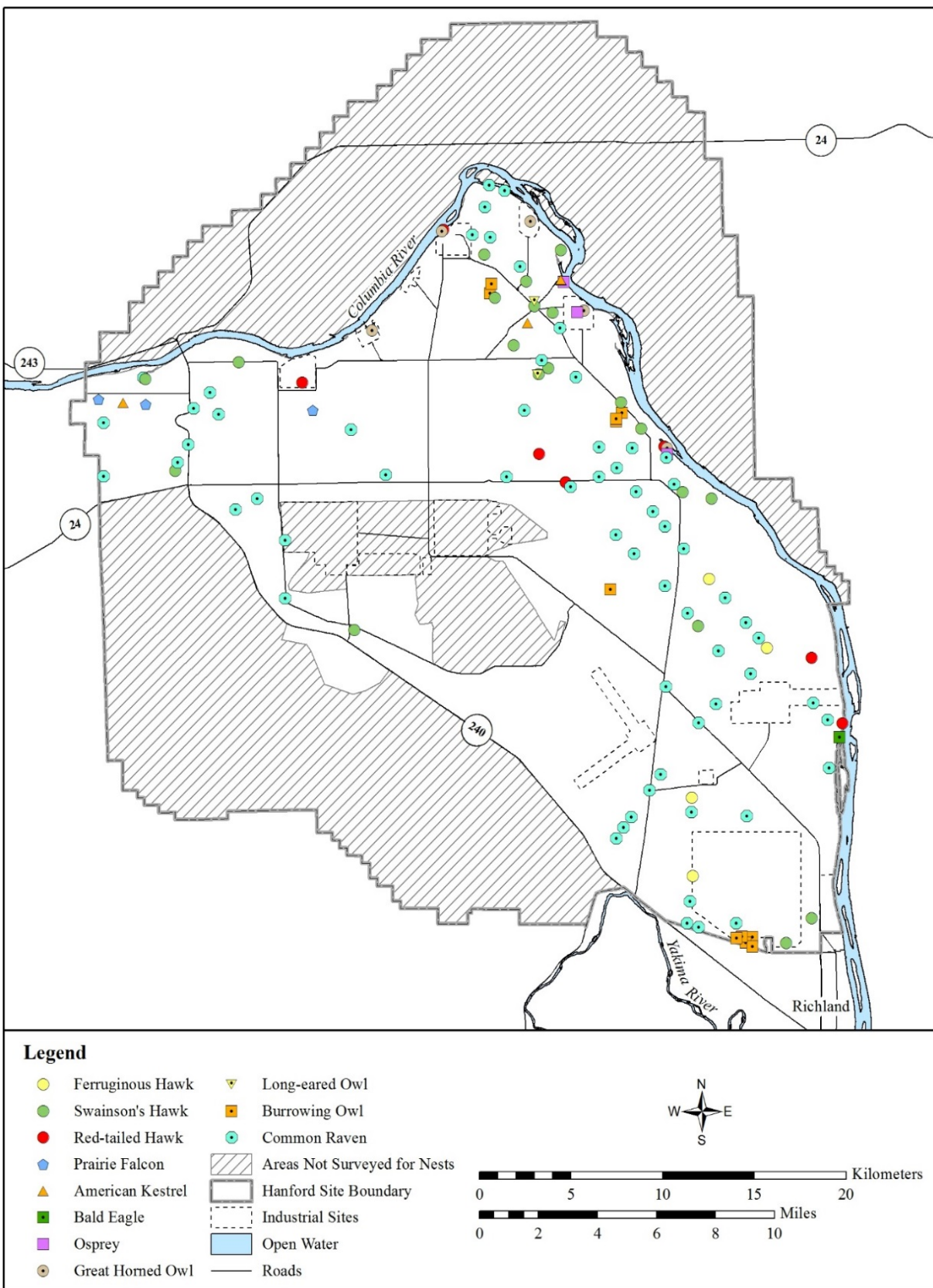


Figure 11.3. Raptor and Common Raven Nests Located on DOE-RL Managed Lands of the Hanford Site in 2015

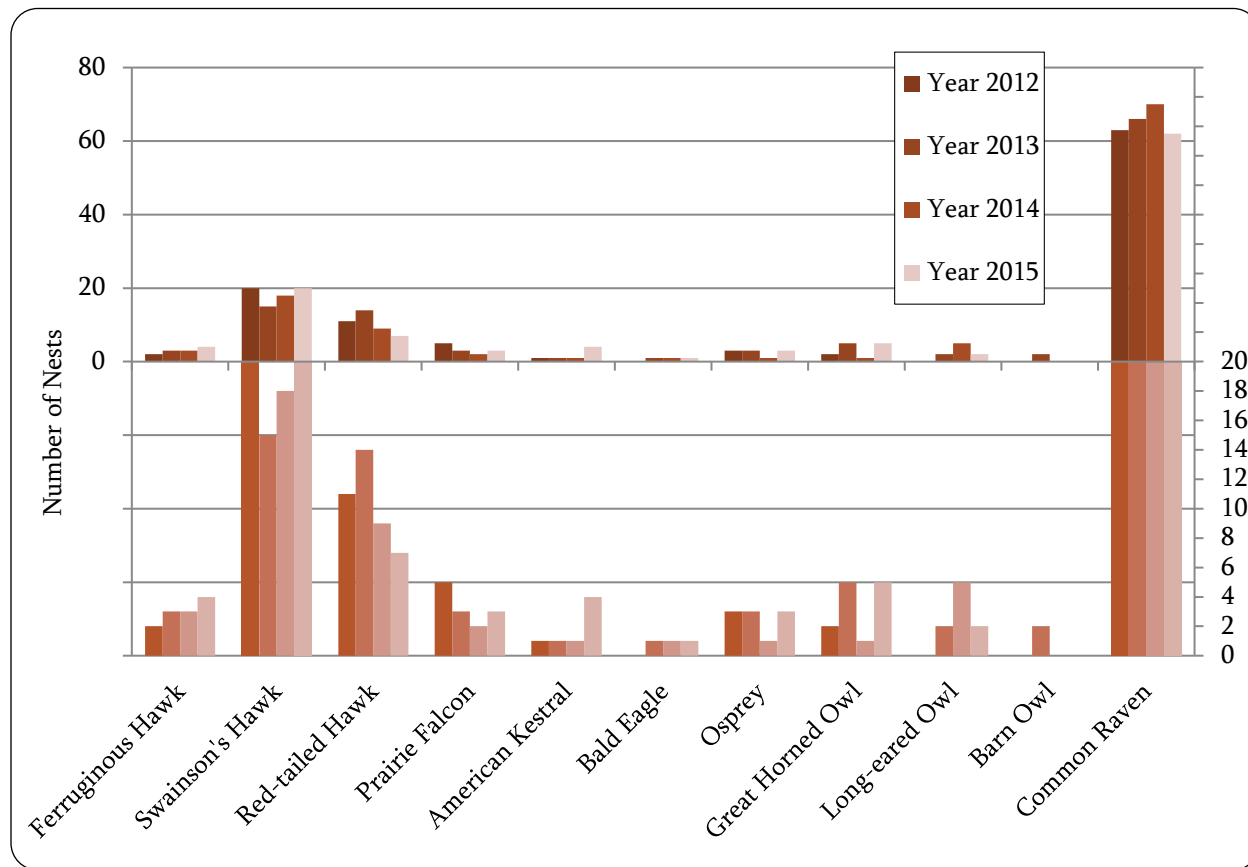


Figure 11.4. Number of Raptor and Raven Nest Sites Located on Hanford Site DOE-RL Managed Lands, 2012–2015

The first known successful bald eagle nest was documented on the Hanford Site upstream of Wooded Island in 2013; the nest site was successful again in 2014 and 2015 ([Cranna et al. 2015a](#); [Cranna et al. 2015b](#)). A second bald eagle nest was constructed on the White Bluffs peninsula in 2015, but its continued occupancy and success could not be determined due to its location being obscured by foliage later in the season. On June 5, surveyors performing a roadside breeding bird survey observed a juvenile bald eagle in the nest tree; however, it was unclear whether this was a young bird from the nest ([Cranna et al. 2015b](#)).

Ferruginous hawks occupied four nest sites on the Hanford Site in 2015, up slightly from two to three nests observed in 2012 through 2014. Twenty Swainson's hawk nests were found in 2015, which was similar to the past 3 years (20 in 2012; 15 in 2013; 18 in 2014). These numbers were within the range (9 to 23 nests) found in the survey area in the last 42 years. The number of red-tailed hawk nests located in 2015 (7) was fewer than observed in the past 3 years (11 in 2012; 14 in 2013; 9 in 2014) and is at the lower end of the range found in the survey area during the past 42 years (7 to 19 nests).

Three prairie falcon nests were found in 2015, which was similar to the past 3 years (five in 2012; three in 2013; two in 2014). American kestrel nest site numbers are expected to be much greater than the four nests located during this survey. As secondary cavity nesters, American kestrels have many opportunities (holes and crevices on trees, cliffs, buildings, and other structures) for nesting on the Hanford Site but are difficult to detect during a survey of this type.

Three osprey nests were located on the Hanford Site in 2015; all nests were situated on nest platforms. These numbers were similar to the past 3 years (three in 2012; three in 2013; one in 2014).

Five great horned owl nests were found on the Hanford Site in 2015; the number of great horned owl nests has ranged from one to seven a year in the survey area in the past 42 years. Two long-eared owl nests were located in 2015; a range of one to six long-eared owl nests in a year have been observed in the survey area in the last 42 years. Barn owl nest numbers have always been infrequent on the Hanford Site. No barn owl nests were detected in 2015, although a single barn owl was seen in the Hanford Townsite on May 27. No barn owl nests were observed in 2012, two in 2013, and none in 2014. No short-eared owl nests were detected during 2012 to 2015. Short-eared owls rarely nest on the Hanford Site.

A separate monitoring effort for burrowing owls was conducted in 2015 (Wilde, Cranna, and Nugent 2016). The scope of the owl monitoring effort in 2015 was to document the status of known active burrows. Eighteen active burrows were located constituting 11 active burrowing owl nest sites. Eleven burrowing owl nest sites were also found in 2014, though neither year likely represents a complete number for the Hanford Site.

Sixty-two common raven nest sites were detected on the Hanford Site in 2015. This number was a decrease from a high of 70 nest sites in 2014. Until 2015, nesting common ravens had been increasing steadily on the Hanford Site with 70 nests in 2014, 66 in 2013, and 63 in 2012 compared to 45 nests in 2005 (PNNL-SA-46396) and 9 to 11 nests located on the entire Hanford Site each year (PNL-2754) from 1975 to 1978. Additional information detailing the 2015 monitoring effort is or will be available at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.1.2.5 Hanford Bird Surveys

The Hanford Site contains a wide expanse of bird habitat such as basalt outcrops, riparian streams and springs, shrub-steppe on slopes and plains, sand dunes and blowouts, and abandoned fields or disturbed areas. The large size of the site provides habitat for shrub-steppe birds that are entirely dependent on large expanses of sagebrush or areas with native grasses in the understory. In the majority of the Columbia Basin, human activities such as farming, urbanization, and industrial development have greatly decreased the amount of natural sagebrush-grass habitat and disturbance-free riparian zones that many endemic birds require for survival. Ultimately, these actions have caused a decrease in a number of shrub-steppe bird populations; some, such as the greater sage grouse (*Centrocercus urophasianus*), have been locally extirpated. Several sagebrush-steppe-dependent species such as the sagebrush sparrow (*Artemisiospiza nevadensis*), sage thrasher (*Oreoscoptes montanus*), and loggerhead shrike (*Lanius ludovicianus*) are currently listed by WDFW as candidate species and have the potential to be listed as threatened or endangered federally. In addition, the Hanford Site and surrounding area provide refuge for 17 state-listed species, including numerous birds: ferruginous hawks, state threatened; American white pelican (*Pelecanus erythrorhynchos*), state endangered; and bald eagle, state sensitive and a federal species of concern.

Ecological monitoring staff conduct roadside surveys to monitor changes in species richness and relative abundance of shrub-steppe birds over time and in response to various types of land-use changes. In 2015, roadside surveys were performed on March 10, 13, 19, and 26; May 28; June 5 and 19; and September 2, 23, 24, and 25. Four Hanford routes (Figure 11.5) were surveyed three times each in 2015. The survey timing corresponded with pre-breeding, breeding, and fall migration surveys. The 12 surveys documented over 3300 individual birds. The surveys performed during breeding season documented 1227 individuals similar to the 1,264 and 1,332 individuals counted during the similar period in 2013 and 2014, respectively. A total of 52 bird species were documented during the breeding season surveys, higher than

the 47 of 2013 and nearly the same richness as the 51 species recorded in similar 2014 breeding season surveys. The breeding season identified the largest richness of species (52) to 43 in pre-breeding survey and 37 during migration survey.

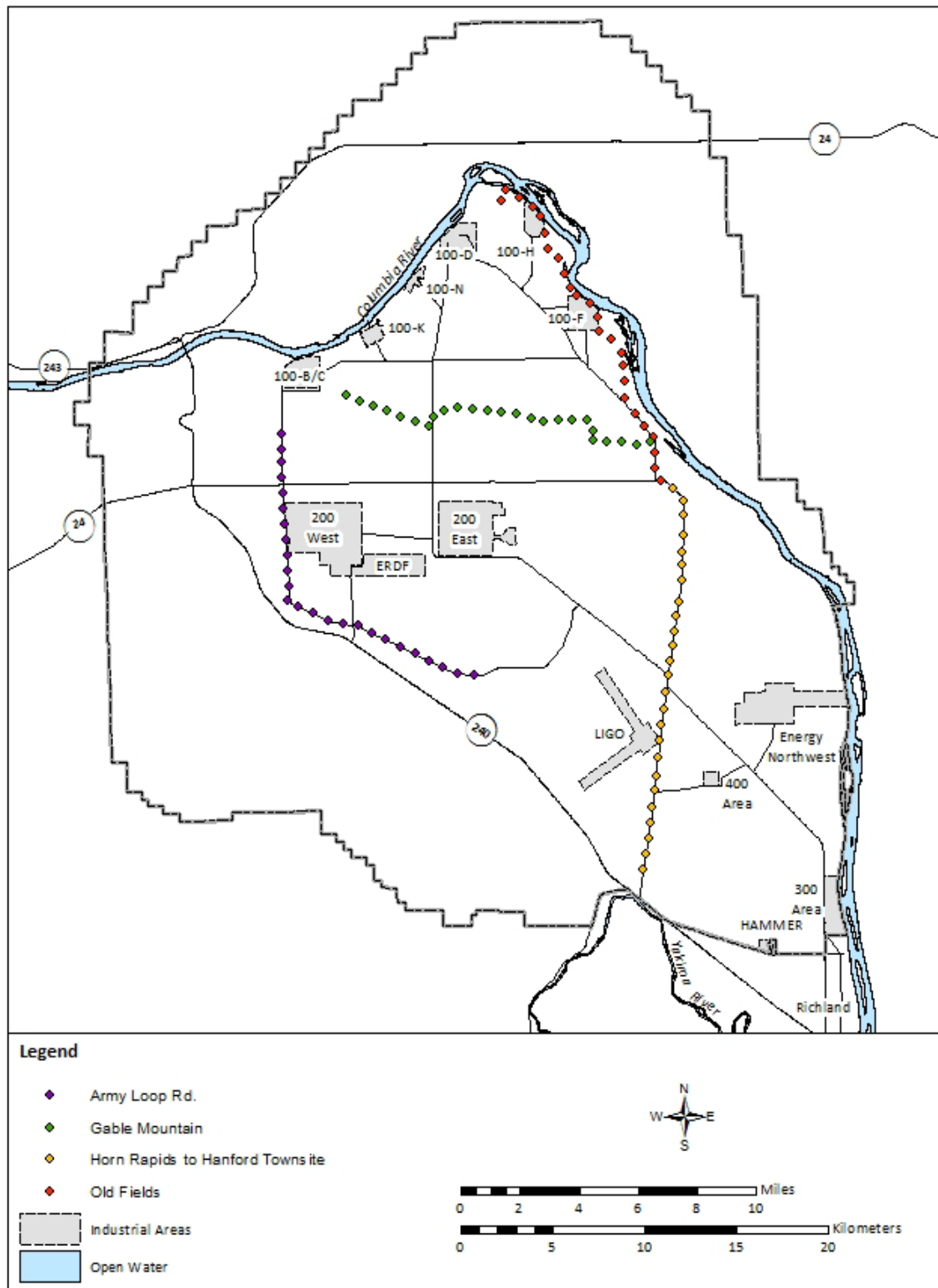


Figure 11.5. Roadside Bird Survey Routes

The Old Fields survey route had the highest species diversity, and the Army Loop Road survey route had the lowest species diversity (Table 11.6). The western meadowlark (*Sturnella neglecta*) was the most abundant species documented along all routes. Surveys documented 885 western meadowlarks, 26.34% of all individuals counted.

Table 11.6. Species Richness and Abundance During 2015 Roadside Bird Surveys

Route Name	Number of Surveys Performed	Number of Species	Abundance
Army Loop Road	3	19	649
Gable Mountain	3	23	551
Horn Rapids to Townsite	3	21	662
Old Fields	3	62	1498
Total	12	68*	3360

*Unique species identified

The second most abundant species counted, the horned lark (*Eremophila alpestris*), had 809 individuals (24.08%) of birds surveyed. Western meadowlarks were counted on 245 survey points (81.67%), and the horned lark was documented on 218 survey points (72.67%). These two species were counted at nearly three times as many survey points as any other species documented in 2015, with the third most survey points being 76 of the common raven.

The Hanford bird monitoring program documents the presence, abundance, and distribution of species of concern on the Hanford Site. Both the USFWS and the WDFW maintain lists of species that are of management concern because populations or habitat availability are limited. In Washington, those listings include (in order of least to greatest concern) state candidate, state sensitive, state threatened, and state endangered. The WDFW also maintains a list of state monitor species, a group of birds not considered species of concern but for which status and distribution data are documented. There are currently no avian species listed as federally threatened or endangered on the Hanford Site, although several are considered federal species of concern in eastern Washington. Six state-listed species were recorded on the Hanford Site in the 2015 surveys: American white pelican, state endangered; ferruginous hawk, state threatened; bald eagle state sensitive; loggerhead shrike, state candidate; and sagebrush sparrow, state candidate. Additional information detailing migratory bird monitoring efforts is available at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.

11.1.2.6 Ground Squirrel Habitat Analysis

The Townsend's ground squirrel (*Urocitellus townsendii*) is listed as a state candidate ([WDFW 2012](#)). Ground squirrels are important to the shrub-steppe ecosystem for many reasons. They serve as a food source for many mammals such as badgers and coyotes and fall prey to predatory birds such as hawks, falcons, and owls. The ground squirrel diet consists of a variety of foods including seeds, which contributes to native plant seed dispersal. The process of digging burrows helps to aerate the soil and provides burrows for other species, including burrowing owls ([Sato 2012](#)). Their decline is due to the loss of suitable habitat and isolation of their communities through fragmentation as well as control programs involving poisoning and shooting that were widely practiced in the past ([WDFW 2012](#)).

Ground squirrels are underground for much of the year for hibernation and estivation, making it essential to monitor during the correct time frame. The ground squirrels' lifecycle consists of several seasonal components. During mid- to late January, squirrels emerge from their burrows after hibernation. They spend the next month breeding, followed by gestation and rearing of young. The young ground squirrels

are active outside the burrow beginning in mid-April. The squirrels then go dormant again in late May to late June, entering a type of torpor called estivation that is used to avoid the hot and dry portion of the year ([WDFW 2012](#)). After estivation, ground squirrels may spend late September and October foraging in preparation for hibernation; thus, the crucial window to observe and monitor these mammals is between late January after hibernation and before late May when estivation begins. These months are the longest active period for the squirrels and thus are the best time for monitoring. Ground squirrels breed and rear young during this time, and age determination is easier because the juveniles are significantly smaller than adults. Protective maternal alarm calls are also used during this period of months, maximizing the likelihood of detecting occupied colonies.

The goal for 2015 was to develop a habitat suitability model for the Townsend's ground squirrel on the Hanford Site that can be used by managers and planners to make informed decisions regarding strategies and management actions such as mitigation, restoration, and habitat improvements. Habitat suitability models delineate important habitats on the Hanford Site to assess the impacts of proposed Hanford Site activities during ecological compliance reviews as well as provide focus areas for more efficient monitoring in the future. Habitat suitability models assess the quality of habitat for a species within a study area based on known and assumed habitat associations for several different factors which, specific to this model, were soil, land cover, slope, and distance to roads, railroads, and power transmission lines. Classifications of each factor were ranked and assigned a suitability value from 0.00 (unsuitable habitat) to 1.00 (optimal habitat). Rankings were based primarily on the model developed for the Washington Connected Landscapes Project's analysis specific to the Columbia Plateau Ecoregion ([Washington WHCWG 2012](#)), with the exception of soil and land cover. The Hanford Site data layers for these factors are of a much finer resolution and contain many more classifications; therefore, these factors were ranked using a literature review and the results of soil and vegetation characterization that was performed at each of the occupied sites. ArcGIS software was used to combine raster layers for each factor and produce a final suitability map resulting in a suitability score for each pixel. All raster layers used or developed were 5 m resolution. The extent of the model encompasses central Hanford and the ALE Reserve to assess connectivity with the surrounding areas.

An example of the model output is illustrated in Figure 11.6, which shows the areas on the Hanford Site (and the ALE reserve) with a habitat suitability score of ≥ 0.90 . The resulting map shows 83 polygons within the DOE managed portion of the Hanford Site, mostly found near Highway 240 adjacent to the ALE Reserve as well as some areas in the northern portion of the site and ranges from less than 1 ha to 1858 ha. Four out of the five currently occupied sites fall within these areas. Mean size was 99 ha and the total area for all 83 polygons was 8175 ha (10% of the total area of Hanford). Additional information detailing Townsend's monitoring efforts is available at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>

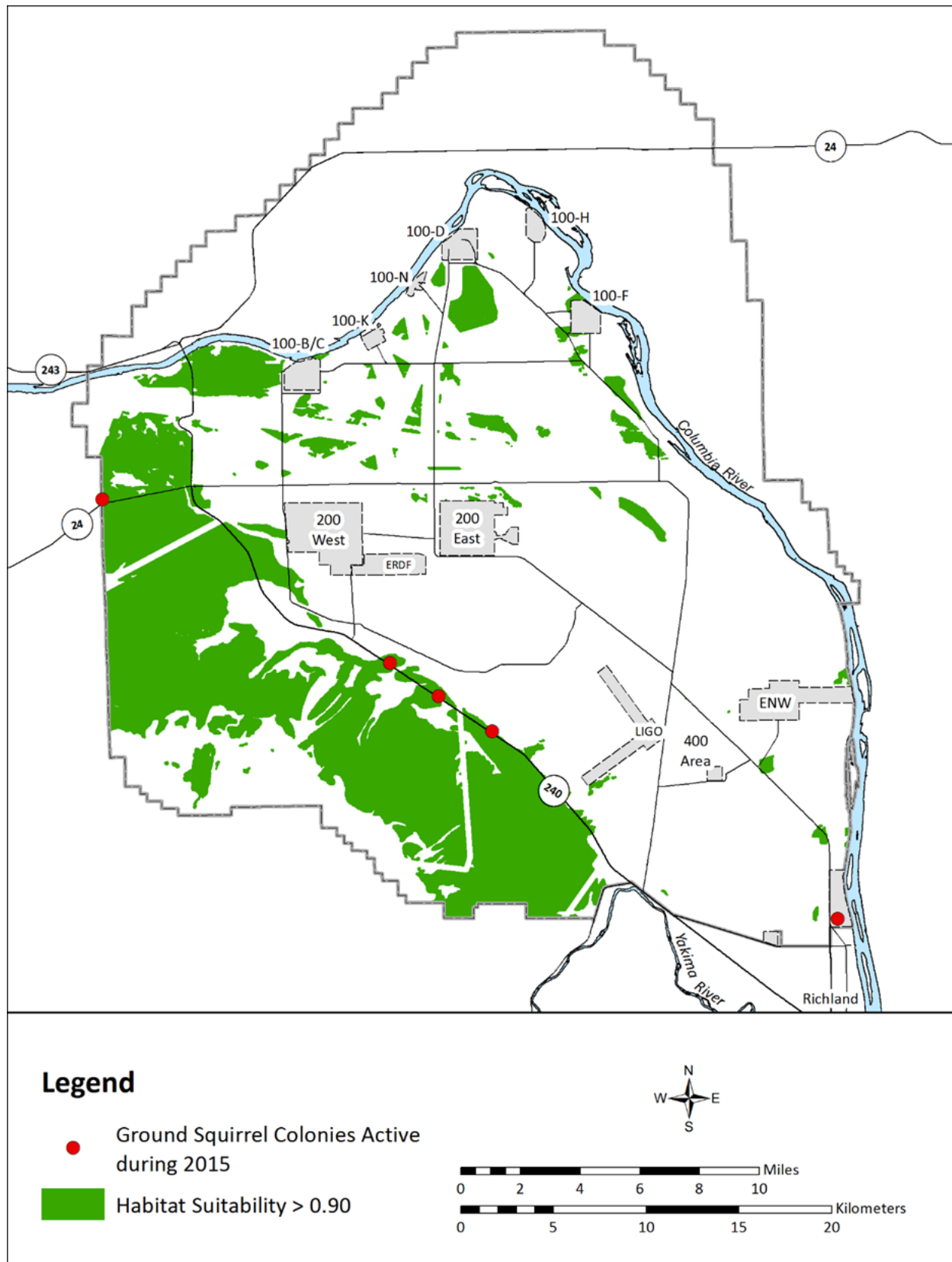


Figure 11.6. DOE-managed Portion of the Hanford Site and ALE Reserve with Habitat Suitability Score >0.90

11.1.2.7 Hanford Reptile Monitoring

The Hanford Site contains remnants of native Washington State shrub-steppe habitat that are relatively untouched by agriculture and large-scale development. These native habitats within the site are likely to support a refuge for many species of reptiles. Of the species documented or presumed to occur on the Hanford Site (Table 11.7), the WDFW currently lists both the sagebrush lizard (*Sceloporus graciosus*) and the striped whipsnake (*Masticophis taeniatus*) as candidates for listing as threatened or endangered. The striped whipsnake is also federally listed as a species of concern. The night snake (*Hypsiglena torquata*), racer (*Coluber constrictor*), and short-horned lizard (*Phrynosoma douglasii*) are all listed as monitored species by WDFW. Relatively few studies of reptiles have been conducted on the Hanford Site and most have been small in scale or observational in nature.

Table 11.7. Federal and State Status of Reptile Species Predicted and Documented to Occur on the Hanford Site

Species	Predicted	Documented	Status	
			Federal	State
Painted turtle (<i>Chrysemys picta</i>)	Yes	Yes		
Short-horned lizard (<i>Phrynosoma douglassii</i>)	Yes	Yes		Monitored
Sagebrush lizard (<i>Sceloporus graciosus</i>)	Yes	Yes	Species of Concern	Candidate
Side-blotched lizard (<i>Uta stansburiana</i>)	Yes	Yes		
Common garter snake (<i>Thamnophis sirtalis</i>)	Yes	Yes		
Western terrestrial garter snake (<i>Thamnophis elegans</i>)	Yes	Yes		
Gopher snake (<i>Pituophis catenifer</i>)	Yes	Yes		
Racer (<i>Coluber constrictor</i>)	Yes	Yes		Monitored
Nightsnake (<i>Hypsiglena torquata</i>)	Yes	Yes		Monitored
Striped whipsnake (<i>Masticophis taeniatus</i>)	Yes	Yes		Candidate
Ringneck snake (<i>Diadophis punctatus</i>)	Yes	No		
Western rattlesnake (<i>Crotalus viridis</i>)	Yes	Yes		

Of the three lizard species found on the Hanford Site, the side-blotched lizard (*Uta stansburiana*) is the most frequently observed and occurs in most native upland habitats. Sagebrush lizards are also found on Hanford and generally occupy habitats where some shrub cover is available. The short-horned lizard is relatively uncommon on the Hanford Site. Most of the snakes commonly occur in upland habitats only, including the racer (*Coluber constrictor*) and gopher snake (*Pituophis melanoleucus*). The western rattlesnake (*Crotalus viridis*) is often found in or near basalt outcrops on Hanford or along the Columbia River, while the striped whipsnake and nightsnake also occur in uplands but have rarely been encountered on the site. The common garter snake (*Thamnophis sirtalis*) prefers riparian habitats. The painted turtle (*Chrysemys picta*) is the only turtle known to occur on the Hanford Site.

Reptiles are ectothermic, meaning their bodies take on the temperature of their surroundings. As a result, they are unable to remain active during temperature conditions that are too hot or too cold. Reptiles must seek refuge to avoid temperature extremes. During the winter months, reptiles seek out underground refugia known as hibernacula. These locations have specialized temperature, humidity, and airflow conditions that allow reptiles to survive without becoming frozen during the winter months.

In this area, snakes typically seek out hibernacula in mid-October and remain inside until mid-April. Upon emergence, snakes will typically spend 2–3 weeks around the den prior to dispersing to feeding ranges, though some species remain nearby longer for breeding and egg laying ([Larsen 1997](#)). Hibernacula locations are readily identifiable during the emergence period from the presence of snakes at the openings.

South-central Washington lizards become active in March or April and are seen less frequently as temperatures drop, though some lizards are observed basking in the open on warm days in fall and winter.

Sixteen 8 km transects were surveyed from June to September in 2015 (Figure 11.7). Surveyors noted all reptile species encountered and the general habitat type where each observation occurred. A total of 513 observations were documented during the visual encounter surveys: 343 (~66%) were side-blotched lizards, 160 (~31%) unidentified lizards, 13 (~3%) sagebrush lizards, and two were snakes (one racer and one unidentified). No short-horned lizards were observed during the transect surveys; however, two were observed in 2015 by biologists performing other natural resource surveys. Additional information detailing reptile monitoring efforts is available at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.

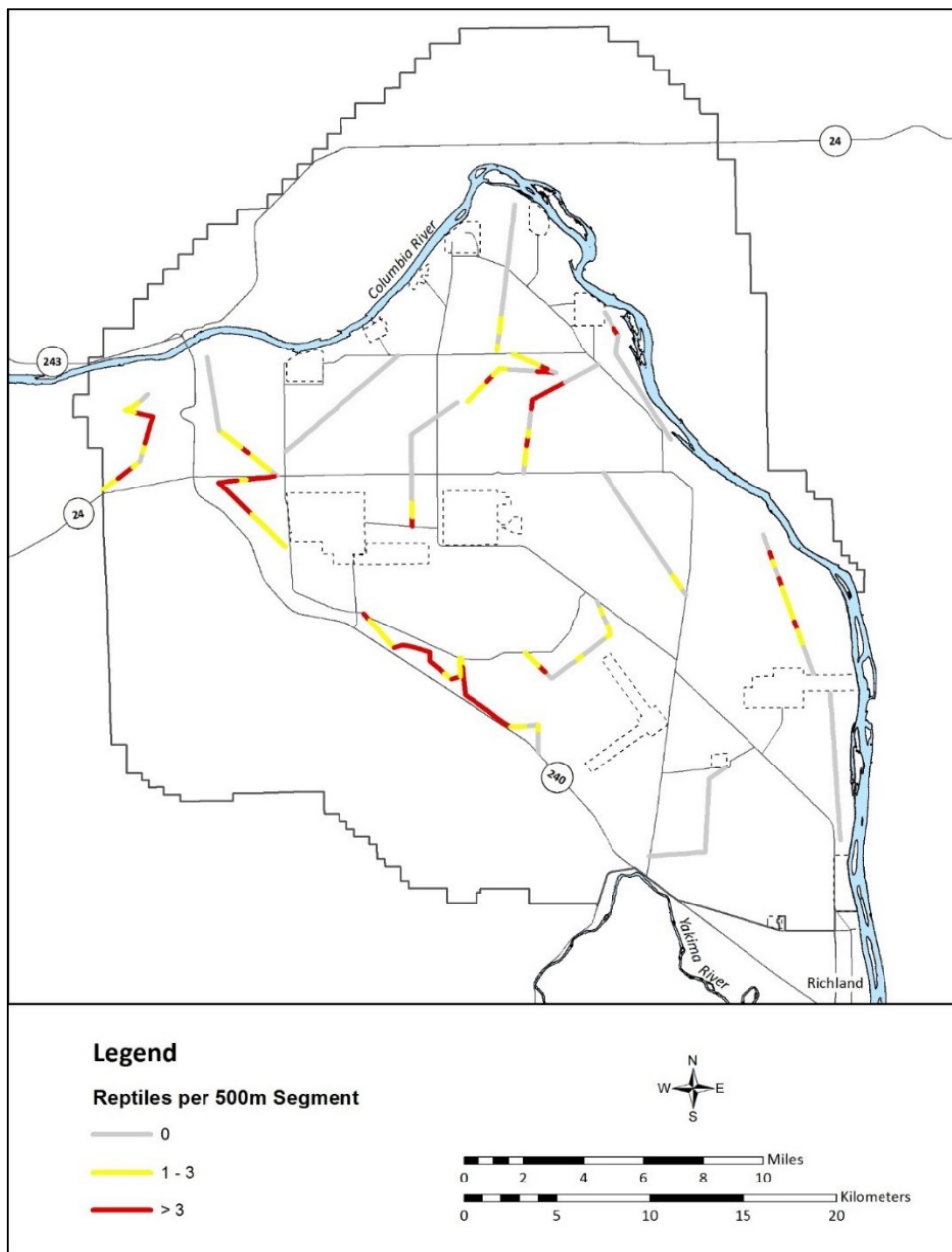


Figure 11.7. Number of Reptiles Observed per 500-m Segment in 2015 Reptile Visual Encounter Transects

11.1.2.8 Burrowing Owls

The burrowing owl is classified as a WDFW candidate species and is considered a USFWS species of concern in eastern Washington. Burrowing owls are also protected under the MBTA. From a decline in Washington State and throughout their historic range ([Conway and Pardieck 2006](#); [WDFW 2012](#)), burrowing owl populations and burrow locations are of concern locally to both DOE and USFWS. Burrowing owl population monitoring contributes to the management and protection of the species, maintenance and management of site-wide biological diversity, and assists with proper impact assessment of Hanford Site projects, many of which include ground surface impacts with activities such as grubbing, excavating, burning, off-road driving, compacting, and leveling. Without documentation of current owl burrow locations, it is difficult to protect them.

A total of 97 historical burrow locations were visited to determine the current status of burrowing owls on the Hanford Site. One new location found during other work was visited as well for a total of 98 burrow locations surveyed. To avoid interfering with breeding of the owl populations, surveys were performed in May. At this point in the season, most of the burrows are occupied with eggs, or the owlets have hatched but are not matured enough to resemble adults. Later in the season, the young may temporarily occupy nearby burrows, which could result in an over-estimation of burrow occupation. Field team members determined if a burrow was active by looking for owls in the burrow or the presence of castings, feces, feathers and/or footprints at the opening of the burrow. Brief scans of the surrounding area for additional burrows were made at each location. All newly discovered burrows were documented with GPS and added to the Hanford Site burrow list. Monitoring of the historic burrows during 2015 found a total of 18 active burrows, 6 natural (3 anthropogenic and 3 mammalian origin), and 12 artificial (Figure 11.8).

Staff members assisted the USFWS collect burrowing owls at the artificial burrow at the HAMMER Emergency Vehicle Operations Course (EVOC). USFWS was attempting to retrieve tracking devices placed on owls in previous year, document previously banded owls, and band any new or hatchling/fledgling owls. The burrow survey discussed above was performed prior to trapping to identify active burrows and clusters being used by owls. This preliminary survey increased the trapping success rates because traps were placed only at active burrows. Traps were double entry swing door style. Staff members retrieved owls from traps, determined the sex and age of the owls, and banded each owl with an identification band before the bird was released.

A total of 12 owls were captured at five nest areas (Figure 11.9), no geolocators were recovered. Six owls were hatch-year birds, the other eight were after-hatch year (likely breeding adults): three males and five females. Two captured owls – one male and one female – were already banded previously. Both owls had bands placed on them from previous captures at EVOC. All other owls were banded on the left leg for hatch-year and right leg for after-hatch year.

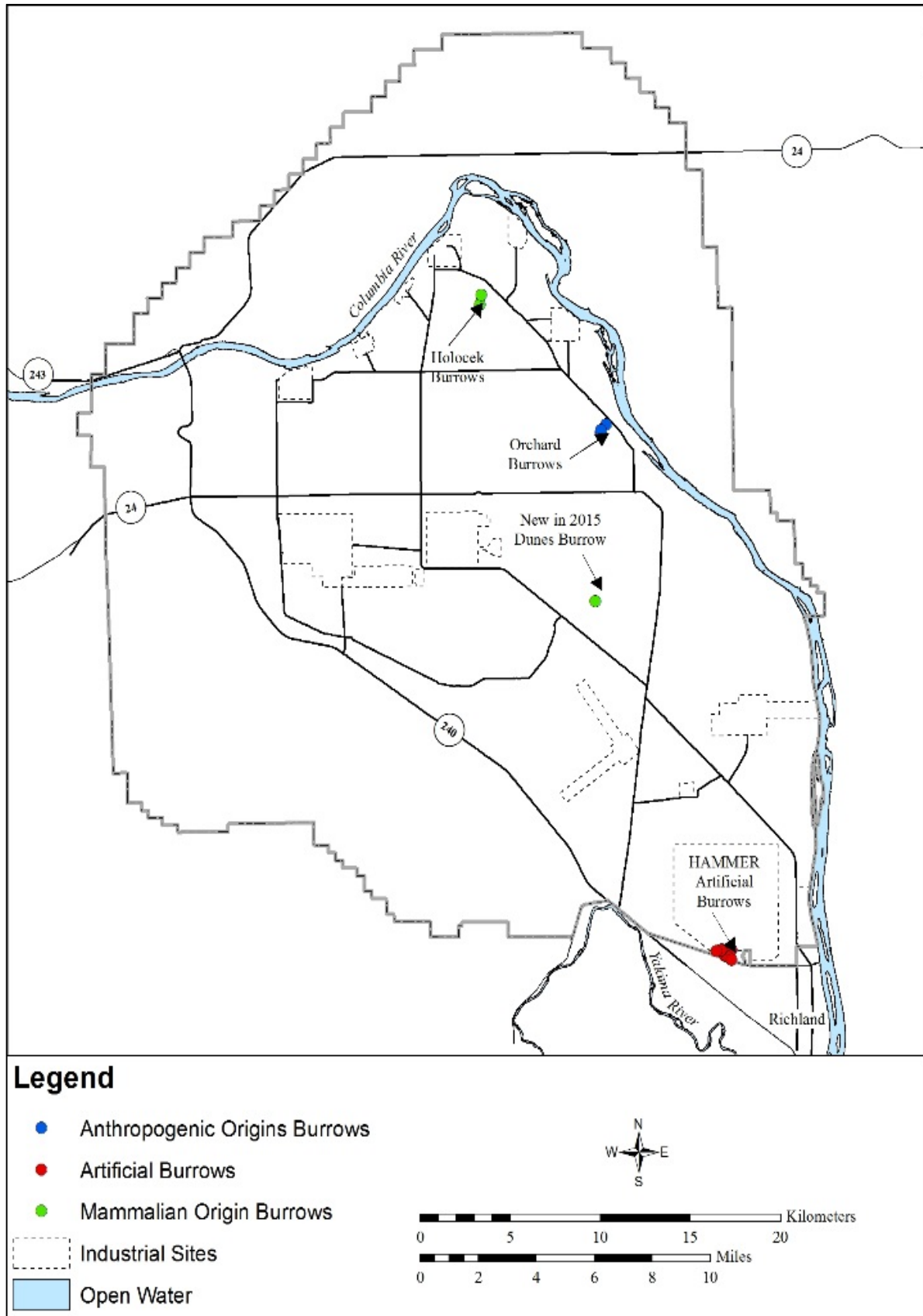


Figure 11.8. Active Burrowing Owl Burrows Documented During 2015 Surveys

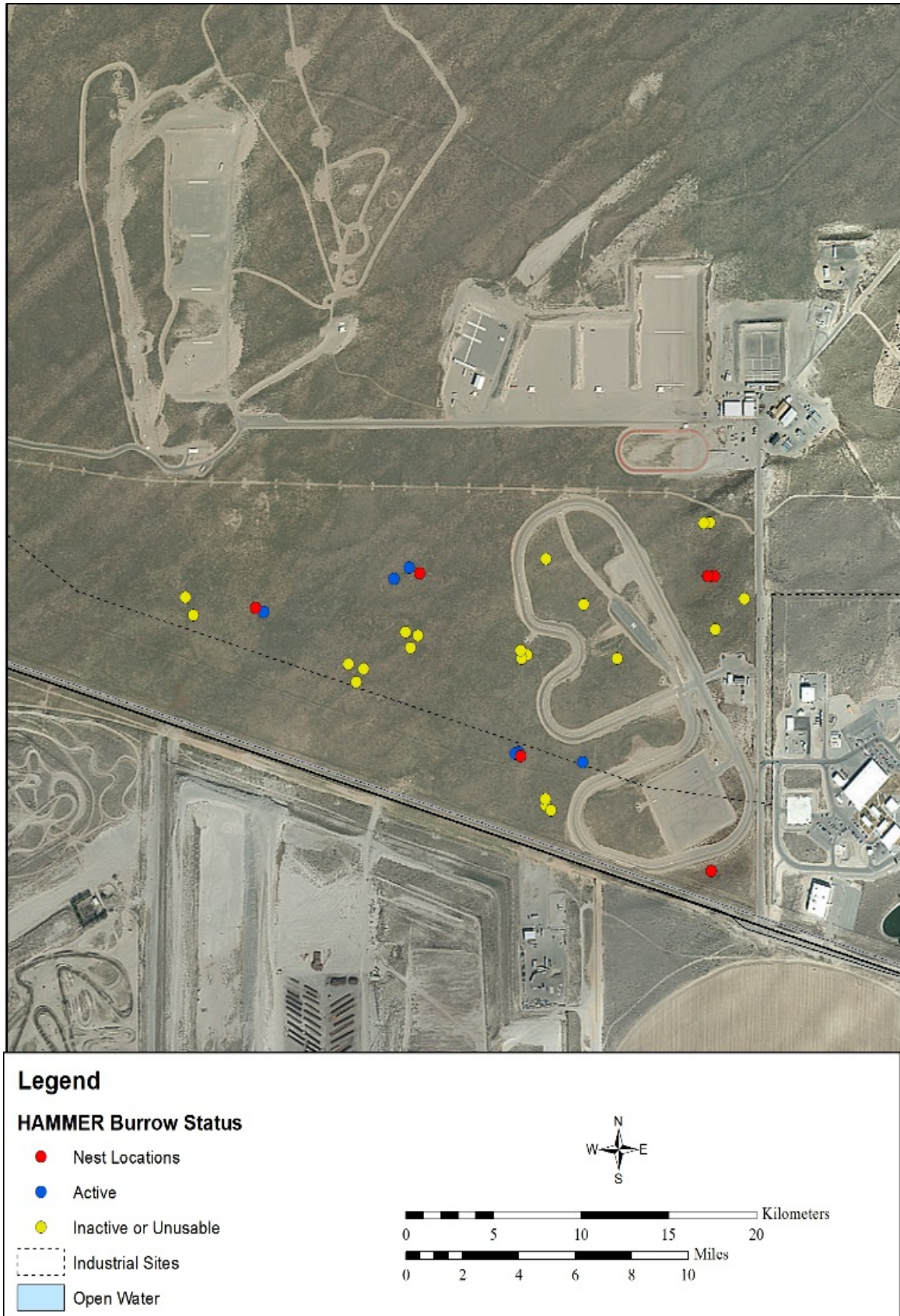


Figure 11.9. HAMMER Burrow Status During 2015 Surveys and Banding

11.1.2.9 Jackrabbits

Evidence suggests that both black- and white-tailed jackrabbits (*L. townsendii*) were historically abundant in Washington ([Ferguson and Atamian 2012](#)). Jackrabbit populations are declining across Washington State due to the loss and fragmentation of native shrub-steppe habitat. Currently, both the black- and white-tailed jackrabbit are candidates for listing as threatened and endangered. In recent years, jackrabbits have been infrequently observed on the Hanford Site, potentially indicating population declines, though other factors such as natural population cycles may be occurring. To understand the extent and causes of possible decline and to implement means to protect the species, it is imperative to collect population status and distribution data before jackrabbits disappear completely from the Hanford Site.

Black-tailed jackrabbits play an important role in the ecosystem, serving as a food source for large mammalian and avian predators, including the coyote (*Canis latrans*), golden eagle (*Aquila chrysaetos*), and the state-listed threatened ferruginous hawk (*Buteo regalis*). Increasing the understanding of jackrabbits on the Hanford Site could benefit both common and sensitive predator species. Jackrabbits do not migrate long distances or go into a hibernation or estivation period. They also rarely use underground burrows or dens (Best 1996); thus, the highly localized and active nature of jackrabbits provides surveying opportunities throughout the year.

Black-tailed jackrabbits prefer sagebrush-dominated habitats in Washington ([PNL-8942](#)) but will also use rabbitbrush (*Ericameria nauseosa* and *Chrysothamnus viscidiflorus*) and antelope bitterbrush (*Purshia tridentata*) communities. Although they prefer grass-dominated habitats typically found at higher elevations in Eastern Washington, white-tailed jackrabbits have been observed on the ALE Reserve, the DOE-RL managed portion of the Hanford Site consists of habitat more commonly associated with black-tailed jackrabbits. A combination of daytime walking transects and nighttime driving transects were conducted on the Hanford Site in FY 2012 ([Wilde, Lindsey, and Nugent 2012](#)); other recent studies on central Hanford consisted of driving surveys ([The Nature Conservancy 1999](#)). Although jackrabbits were detected using these methods, data did not provide the information necessary to address distribution and abundance of jackrabbits on the Hanford Site; therefore, monitoring for FYs 2013–15 focused on the black-tailed jackrabbit on the DOE-RL managed portion of the Hanford Site using motion-activated trail cameras ([Lindsey et al. 2014](#); [Grzyb, Nugent, and Wilde 2016](#)).

The entire central Hanford Site was divided into a mesh of hexagonal survey areas measuring 1 km² (0.39 mi²) using a Geographic Information System (GIS). Hexagonal sample area size was based on the approximate size of a jackrabbit home range, reported between 0.02 km² and 1 km² (0.01 to 0.39 mi²) and >0.5 km² (>0.19 mi²) on the Hanford Site (Major 1993). The upper limit of the home range size was selected for this project so that a rabbit observed in one transect is assumed not to be present, and therefore not detectable, in any adjacent hexagon. This process provided a more coarse scale map of jackrabbit distribution and allowed for a larger portion of the Hanford Site to be surveyed per-unit effort. Trail cameras were used to document definitively the presence of jackrabbits within each hexagonal survey area.

A total of 820 1-km² hexagons were identified across the DOE-RL managed portion of the Hanford Site. Surveying every hexagon would have been prohibitively time consuming, so initial camera setup locations were determined based on the presence of activity center termed a “core area,” defined as locations with high levels of visibly detectable jackrabbit activity such as active trails and fresh scat. Jackrabbits were confirmed at core areas using the cameras, and all adjacent hexagons were monitored using the camera

setup. If any hexagons adjacent to the original core areas were found to contain jackrabbits based on camera-trap observations, then the search area was expanded to include all hexagons adjacent to the newly discovered active hexagon. Monitoring with trail cameras began February 2, 2013, and the last camera trap was retrieved on July 13, 2015. The data summarized are a comprehensive catalogue for all data gathered from the study's first camera deployment through July 13, 2015. During this time, 4334 jackrabbit images were captured on the remote cameras, with a total of 257 hexagons successfully surveyed. Jackrabbits were detected within 72 of the hexagons surveyed (Figure 11.10).

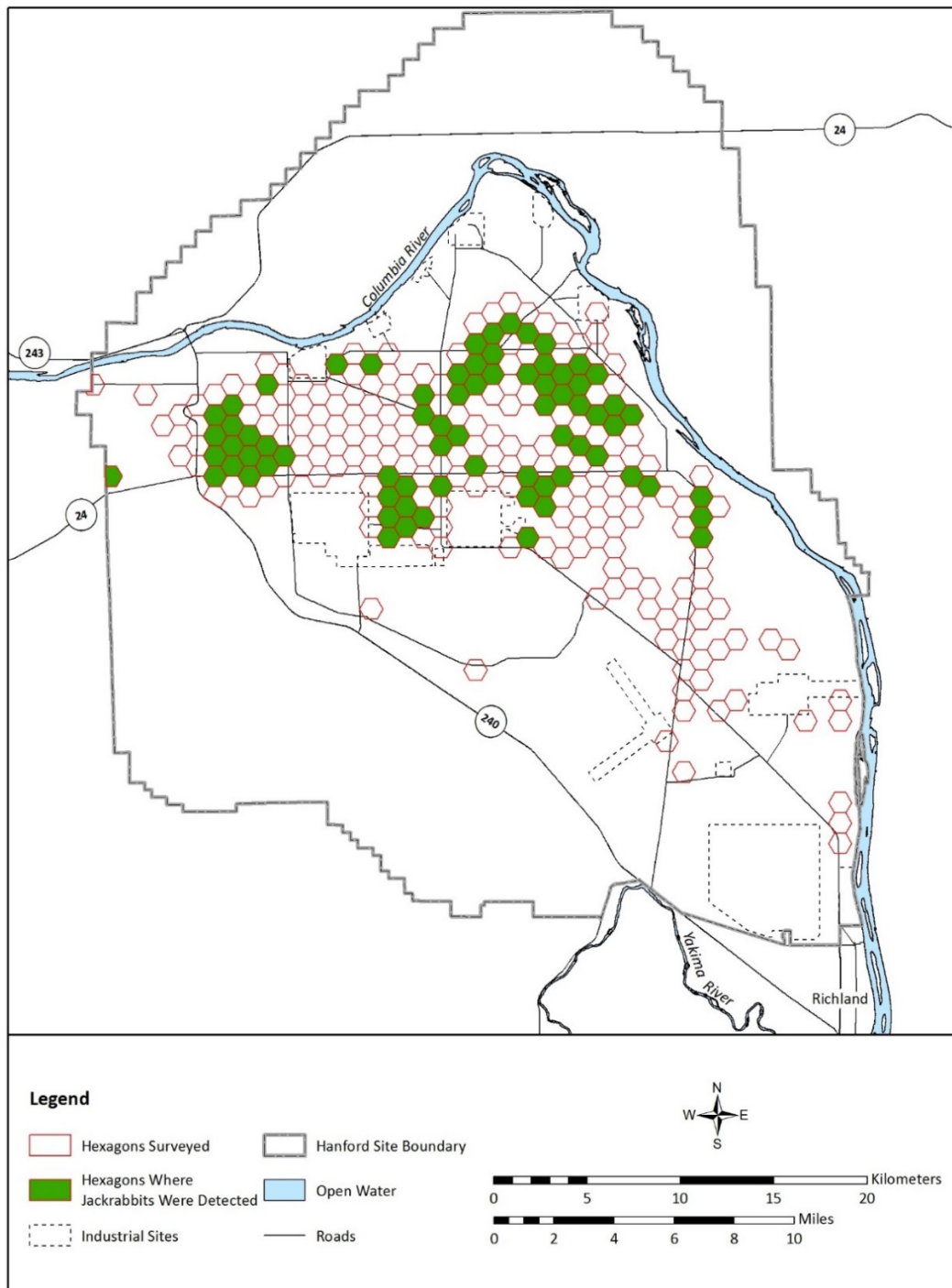


Figure 11.10. Hexagons Surveyed for Black-tailed Jackrabbits

All locations where jackrabbits were observed on the Hanford Site while setting trail cameras, driving, or performing other surveys were recorded. These occurrences included flushed individuals and road kill observations. Locations were recorded using a GPS, or the approximate location was marked on a map by the observer and later digitized into electronically to capture coordinates. All locations were stored and mapped using GIS.

The status of the black-tailed jackrabbit population on the Hanford Site was largely unknown at the start of this project. Until official documented surveys commenced, jackrabbit data consisted of occasional, isolated sightings. The data generated by this project begin to show the status and distribution of black-tailed jackrabbits across the DOE-RL managed portion of the Hanford Site. This knowledge provides a foundation of where habitat conservation efforts can be focused while site cleanup continues. Additional information detailing jackrabbit monitoring efforts is available at

<http://www.hanford.gov/page.cfm/ecologicalmonitoring>

11.1.2.10 American Badger

The BRMP ranks wildlife species and habitats (Levels 0–5), providing a graded approach to monitoring biological resources based on the level of concern for each resource. The American badger (*Taxidea taxus*) is ranked at Level 2, a potential species of concern according to the BRMP ([DOE/RL-96-32](#)). The WDFW lists the American badger as a state monitored species, meaning that it requires management, survey, or data emphasis. No previous monitoring efforts have been completed for badgers on the Hanford Site; therefore, no concrete evidence exists regarding their relative abundance or habitat distribution. The monitoring data will be useful for determining the badger's selected habitat characteristics and the level of connectivity between active badger-occupied areas. If unconnected populations are determined to be present, these will be considered opportunities to restore connectivity for badgers and sagebrush species who utilize these areas on the Hanford Site.

The entire central Hanford Site was divided into hexagonal transects 6 km² in size. Transect size was based on the approximate size of a female badger home range in eastern Washington. Thus, a badger observed in one transect is not assumed to be present, and therefore not detectable, in any adjacent hexagon. Trail cameras were used to document the presence of badgers definitively within each hexagonal area. A total of 134 hexagons were designated for this project.

In total, 44 hexagons were monitored with trail cameras between April 2 and November 11, 2015. Thus far, cameras have been deployed for 587 nights, with a total number of three confirmed American badger sightings. Starting on April 21, 2013, all incidental observations and their respective locations were recorded. Currently, 13 of the 14 incidental observations have occurred in late winter and early spring. While they do not hibernate, badgers are much less active during the winter months, spending most of the time underground conserving energy. It is possible that these observations indicate the time of year when reliant food sources become available for badgers on the Hanford Site after the cold winter months. Staff members often take to the field, traversing vast remote areas of the Hanford Site while conducting field research. To maximize gathering additional data, staff members recorded badger activity while hiking 5-mile long transects during the 2015 reptile monitoring (Section 11.1.2.7 of this report). The number of badger diggings (both burrows and holes) were recorded.

The status of the American badger population on the Hanford Site was largely unknown at the start of this project. Until official documented surveys commenced, badger data consisted of occasional, isolated

sightings. The data in this report begin to show the status and distribution of badgers across the DOE-RL managed portion of the Hanford Site as seen in a distribution map of all recorded data to date (Figure 11.11). The data in this report aids in the identification of high-value areas for shrub-steppe connectivity restoration. Collectively, the information contained in this monitoring report will be useful during site development planning to minimize potential project-related impacts to badgers, sagebrush obligate species, and other species of concern who utilize similar habitats and corridors on the Hanford Site. Habitat surveys in areas occupied and unoccupied by badgers greatly contribute to the understanding of badger habitat requirements. Additional information detailing American badger monitoring efforts is available at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.

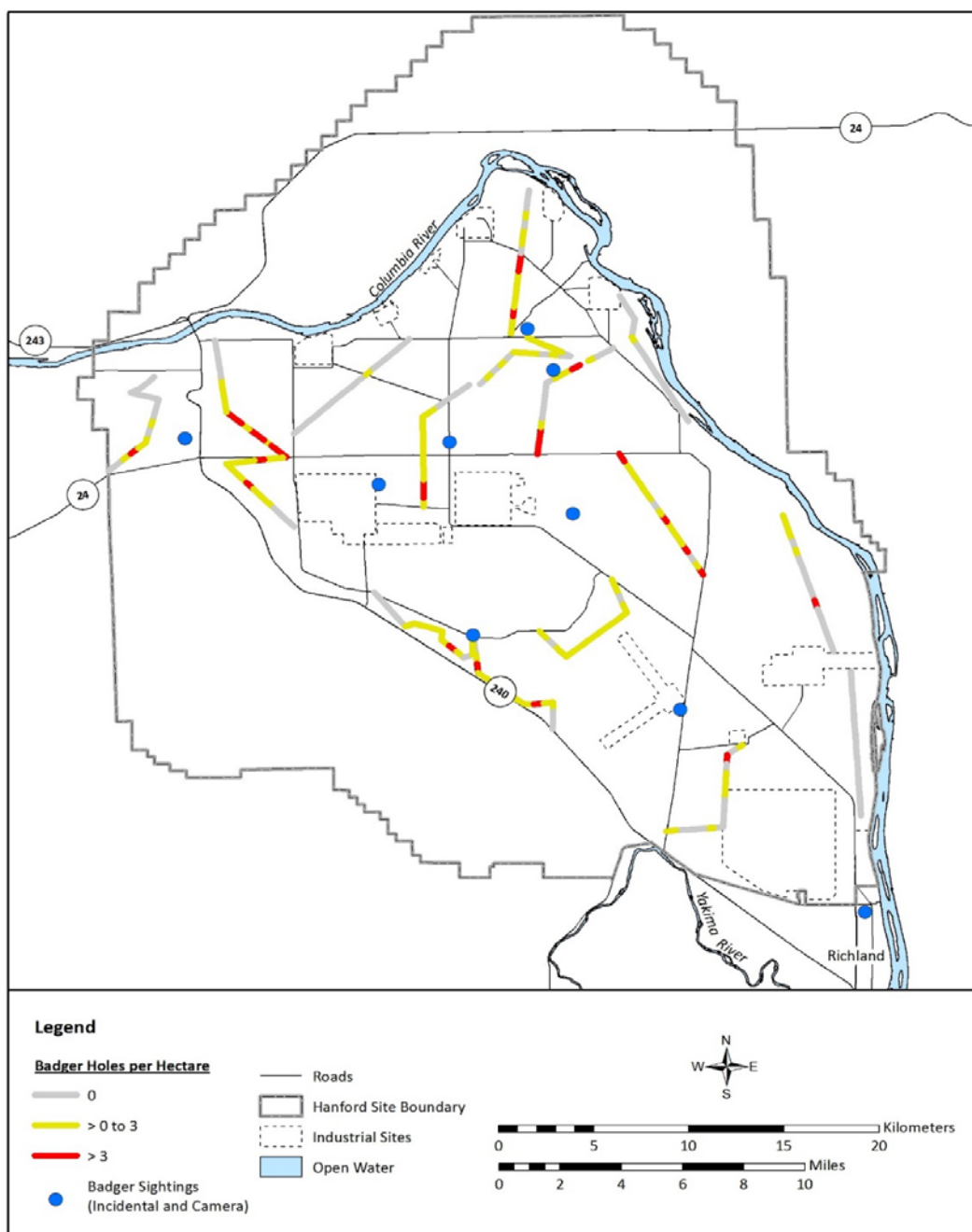


Figure 11.11. Distribution Map Containing All Badger Data to Date

11.2 Endangered and Threatened Species

JA Pottmeyer

This section describes federal and state endangered and threatened species, candidate or sensitive plant and animal species, and other species of concern potentially found at 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 near 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 USFWS in [50 CFR 17.11](#), “Endangered and Threatened Wildlife” and [50 CFR 17.12](#), “Endangered and Threatened Plants.” The Washington Natural Heritage Program ([WNHP 2014](#)) and WDFW ([WDFW 2016](#)) maintain state lists.

The purposes of the *Endangered Species Act of 1973* ([16 U.S.C. 1531](#), 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 appropriate steps are taken to achieve the purposes of the treaties and conventions established under the Act. Washington State regulations also list species as endangered and threatened, but such a listing does not carry the protection of the federal Endangered Species Act. The National Oceanic and Atmospheric Administration’s (NOAA) National Marine Fisheries Service ([NOAA 2015](#)) has the responsibility for federal listing of anadromous fish (i.e., fish that require both saltwater and freshwater to complete a lifecycle). The USFWS is responsible for all other federally listed species at the Hanford Site. Table 11.8 lists the federal species of plants and animals that occur or potentially occur on the Hanford Site and are listed as endangered, threatened, sensitive, or candidate by either the federal or state government.

Table 11.8. Federal and State Endangered, Threatened, Sensitive, and Candidate Species

Species	Status*	
	Federal	State
Plants		
Annual sandwort (<i>Minuartia pusilla</i> var. <i>pusilla</i>)		Sensitive
Awned halfchaff sedge (<i>Lipocarpa aristulata</i>)		Threatened
Beaked spike-rush (<i>Eleocharis rostellata</i>)		Sensitive
Canadian St. John’s wort (<i>Hypericum majus</i>)		Sensitive
Columbia milkvetch (<i>Astragalus columbianus</i>)	Species of concern	Sensitive
Columbia yellowcress (<i>Rorippa columbiae</i>)	Species of concern	Threatened
Coyote tobacco (<i>Nicotiana attenuata</i>)		Sensitive
Desert dodder (<i>Cuscuta denticulata</i>)		Threatened
Dwarf evening primrose (<i>Eremothera pygmaea</i>)		Sensitive
Geyer’s milkvetch (<i>Astragalus geyeri</i> var. <i>geyeri</i>)		Threatened
Grand redstem (<i>Ammannia robusta</i>)		Threatened
Gray cryptantha (<i>Cryptantha leucophaea</i>)	Species of concern	Sensitive
Great Basin gilia (<i>Aliciella leptomeria</i>)		Threatened
Hairy bugseed (<i>Corispermum villosum</i>)		Sensitive
Hoover’s desert parsley (<i>Lomatium tuberosum</i>)	Species of concern	Sensitive
Loeflingia (<i>Loeflingia squarrosa</i>)		Threatened
Lowland toothcup (<i>Rotala ramosior</i>)		Threatened
Miner’s candle (<i>Cryptantha scoparia</i>)		Sensitive
Piper’s daisy (<i>Erigeron piperianus</i>)		Sensitive
Rosy pussypaws (<i>Cistanthe rosea</i>)		Threatened
Small-flower evening-primrose (<i>Eremothera minor</i>)		Sensitive
Snake River cryptantha (<i>Cryptantha spiculifera</i>)		Sensitive
Snowball cactus (<i>Pediocactus nigrispinus</i>)		Sensitive
Suksdorf’s monkey flower (<i>Erythranthe suksdorfii</i>)		Sensitive

Table 11.8. Federal and State Endangered, Threatened, Sensitive, and Candidate Species

Species	Status*	
	Federal	State
Thompson's sandwort (<i>Eremogone franklinii</i> var. <i>thompsonii</i>)		Sensitive
Tufted evening-primrose (<i>Oenothera cespitosa</i> ssp. <i>cespitosa</i>)		Sensitive
Umtanum desert buckwheat (<i>Eriogonum codium</i>)	Threatened	Endangered
White Bluffs bladderpod (<i>Physaria douglasii</i> ssp. <i>tuplashensis</i>)	Threatened	Threatened
White eatonella (<i>Eatonella nivea</i>)		Threatened
Mollusks		
California floater (<i>Anodonta californiensis</i>)		Candidate
Columbia pebblesnail (<i>Fluminicola columbiana</i>)		Candidate
Shortface lanx (<i>Fisherola nuttalli</i>)		Candidate
Insects		
Columbia clubtail (dragonfly; <i>Gomphus lynnae</i>)		Candidate
Columbia River tiger beetle (<i>Cicindela columbica</i>)†		Candidate
Silver-bordered fritillary (<i>Boloria selene atrocotalis</i>)		Candidate
Fish		
Bull trout (<i>Salvelinus confluentus</i>)‡	Threatened	Candidate
Chinook salmon (upper Columbia spring-run; <i>Oncorhynchus tshawytscha</i>)	Endangered	Candidate
Leopard dace (<i>Rhinichthys falcatus</i>)‡		Candidate
Mountain sucker (<i>Catostomus platyrhynchus</i>)‡		Candidate
River lamprey (<i>Lampetra ayresi</i>)‡	Species of concern	Candidate
Steelhead (upper Columbia; <i>Oncorhynchus mykiss</i>)	Threatened	Candidate
Birds		
American white pelican (<i>Pelecanus erythrorhynchos</i>)		Endangered
Bald eagle (<i>Haliaeetus leucocephalus</i>)	Species of concern	Sensitive
Burrowing owl (<i>Athene cunicularia</i>)		Candidate
Clark's grebe (<i>Aechmophorus clarkii</i>)		Candidate
Common loon (<i>Gavia immer</i>)		Sensitive
Ferruginous hawk (<i>Buteo regalis</i>)		Threatened
Flammulated owl (<i>Otus flammeolus</i>)‡		Candidate
Golden eagle (<i>Aquila chrysaetos</i>)		Candidate
Greater sage grouse (<i>Centrocercus urophasianus</i>)		Threatened
Lewis's woodpecker‡ (<i>Melanerpes lewis</i>)‡		Candidate
Loggerhead shrike (<i>Lanius ludovicianus</i>)		Candidate
Northern goshawk‡ (<i>Accipiter gentilis</i>)‡		Candidate
Peregrine falcon (<i>Falco peregrinus</i>)	Species of concern	Sensitive
Sagebrush sparrow (<i>Artemisiospiza nevadensis</i>)		Candidate
Sage thrasher (<i>Oreoscoptes montanus</i>)		Candidate
Sandhill crane (<i>Grus canadensis</i>)		Endangered
Western grebe (<i>Aechmophorus occidentalis</i>)		Candidate
Amphibians and Reptiles		
Sagebrush lizard (<i>Sceloporus graciosus</i>)		Candidate
Striped whipsnake (<i>Masticophis taeniatus</i>)		Candidate
Western toad (<i>Bufo boreas</i>)		Candidate
Mammals		
Black-tailed jackrabbit (<i>Lepus californicus</i>)		Candidate
Merriam's shrew (<i>Sorex merriami</i>)		Candidate
Townsend's ground squirrel (<i>Urocitellus townsendii</i>)		Candidate
Washington ground squirrel (<i>Urocitellus washingtoni</i>)‡	Candidate	Candidate
White-tailed jackrabbit (<i>Lepus townsendii</i>)		Candidate

*Endangered=Species in danger of extinction within all or a significant portion of its range; Threatened=Species likely to become endangered in the near future; Candidate=Species believed to qualify for threatened or endangered species status but for which listing proposals have not been prepared; Sensitive=Taxa vulnerable or declining that could become endangered or threatened without active management or removal of threats; Species of concern=Not currently listed or candidates under the Endangered Species Act of 1973 but of conservation concern within specific USFWS regions.

†Probable but not observed on the Hanford Site.

‡Reported but seldom observed on the Hanford Site.

Two federally listed fish species, spring-run Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*), are known to occur regularly in the Hanford Reach of the Columbia River. One additional fish species, bull trout (*Salvelinus confluentus*), was recorded at the Hanford Site, but scientists believe this species is transient. Two plant species, Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Physaria douglasii* ssp. *tuplashensis*), were listed as threatened under the federal *Endangered Species Act* in April 2013; the rule was reaffirmed and made effective later that year ([78 FR 23984](#)). No other plants or animals known to occur on the Hanford Site are currently on the federal list of endangered and threatened species ([50 CFR 17](#)), but one mammal species (Washington ground squirrel) is currently a candidate for federal listing. In addition, 12 plant species and 4 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 33 state-level sensitive and candidate species of animals and 17 sensitive plant species occurring or potentially occurring on the Hanford Site.

Washington State officials maintain additional lower level lists of species, including a monitor list for animals ([WDFW 2016](#)) and review and watch lists for plants ([WNHP 2014](#)). Species on the state monitor, watch, and review lists are not considered species of concern but are monitored for status and distribution (Table 11.9). These species are managed as needed by the state to prevent them from becoming endangered, threatened, or sensitive, and an abundance of these species may be indicative of an ecosystem with relatively high native diversity. Approximately 50 state monitor list animal species occur or potentially occur on the Hanford Site (Table 11.9), along with 24 watch or review list plant species (Table 11.10).

Table 11.9. Washington State Monitored Animal Species

Species	Species
Birds	Insects
Arctic tern (<i>Sterna paradisaea</i>)*	Juba skipper (<i>Hesperia juba</i>)
Ash-throated flycatcher (<i>Myiarchus cinerascens</i>)*	Nevada skipper (<i>Hesperia nevada</i>)
Black tern (<i>Chlidonias niger</i>)*	Pasco pearl crescent (<i>Phyciodes tharos pascoensis</i>)
Black-crowned night-heron (<i>Nycticorax nycticorax</i>)	Persius' duskywing (<i>Erynnis persius</i>)
Black-necked stilt (<i>Himantopus mexicanus</i>)	Purplish copper (<i>Lycaena helloides</i>)
Bobolink (<i>Dolichonyx oryzivorus</i>)*	Ruddy copper (<i>Lycaena rubida perkinsorum</i>)
Caspian tern (<i>Sterna caspia</i>)	Viceroy (<i>Limenitis archippus lahontani</i>)
Forster's tern (<i>Sterna forsteri</i>)	Amphibians and Reptiles
Grasshopper sparrow (<i>Ammodramus savannarum</i>)	Night snake (<i>Hypsiglena torquata</i>)
Gray flycatcher (<i>Empidonax wrightii</i>)	Racer (<i>Coluber constrictor</i>)
Great blue heron (<i>Ardea herodias</i>)	Short-horned lizard (<i>Phrynosoma douglasii</i>)
Great egret (<i>Ardea alba</i>)	Tiger salamander (<i>Ambystoma tigrinum</i>)
Gyr Falcon (<i>Falco rusticolus</i>)*	Woodhouse's toad (<i>Anaxyrus woodhousii</i>)
Horned grebe (<i>Podiceps auritus</i>)	Mollusks
Lesser goldfinch (<i>Spinus psaltria</i>)	Oregon floater (<i>Anodonta oregonensis</i>)
Long-billed curlew (<i>Numenius americanus</i>)	Western floater (<i>Anodonta kennerlyi</i>)
Osprey (<i>Pandion haliaetus</i>)	Western pearlshell (<i>Margaritifera falcata</i>)
Prairie falcon (<i>Falco mexicanus</i>)	Winged floater (<i>Anodonta nuttalliana</i>)
Red-necked grebe (<i>Podiceps grisegena</i>)*	Mammals
Snowy owl (<i>Nyctea scandiaca</i>)	American badger (<i>Taxidea taxus</i>)
Swainson's hawk (<i>Buteo swainsoni</i>)	Canyon bat (<i>Parastrellus hesperus</i>)
Turkey vulture (<i>Cathartes aura</i>)*	Long-legged myotis (<i>Myotis volans</i>)†
Western bluebird (<i>Sialia mexicana</i>)	Northern grasshopper mouse (<i>Onychomys leucogaster</i>)
Fish	Pallid bat (<i>Antrozous pallidus</i>)
Pacific lamprey (<i>Lampetra tridentata</i>)†	Sagebrush vole (<i>Lemmiscus curtatus</i>)
Paiute sculpin (<i>Cottus beldingi</i>)	Western small-footed myotis (<i>Myotis ciliolabrum</i>)†
Reticulate sculpin (<i>Cottus perplexus</i>)	
Sand roller (<i>Percopsis transmontana</i>)	

*Reported but seldom observed on the Hanford Site; †Federal species of concern.

Table 11.10. Hanford Site Washington State Review and Watch List Plant Species

Species	State Listing*
Annual paintbrush (<i>Castilleja exilis</i>)	Watch List
Basalt milkvetch (<i>Astragalus conjunctus</i> var. <i>rickardii</i>)	Watch List
Bristly combseed (<i>Pectocarya setosa</i>)	Watch List
Chaffweed (<i>Anagallis minima</i>)	Watch List
Columbia River mugwort (<i>Artemisia lindleyana</i>)	Watch List
Crouching milkvetch (<i>Astragalus succumbens</i>)	Watch List
False pimpernel (<i>Lindernia dubia</i> var. <i>anagallidea</i>)	Watch List
Giant helleborine (<i>Epipactis gigantea</i>)	Watch List
Kittitas larkspur (<i>Delphinium multiplex</i>)	Watch List
Medic milkvetch (<i>Astragalus speirocarpus</i>)	Watch List
Pigmy-weed (<i>Crassula aquatica</i>)	Watch List
Porcupine sedge (<i>Carex hystericina</i>)	Watch List
Robinson's onion (<i>Allium robinsonii</i>)	Watch List
Rosy balsamroot (<i>Balsamorhiza rosea</i>)	Watch List
Scilla onion (<i>Allium scilloides</i>)	Watch List
Shining flatsedge (<i>Cyperus bipartitus</i>)	Watch List
Shy gilly-flower (<i>Gilia inconspicua</i>)	Review Group 1
Small-flowered nama (<i>Nama densum</i> var. <i>parviflorum</i>)	Watch List
Smooth cliffbrake (<i>Pellaea glabella</i> var. <i>simplex</i>)	Watch List
Smooth willowherb (<i>Epilobium campestre</i>)	Review Group
Southern mudwort (<i>Limosella acaulis</i>)	Watch List
Stalked-pod milkvetch (<i>Astragalus sclerocarpus</i>)	Watch List
Vanilla grass (<i>Anthoxanthum hirtum</i>)	Review Group 1
Winged combseed (<i>Pectocarya penicillata</i>)	Watch List
*Watch List: Taxa of conservation concern but more abundant and/or less threatened than previously assumed. Review Group 1: Taxa for which currently there are insufficient data available to support listing as threatened, endangered, or sensitive.	

11.3 Cultural and Historic Resource Protection

CD Currie, AP Fergusson, KM Mendez

Cultural and historic resources protection on the Hanford Site is conducted under the direction of the DOE-RL Cultural Resources Program to ensure site compliance with federal cultural resources laws and regulations (Section 2.5). Program activities in 2015 included the following:

- Performed Cultural Resource Reviews for federal undertakings conducted at the Hanford Site in accordance with Section 106 of the NHPA ([16 U.S.C. 470](#)) and NEPA ([42 U.S.C. 4321 et seq.](#));
- Monitored site conditions to ensure important cultural resources are protected;
- Maintained a database of cultural resources site records, project records, and regional ethno-history;
- Maintained archaeological and historical collections;
- Identified and evaluated new cultural resources to ensure they are appropriately managed;
- Consulted with Native American Tribes and other stakeholders to gather input on the identification, documentation, and management of cultural resources important to them.

DOE-RL's Cultural Resources Program personnel oversee all cultural resource activities at the Hanford Site. Project-specific NHPA Section 106 compliance work scope in 2015 was performed by staff archaeologists from MSA and WCH.

The DOE-RL Cultural Resources Program also schedules monthly meetings with archaeological staff from Hanford Site contractors (MSA and WCH) to discuss and resolve issues relating to Cultural Resources Management (including survey procedures, site testing, site evaluation, consultations with external parties, etc.), with the objective of establishing and maintaining consistency among contractors.

11.3.1 Cultural Resources Reviews

Pursuant to the NEPA, and Section 106 of the *National Historic Preservation Act of 1966*, DOE-RL conducts cultural resources reviews of federal undertakings at the Hanford Site. The Section 106 regulations are also addressed as ARAR (Section 121[d]) under the CERCLA, requiring remedial actions to identify and take into account the effects of activities on historic properties included on or eligible for inclusion on the National Register of Historic Places (NRHP; National Register). NHPA Section 106 cultural resource reviews ensure that important cultural resources are identified and effects to those resources are evaluated prior to project initiation so that mitigation measures can be conducted, if necessary.

In 2015, Hanford Site archaeologists completed 103 NHPA Section 106 cultural resource reviews, which included the following:

- Twenty-three undertakings in 2015 that had the potential to affect cultural resources, which included efforts to identify cultural resources that might be affected by project activity, an assessment of potential impacts, and the development of mitigation measures, if necessary[‡];
 - Nine were identified as *No Historic Properties Affected*;
 - Eleven were determined to have *No Adverse Effects* to historic properties;
 - Three projects were identified as having *Adverse Effects* requiring mitigation measures as documented in a resulting project-specific Memorandum of Agreement. Adverse effects were avoided by taking specific actions to minimize impacts, including avoidance, following treatment plan guidelines, and archaeological monitoring.
- Twenty-seven projects that affected historic buildings but did not involve ground disturbance and were determined exempt by Hanford Site archaeologists after meeting the DOE-approved historic buildings programmatic agreement ([DOE/RL-96-77](#)) exemption criteria following an initial review;
- Fifty-four projects that had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews (Previously Reviewed Project Analyses Reviewed Project Analysis);
- Ten projects were reviewed and completed by Hanford Site archaeologists under an emergency declaration (Post Reviews) in accordance with Section 5.1.1 of the *Hanford Cultural Resources Management Plan* ([DOE/RL-98-10](#)).

A total of 4,645.13 ac (1,879.81 ha) of new ground was surveyed for cultural resources from NHPA Section 106 project specific surveys. In addition, some undertakings required NRHP ([36 CFR 60](#)) eligibility evaluations. Most projects cleared under these expedited reviews occurred in the 200 Areas of the Hanford Site (Figure 11.12).

[‡]This number does not reflect all full cultural resources reviews initiated in 2015. Additional reviews were initiated in 2015 but completed in 2016 and are not included in this report.

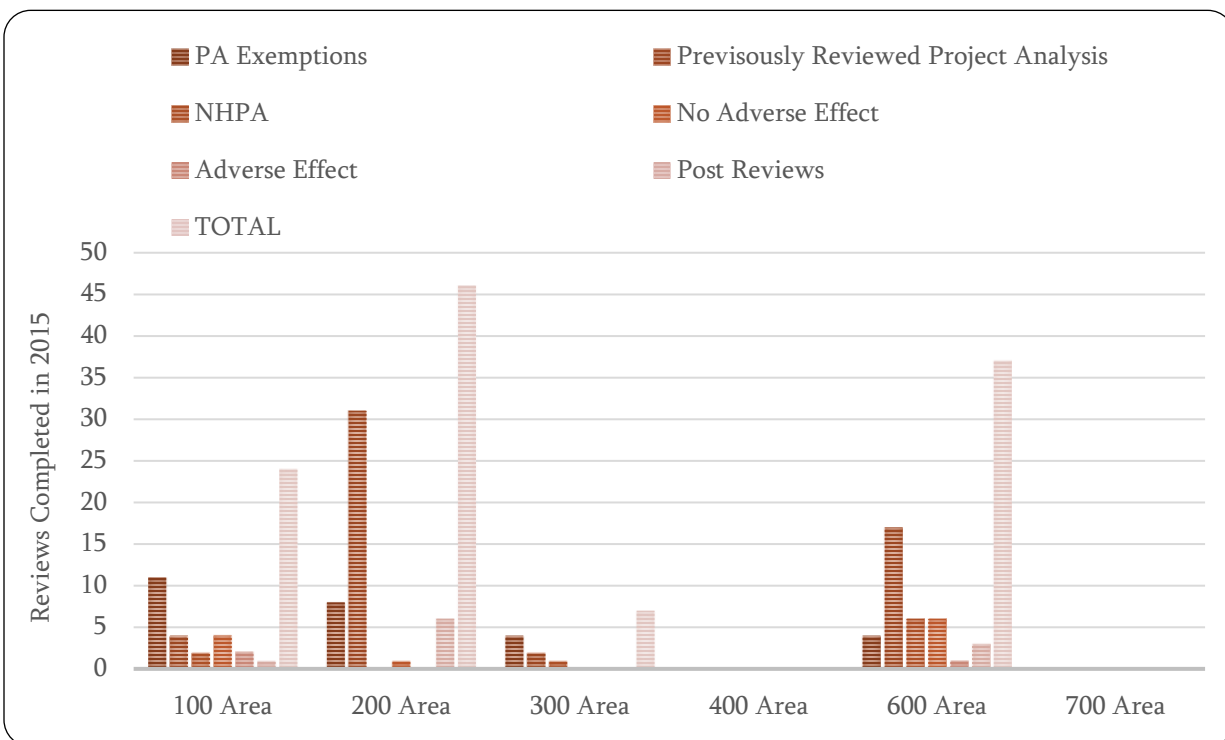


Figure 11.12. Hanford Site National Historic Preservation Act Section 106 Reviews by Area

11.3.2 Cultural Resources Protections and Section 110 Activities

To ensure protection of cultural and historic resources located on the Hanford Site, monitoring activities are conducted to comply with Section 110 of the NHPA ([16 U.S.C. 470](#)) and the Archaeological Resources Protection Act ([16 U.S.C. 470](#)) formed

to secure, for the present and future benefit of the American people, the protection of archaeological resources and sites which are on public lands and Indian lands, and to foster increased cooperation and exchange of information between governmental authorities, the professional archaeological community, and private individuals (Sec. 2(4)(b)).

A monitoring program has been in place since 1989 to assess weathering and erosion effects and/or unauthorized excavation and collection of significant cultural resources on the Hanford Site. Activities include on-site inspections to monitor site conditions, assess impacts, and identify protective measures, if necessary.

In 2015, eight pre-contact archaeological sites were monitored under the Section 110 Site Conditions Monitoring program. Site visits are conducted with the participation of tribal cultural resources personnel. In addition, the Section 110 program was adjusted to ensure compliance with applicable regulations. A work plan was established that will ensure all components of Section 110 are addressed, including identification, nomination, and protection of historic properties. A five-year plan was established that, if implemented, will allow all sites included in the monitoring program to be evaluated for National Register eligibility by 2020. The changes made to the monitoring program will ensure that site condition monitoring is completed in a comprehensive and efficient manner that can be helpful in making resource management decisions.

11.3.2.1 Identification and Evaluation Activities

Identification and evaluation activities are performed to comply with Sections 106 and 110 of the NHPA. In 2015, approximately 500 ac (202 ha) of new ground was surveyed for cultural resources under the Section 110 program. Two new archaeological sites and one new isolate were recorded during this survey effort. Also in 2015, 27 new archaeological sites were recorded, and 60 new isolated finds were located (Table 11.11). National Register evaluations have not been completed on the newly discovered sites. Archaeological site forms for three previously recorded archaeological sites were updated, of which two were previously determined eligible for the National Register and one was not evaluated. Thirteen archaeological sites were determined eligible to the National Register for sites recorded in previous reviews. Ten archaeological sites recorded in previous years were determined not eligible. No Historic Property Inventory Forms (HPIF) were completed during the reporting period for components of Hanford's built environment.

Table 11.11. Sites and Isolates Recorded or Updated

2015	Eligible	Not Eligible	Unevaluated	Total
Site updates	2	0	1	3
New sites	0	0	31	31
New isolates	0	0	62	62
Historic Property Inventory Form	0	0	0	0
Total	2	0	94	96

11.3.2.2 Data and Artifact Collections Management

In 2014, the Cultural Resources Program transitioned to a paperless record keeping system, a process that continued in 2015. The Hanford Site Section 106 database tracks all cultural resource reviews conducted on the Hanford Site. The Section 106 database tracks dates, actions, letters, and results of the cultural resource reviews. Once a project is complete, it is closed out in the database and accessioned into the MSA digital archives for use by all Hanford Site Cultural Resource contractors and other interested researchers. Maintenance of these files is essential to the completion of all cultural resource compliance activities conducted on the Hanford Site.

In 2015, 138 new projects were opened, with pertinent information entered as acquired into the Section 106 database, and 165§ projects were closed out after data entry was complete, with a digital copy of the project documentation added to the digital archive.

The cultural resources GIS database contains cultural resource data collected from Hanford Site contractors, including new archaeological surveys completed as part of Section 106 work, newly recorded, and updated archaeological site locations, and contextual information describing the survey or site. All Hanford Site contractors use the GIS database for literature reviews, cultural resource compliance reporting, and documentation, and research by DOE-approved users. As part of ongoing database management in 2015, a total of 17 polygons delineating completed archaeological surveys were added to the Hanford Site Survey Master shapefiles (map file), and three new archaeological sites/isolates, together with associated spatial and contextual information, were added to the GIS Archaeological Site and Isolate

§This number is larger than the number of projects opened because projects from previous years were closed during 2015.

database. Spatial and contextual information for three archaeological sites/isolates were updated in this database based on information gathered during recent re-visits to these locations.

Largely due to excavations conducted as mitigation for adverse effects on archaeological sites, the Cultural and Historic Resources Program manages a collection of artifacts relating to the Native American settlement of the area within the mid-Columbia Basin that would become the Hanford Site. Similarly, a small collection of artifacts that mark the pre-1943 Euro-American settlement of the Priest Rapids Valley, later designated as the Hanford Site, is also maintained. These artifacts are stored at the Washington State University Tri-Cities Campus, Central Information Center, which maintains a climate controlled, restricted access facility. The forms and reports that document the excavations and interpret these sites also are held by the Cultural and Historic Resources Program. No new artifacts were added to either the prehistoric or the pre-Hanford collections in 2015.

11.3.3 Cultural Resources Consultations and Public Involvement

DOE conducts formal consultations with the Washington State Historic Preservation Officer (SHPO) within the DAHP, Native American tribes, and other interested parties for cultural resource reviews to comply with Section 106 of the NHPA and NEPA (Section 2.1.4). DOE-RL consulted with the Washington SHPO and Native American tribes on all 24 projects that required a full review because of their potential to affect cultural resources within the project area.

DOE Cultural Resources Program staff members held nine meetings in 2015 with Tribal Cultural Resources staff members from the Nez Perce Tribe, CTUIR, Confederated Tribes and Bands of Yakama Nation, and Wanapum. Discussions focused on the cultural resource reviews completed and initiated in 2015; proposed undertakings within traditional cultural property (TCP) boundaries and view sheds; and approaches to protecting threatened archaeological sites and places containing Native American human remains.

11.4 Collection Management and Curation

MC Petrich-Guy

The Hanford Collection comprises artifacts from the Manhattan Project and Cold War era obtained in compliance with [DOE/RL-96-77](#), *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 Hanford Site, Washington*. This programmatic agreement directs DOE-RL to identify and preserve any artifacts that may have value as interpretive or educational exhibits within national, state, or local museums. During 2015, 70 artifacts were picked up from Hanford Site facilities and delivered to the 4732-A Artifact Staging Facility, leaving 26 (3.5%) of the 743 tagged artifacts scheduled for collection between 2016 and 2048.



Figure 11.13. Archives Storage Area at WSU-TC

Consolidated Information Center curation facility. Prior to being moved move off site, Collection items were screened for residual radioactivity above allowable limits ([DOE O 458.1](#)) and controlled or classified materials to determine whether items could be released to the public. The remaining 60% of the collection is scheduled for transition during 2016.

The MSA Curation Services program awarded a subcontract to Washington State University Tri-Cities (WSU-TC) to provide professional curatorial and archival services for the management, conservation, and interpretation of the Hanford Collection consisting of artifacts and multimedia relating to the Manhattan Project and Cold War Era (Figure 11.13). With its local, national, and international ties to scholars and researchers, WSU-TC uniquely satisfied one of the principal objectives of DOE-RL to gather, preserve, and make the Hanford Collection broadly available to students and the public. In addition to public outreach and education, WSU-TC will also provide a repository for the collection that meets the requirements of [36 CFR 79](#), “Curation of Federally-Owned and Administered Archaeological Collections,” including protecting these resources from theft, fire, breakage, or deterioration.

The transition of the Hanford Collection to the WSU-TC facility began in July 2015. During 2015, 40% of the Collection was moved from the artifact staging facility on the Hanford Site to the WSU-TC

12.0 Quality Assurance

WS Thompson

Quality assurance (QA) and quality control (QC) practices encompass all aspects of Hanford Site environmental monitoring and surveillance activities. Hanford Site contractors, subcontractors, and multiple DOE organizations are involved in and conduct environmental monitoring and surveillance activities independently, each driven by different missions and regulatory requirements but with the same goal in mind. This section describes the Environmental Surveillance program, part of the Public Safety and Resource Protection Program (PSRP) managed by MSA. The Environmental Surveillance program includes environmental surveillance and monitoring across multiple media types both on and off the Hanford Site. The program conducts multi-media environmental monitoring to assess Hanford Site and off-site human health exposures to radionuclides and chemicals and evaluate the potential impact of site operations on the environment. This section provides information on specific measures taken in 2015 to ensure quality and defensibility in project management, sample collection, and analytical results.

Note: Because of the complexity of the groundwater program, QA/QC specifications for groundwater sampling and program management are reported independently in the *Hanford Site Groundwater Monitoring Report for 2015* (DOE/RL-2016-09) and are not discussed in this section.

Quality assurances and controls of the Hanford Site and offsite surveillance programs are documented through QA program plans and describe applicable QA elements (e.g., MSC-23333, *Environmental Quality Assurance Program Plan*). Sample analyses across all media types are performed by contracted laboratories, which are also required to meet these plan specifications. To ensure the highest quality data are obtained, accredited off-site laboratories used were audited for equipment and services before the contract awards were made.

12.1 Program Management

Per federal requirements, environmental surveillance activities are subject to an overall QA program that satisfies requirements for collecting and assessing environmental data in compliance with the following:

- [10 CFR 830](#), “Nuclear Safety Management,” Subpart A, “Quality Assurance Requirements”
- [DOE O 414.1D](#), *Quality Assurance*
- [Analytical Services - Hanford Site](#), *Hanford Analytical Services Quality Assurance Requirements Documents* (HASQARD)
- *EPA Requirements for Quality Assurance Project Plans* ([EPA 2001b](#))
- Richland Requirements Document 008, Quality Assurance Program Requirements
- Project-specific QA plans and documentation are found in MSC-23333 and describe the QA/QC elements associated with the Environmental Surveillance program.

DOE O 414.1D QA Program Requirements

Management/QA Program
Personnel Training/Qualification
Quality Improvement
Documents and Records
Work Processes
Design
Procurement
Inspection and Acceptance Testing
Management Assessment
Independent Assessment

Personnel Training and Qualifications

Hanford Site personnel are provided with the knowledge and skills necessary to perform specific jobs safely, effectively, and efficiently with minimal supervision. This capacity is accomplished by establishing and enforcing site-wide policies, procedures, and guidance through training programs that provide general and specialized training classes and housing hands-on training facilities dedicated to ensuring personnel are qualified and confident to perform the task safely. The following principles and practices are included in the training program and are documented in MSC-23333:

- Develop training standards and procedures that meet valid requirements and regulations and are consistent with industry-proven best management practices
- Recognize management's responsibility to lead and coach their employees to ensure employees are trained and remain proficient to perform assigned tasks
- Conduct evaluations of employee training to ensure regulatory compliance, compliance with standards and instructions, and improve the training process
- Employ instructional staff and subject matter experts who are qualified and maintain their instructional and subject area skills and knowledge
- Use a graded approach to develop training programs to ensure value and effectiveness.

12.2 Quality Control Samples

Several types of QC samples are collected during monitoring and sampling events. The QC samples are in place to help reduce data uncertainty and collect the highest quality data possible. The tasks vary by monitoring and sampling event, and QC procedures are followed in the field and laboratory to ensure that reliable data are obtained.

Field environmental QC samples are collected to evaluate the potential for cross-contamination and provide information pertinent to field variability. Field QC samples require the collection of field duplicates, trip or field blanks, and equipment blanks. Laboratory QC samples estimate the precision and accuracy of the analytical data and include method blanks, laboratory replicates, matrix spikes, and matrix spike duplicates. Table 12.1 summarizes the different types, characteristics, and frequency of QC samples. A QC sample frequency goal of 5% (1 in 20 samples) where feasible is set for environmental surveillance activities on the Hanford Site for the number of QC samples needed for environmental data collection and surveillance activities.

Table 12.1. Field and Laboratory Quality Control Sample Types, Characteristics, and Frequency

Sample Type	Primary Characteristics Evaluated	Frequency
Field QC Samples		
Field trip blank (FTB)	Volatile organic compound cross-contamination from other sources during transportation	1 per field trip
Equipment blank (EB)	Cross-contamination from non-dedicated equipment	1 per sampling method type per year for selected analytes
Duplicate	Reproducibility	1 per 20 samples, where feasible
Laboratory QC Samples		
Method blank	Laboratory contamination	As defined in the laboratory contract or QA plan, and/or analysis procedures.
Laboratory replicate	Laboratory reproducibility	
Matrix spike	Matrix effect and laboratory accuracy	
Matrix spike duplicate	Laboratory reproducibility/accuracy	

Blanks. A sample of the carrying agent (gas, liquid, or solid) normally used to measure selectively a material of interest subjected to the usual analytical process and associated procedures to establish a baseline or background value. This value is then used to adjust or correct the routine analytical results.

Field Duplicate Samples. Two samples produced from material collected in the same location at roughly the same time. The parent sample and its duplicate are each uniquely labeled and used to provide information on the homogeneity of the matrix and ensure consistency in sample collection procedures.

Laboratory Replicate Sample. A single sample aliquoted alternately into two sets of sample containers for duplicate analysis by the primary laboratory. Replicates are a measure of variation of aliquots analyzed from the same sample.

Spiked Sample. A normal sample of material (gas, liquid, or solid) to which a known amount of some substance of interest is added. Spiked samples check the accuracy of a routine analysis or the recovery efficiency of an analytical method. Spiked samples are exclusively used by the laboratory.

12.3 Sample Collection Quality Assurance and Quality Control

Trained personnel collected environmental samples for air, surface water, biota (wildlife and food/farm products), soil and vegetation, and sediment in accordance with approved desk instructions or procedures. Established sampling locations were accurately identified with visible postings or plotted GPS readings and documented to ensure data continuity. In 2015, collected environmental samples were submitted to General Engineering Laboratories, LLC (GEL) or TestAmerica Richland Laboratories (TARL; Table 12.2).

Table 12.2. Laboratories and Types of Environmental Surveillance Samples Analyzed

Analytical Laboratory	Environmental Monitoring and Surveillance Samples			
	Air	Water	Biota	Other
TARL (TestAmerica Richland Laboratory)	X			X
GEL (General Engineering Laboratories, LLC)	X	X	X	X

Personnel are trained to conduct sampling in accordance with approved schedules, instructions, and procedures. Field assessments are routinely performed by media task leads and documented. Field duplicate samples are used to assess sampling and measurement precision. In 2015, duplicate samples were collected and analyzed for air, soil, Columbia River water, natural vegetation, milk, wine, mulberries, wildlife, irrigation water, sediment, and seep samples (Table 12.3).

Table 12.3. Field Duplicate Samples and Locations

Media	Location	Number of Samples
Air	Various	39
Columbia River Water	Richland Pumphouse – Hanford River Mile (HRM) 46.4	1
Columbia River Water	Priest Rapids Dam	2
Columbia River Water Transects	Various	4
Irrigation Water	Horn Rapids Area	1
Milk	East Wahluke Area	1
Mulberries	100-N Area	3
Natural Vegetation	Various	5
Sediment	West Lake	1
Sediment	Columbia River	1
Seep	300 Area	1
Seep	100-K Area	1
Soil	Various	8
Wine	Columbia Basin	2
Wildlife	Various	9

Analytical results for on- and off-site parent and duplicate samples were reviewed against the criterion that the result must be greater than the minimum detectable activity value or method detection limit to be evaluated (commonly known as a detect). To be considered an acceptable result (within the control limits), the relative percent difference (RPD) of the detected routine sample and its duplicate must be less than 30%. Duplicate results for 2015 are shown in Table 12.4.

Relative Percent Difference (RPD)

A measure of precision of the measurement of a sample (S) and its duplicate (D). The formula is as follows:

$$RPD = \left(\frac{|S - D|}{\frac{(S + D)}{2}} \right) \times 100$$

Table 12.4. Field Duplicate Sample Results

Media	Detected Analytes	Number of Results Within Control Limits*	Percent of Results within Control Limits
Radionuclides			
Air	Alpha (gross)	31 of 39	79
	Beta (gross)	31 of 39	79
	Americium-241	4 of 4	100
	Antimony-125	4 of 4	100
	Cobalt-60	4 of 4	100
	Cesium-134	4 of 4	100
	Cesium-137	4 of 4	100
	Europium-152	4 of 4	100
	Europium-154	4 of 4	100
	Europium-155	4 of 4	100
	Hydrogen-3 (tritium)	14 of 14	100
	Plutonium-238	4 of 4	100
	Plutonium-239/-240	4 of 4	100
	Potassium-40	4 of 4	100
	Ruthenium-106	4 of 4	100
	Strontium-90	4 of 4	100
	Uranium-234	4 of 4	100
	Uranium-235	4 of 4	100
	Uranium-238	4 of 4	100
	Antimony-125	8 of 8	100
Soil	Cesium-134	7 of 8	87
	Cesium-137	7 of 8	87
	Cobalt-60	8 of 8	100
	Europium-152	8 of 8	100
	Europium-154	8 of 8	100
	Europium-155	8 of 8	100
	Plutonium-238	8 of 8	100
	Plutonium-239/-240	8 of 8	100
	Potassium-40	8 of 8	100
	Ruthenium-106	8 of 8	100
	Strontium-90	8 of 8	100
	Uranium-234	8 of 8	100
	Uranium-235	8 of 8	100
	Uranium-238	8 of 8	100
Natural Vegetation	Antimony-125	5 of 5	100
	Cesium-134	5 of 5	100
	Cesium-137	5 of 5	100
	Cobalt-60	5 of 5	100

Table 12.4. Field Duplicate Sample Results

Media	Detected Analytes	Number of Results Within Control Limits*	Percent of Results within Control Limits
	Europium-152	5 of 5	100
	Europium-154	5 of 5	100
	Europium-155	5 of 5	100
	Plutonium-238	5 of 5	100
	Plutonium-239/-240	5 of 5	100
	Potassium-40	5 of 5	100
	Ruthenium-106	5 of 5	100
	Strontium-90	5 of 5	100
	Uranium-234	5 of 5	100
	Uranium-235	5 of 5	100
	Uranium-238	5 of 5	100
Mulberries			
Bark	Strontium-90	1 of 1	100
	Uranium-234	0 of 1	0
	Uranium-238	1 of 1	100
Fruit	Potassium-40	1 of 1	100
	Uranium-235	0 of 1	0
	Uranium-238	0 of 1	0
Leaves	Beryllium-7	0 of 1	0
	Potassium-40	1 of 1	100
	Strontium-90	0 of 1	0
	Tritium	1 of 1	100
	Uranium-234	1 of 1	100
	Uranium-235	1 of 1	100
	Uranium-238	1 of 1	100
Farm Products			
Milk	Hydrogen-3 (tritium)	1 of 1	100
	Potassium-40	1 of 1	100
Wine	Hydrogen-3 (tritium)	1 of 2	50
	Potassium-40	2 of 2	100
Surface Water			
Columbia River	Hydrogen-3 (tritium)	1 of 2	50
	Uranium-234	2 of 2	100
	Uranium-238	2 of 2	100
Seep	Alpha (gross)	1 of 1	100
	Beta (gross)	1 of 1	100
	Hydrogen-3 (tritium)	1 of 1	100
	Uranium-234	1 of 1	100
	Uranium-235	1 of 1	100
	Uranium-238	1 of 1	100
Columbia River Transects	Hydrogen-3 (tritium)	4 of 4	100
	Uranium-234	3 of 4	75
	Uranium-235	1 of 2	50
	Uranium-238	3 of 4	75
Off-site Irrigation	Hydrogen-3 (tritium)	1 of 1	100

Table 12.4. Field Duplicate Sample Results

Media	Detected Analytes	Number of Results Within Control Limits*	Percent of Results within Control Limits
Sediment			
West Lake Sediment	Cesium-137	1 of 1	100
	Alpha (gross)	1 of 1	100
	Beta (gross)	1 of 1	100
	Potassium-40	1 of 1	100
	Uranium-234	1 of 1	100
	Uranium-235	1 of 1	100
	Uranium-238	1 of 1	100
Columbia River Sediment	Cesium-137	1 of 1	100
	Plutonium-239/-240	1 of 1	100
	Potassium-40	1 of 1	100
	Uranium-234	1 of 1	100
	Uranium-235	1 of 1	100
	Uranium-238	1 of 1	100
Wildlife	Cesium-137	1 of 1	100
	Potassium-40	5 of 5	100
	Uranium-234	1 of 1	100
	Uranium-238	1 of 1	100
Anions			
Surface Water Transects	Chloride	4 of 4	100
	Fluoride	4 of 4	100
	Nitrate	4 of 4	100
	Sulfate	4 of 4	100
Seep	Bromide		
	Chloride	1 of 1	100
	Fluoride	1 of 1	100
	Nitrate	1 of 1	100
Columbia River Sediment	Sulfate	1 of 1	100
	Chloride	1 of 1	100
Metals			
Surface Water Transects	Aluminum	3 of 3	100
	Barium (filtered)	4 of 4	100
	Barium (non-filtered)	4 of 4	100
	Boron (filtered)	3 of 4	75
	Boron (non-filtered)	4 of 4	100
	Calcium (filtered)	4 of 4	100
	Calcium (non-filtered)	4 of 4	100
	Cobalt (filtered)	0 of 3	0
	Copper (filtered)	3 of 4	75
	Copper (non-filtered)	4 of 4	100
	Iron (non-filtered)	1 of 1	100
	Magnesium (filtered)	4 of 4	100
	Magnesium (non-filtered)	4 of 4	100
	Manganese (filtered)	2 of 3	67
	Manganese (non-filtered)	4 of 4	100
	Molybdenum (filtered)	4 of 4	100
	Molybdenum (non-filtered)	4 of 4	100
	Potassium (filtered)	4 of 4	100
	Potassium (non-filtered)	4 of 4	100

Table 12.4. Field Duplicate Sample Results

Media	Detected Analytes	Number of Results Within Control Limits*	Percent of Results within Control Limits
	Sodium (filtered)	4 of 4	100
	Sodium (non-filtered)	4 of 4	100
	Strontium (filtered)	4 of 4	100
	Strontium (non-filtered)	4 of 4	100
	Uranium (filtered)	4 of 4	100
	Uranium (non-filtered)	4 of 4	100
	Vanadium (filtered)	1 of 1	100
	Vanadium (non-filtered)	2 of 2	100
	Zinc (filtered)	1 of 1	100
	Zinc (non-filtered)	1 of 1	100
Wildlife	Copper	1 of 3	33
	Mercury	2 of 2	100
	Selenium	1 of 1	100
	Thorium	1 of 1	100
	Zinc	2 of 3	67
Columbia River Sediment	Antimony	0 of 1	0
	Arsenic	1 of 1	100
	Cadmium	1 of 1	100
	Chromium	1 of 1	100
	Copper	1 of 1	100
	Hexavalent chromium	0 of 1	0
	Lead	1 of 1	100
	Mercury	0 of 1	0
	Nickel	1 of 1	100
	Zinc	1 of 1	100
Volatile Organics			
Seep	Trichlorethene	1 of 1	100
Other			
Columbia River Sediment	Total Organic Carbon	0 of 1	0

*Number of reported results within control limits are those with the RPD value less than 30%, and the result is greater than the minimum detectable activity or method detection limit.

12.4 Media Audits and Comparisons

Selected sediment, surface water, food and farm products, wildlife, soil, and vegetation samples are provided to the WDOH for comparative analysis as part of the Public Safety and Resource Protection QA program ([DOE/RL-91-50](#)). The Hanford Environmental Radiation Oversight Program of the WDOH independently verifies the quality of DOE monitoring programs at the Hanford Site. Since 1985, WDOH and DOE have collaboratively participated in the collection of environmental samples located on or in the surrounding areas of the Hanford Site ([DOH 320-111](#), *Hanford Environmental Radiation Oversight Program: 2014 Data Summary Report*). This includes but is not limited to conducting split, collocated, and independent sampling at locations that have the potential to release radionuclides to the environment or that could be impacted by such releases. This program is not intended to characterize completely the environmental radiation on the Hanford Site but provides oversight to Hanford Site contractors in determining the impact of Hanford releases on the environment and the public. More information can be found on the WDOH Environmental Sciences website at

<http://www.doh.wa.gov/CommunityandEnvironment/Radiation/EnvironmentalSciences.aspx>.

Media types analyzed by the WDOH in 2015 included the following:

- Air Filters from 12 locations
- Sediment from 5 locations
- Cherries from 2 locations
- Pheasant from 1 location
- Bass from 1 location
- Carp from 2 locations
- Backtail deer from 1 background location
- Columbia River surface water from 1 locations
- Off-site irrigation water from 2 locations
- Columbia River shoreline springs (seeps) from 6 locations.

No comparison data for 2015 were available at the time this report was written; however, links to past data summary reports and other environmental science publications for the Hanford Environmental Radiation Oversight program are available at

<http://www.doh.wa.gov/communityandenvironment/radiation/publications/environmentalsciences.aspx>.

12.5 Laboratory Quality Assurance Programs

Contracted analytical laboratories are required to maintain internal QC programs and participate in independent QC programs used to determine analytical precision and accuracy. These laboratories house chemical technologists who are qualified to perform these analyses through formal classroom education and on-the-job training. Internal QC programs for contracted laboratories involve routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation-check sources and background counts, replicate and spiked sample analyses, use of matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Examples of independent QC programs are the Mixed Analyte Performance Evaluation Program (MAPEP) and the DOE Consolidated Audit Program (DOECAP) described in the following sections.

12.5.1 Analytical Quality Assurance and Quality Control

Hanford Site environmental samples were sent to two laboratories in 2015 (Tables 12.5 and 12.6) and included routine chemical and radiological analyses of air, water, soil, vegetation, sediment and biota. In 2015, General Engineering Laboratories, LLC (GEL) and TestAmerica Richland Laboratory (TARL) participated in independent QA and QC programs including MAPEP and DOECAP. These managed programs use standardized audit methods, processes, and procedures to ensure the validity, reliability, and defensibility of data annually from the contract laboratories.

Table 12.5. DOE Mixed Analyte Performance Evaluation Program Results for General Engineering Laboratories, LLC

Environmental Sample Media and Analytes		MAPEP 32 Series March 2015*	MAPEP 33 Series August 2015*
Radionuclides			
Air Filters	Alpha (gross), beta (gross), americium-241, cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/-240, strontium-90, uranium-234/233, uranium-235, uranium-238	100% Acceptable	100% Acceptable
Water	Alpha (gross), beta (gross), americium-241, cesium-134, cesium-137, cobalt-60, iodine-129 plutonium-238, plutonium-239/-240, potassium-40, strontium-90, technetium-99, tritium, uranium-234/233, uranium-238	100% Acceptable	100% Acceptable
Vegetation	Americium-241, cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/-240, strontium-90, uranium-234/233, uranium-238	100% Acceptable	100% Acceptable
Soil	Americium-241, cesium-134, cesium-137, cobalt-60, potassium-40, plutonium-238, plutonium-239/-240, strontium-90, technetium-99	100% Acceptable	100% Acceptable
Inorganic Compounds			
Water	Antimony, arsenic, barium, beryllium, cadmium, chromium, copper, copper, lead, mercury, nickel, selenium, thallium, vanadium, zinc	Zinc†	100% Acceptable

*Performance results 100% acceptable for all analytes unless otherwise noted.
†False negative. No adverse effect on Hanford samples.

Table 12.6. DOE Mixed Analyte Performance Evaluation Program Results for TestAmerica Richland Laboratory

Environmental Sample Media and Analytes		MAPEP 32 Series March 2015*	MAPEP 33 Series August 2015*
Radionuclides			
Air Filters	Alpha (gross), beta (gross), americium-241, cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/-240, strontium-90, uranium-234/233, uranium-238	Gross alpha† Americium-241†	100% Acceptable
Water	Alpha (gross), beta (gross), americium-241, cesium-134, cesium-137, cobalt-60, iodine-129 plutonium-238, plutonium-239/-240, potassium-40, strontium-90, technetium-99, tritium, uranium-234/-233, uranium-238	100% Acceptable	Uranium-234/-233† Uranium-238†
Vegetation	Americium-241, cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/-240, strontium-90, uranium-234/-233, uranium-238	100% Acceptable	100% Acceptable
Soil	Americium-241, cesium-134, cesium-137, cobalt-60, potassium-40, plutonium-238, plutonium-239/-240, strontium-90, technetium-99	100% Acceptable	100% Acceptable

*Performance results 100% acceptable for all analytes unless otherwise noted.
†Result not acceptable; bias >30%.

In 2015, GEL and TARL were audited by DOECAP, whose objective is to ensure the application of consistent standards between the analytical laboratories supporting the DOE complex and its compliance programs. Audit objectives included assessing the ability of the laboratory to produce data of acceptable and documented quality through analytical operations that follow approved and technically sound methods, and the handling of DOE samples and associated waste in a manner that protected human health and the environment. GEL and TARL also participated in MAPEP Studies 32 and 33 and a number of Environmental Resource Associate's proficiency studies for water, soil, air filter, and vegetation matrices.

12.5.2 Laboratory Performance Evaluation and Proficiency Testing

Participation of Hanford Site analytical laboratories in DOE and EPA laboratory performance evaluation programs serves to ensure data quality. Hanford Site environmental monitoring contract laboratories participate in MAPEP-sanctioned proficiency testing provided by an independent laboratory (e.g., Environmental Resource Associates).

DOE's MAPEP provides critical QA testing for environmental analytical services. Radiological and non-radiological (organic and inorganic) constituents are evaluated by performing semiannual proficiency testing of the Hanford Site DOE laboratories, and other federal, state, commercial, and international laboratories. MAPEP proficiency tests help to ensure the accuracy of analytical results reported to DOE and other stakeholders, while also providing an efficient means for laboratories to demonstrate analytical proficiency. Results to past MAPEP studies can be found on the DOE's Mixed Analyte Performance Evaluation Program webpage at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

GEL's MAPEP program radiological results were 100% acceptable for Studies 32 and 33 in 2015 for air, water, soil, and vegetation. Results for inorganic compounds in water were 100% acceptable with the exception of the Study 32 result for zinc which reported a false negative associated with a sensitivity analysis. Results of MAPEP Studies 32 and 33 for GEL are provided in Table 12.5 or at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

TARL's MAPEP program radiological results were 100% acceptable for Studies 32 and 33 in 2015 for air, water, soil, and vegetation with the exception of the gross alpha and americium-241 results in Study 32 and the uranium-233/234 and uranium-238 results in Study 33. These results were not acceptable due to bias greater exceeding 30%. Results of MAPEP Studies 32 and 33 for TARL are provided in Table 12.6 or at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

12.6 Data Recording and Data Management

Record keeping is a vital part of all environmental programs on the Hanford Site. Maintenance of environmental data is essential for QA, regulatory compliance, trend analysis, and optimization purposes. The Environmental Surveillance program is responsible for ensuring that analytical data are appropriately reviewed, managed, and stored in accordance with applicable programmatic requirements governing data management procedures. Project documentation includes environmental sample logbooks and processing forms, and as applicable, monthly, quarterly, and annual occurrence reports. Several electronic data repositories are used to house the environmental data, all of which have their own internal QA and QC policies and procedures.

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Appendix A**Glossary**

A. Glossary	A.1
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B	A.1
C	A.2
D	A.2
E	A.3
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A. Glossary

This glossary contains selected words and phrases used in this report that may not be familiar to the reader. Words appearing in *italic* type within a definition are also defined in this glossary.

A

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*, the International System of Units (SI) equivalent (1 *gray* = 100 *rad*).

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 *radionuclide*. 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.

apatite – A mineral that has the capability to capture and retain radioactive metal contaminants.

aquifer – Underground sediment or rock that stores and/or transmits water.

aquifer tube – A small diameter flexible plastic tube used to sample shallow *aquifers*, natural seepage areas, or springs.

B

background radiation – *Radiation* in the natural environment, including cosmic rays from space and *radiation* from naturally occurring radioactive elements in the air, earth, and human bodies. It also includes *radiation* from worldwide *fallout* from historical atmospheric nuclear weapons testing. In the United States, the average person receives approximately 310 *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.

biological half-life – Time required for one-half of the amount of a *radionuclide* to be expelled from the body by natural metabolic processes, excluding radioactive *decay*, following ingestion, inhalation, or absorption.

black cell – A section of the Hanford Tank Waste Treatment and Immobilization Plant where high-level nuclear waste will be routed that will never be accessible to humans because of its high *radiation* levels.

C

cation – A positively charged ion.

clean closed – A facility is classified as “clean closed” under *Resource Conservation and Recovery Act of 1976* regulations when all hazardous waste has been removed and *any remaining hazardous waste constituents do not exceed applicable cleanup levels*.

collective total effective dose (equivalent; also referred to as “collective dose”) – Sum of the *total effective dose* for individuals comprising a defined population. Collective dose is expressed in units of *person-rem* or *-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. *Groundwater* in the confined aquifer is under a pressure greater than atmospheric pressure.

continuous sample – Sample formed by the continuous collection of the medium or contaminants within the medium during the entire 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 after having traveled through a connected tile field. These structures are no longer used at the Hanford Site.

curie (Ci) – A unit of *radioactivity* equal to 37 billion (3.7×10^{10}) nuclear transformations per second (*becquerels*).

D

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) and are 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 a *total effective dose (equivalent)* of greater than 100 *millirem* per year.

desiccation – A process whereby water or moisture is removed, resulting in dryness.

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).

direct-push technology – A cost-effective means of collecting subsurface samples; this technology uses a hydraulic hammer to drive a hollow rod into the soil either vertically or at an angle. Sensors can be deployed within the rod to detect radioactive contaminants, soil moisture, and other sampling criteria.

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 limits (regulatory) – Public and occupational regulatory dose limits are set by federal (i.e., U.S. Environmental Protection Agency, U.S. Nuclear Regulatory Commission, and U.S. Department of Energy) and state agencies to limit cancer risk. Other radiation dose limits are applied to limit other potential biological effects with workers' skin and lens of the eye.

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.

E

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.

F

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.

field duplicate sample – Replicate sample to determine the precision of the sampling and analytical measurement process by comparing results from identical samples collected at the same time and location. Matching field duplicates are stored in separate containers and are analyzed independently by the same laboratory.

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.

found fuel – Incomplete pieces of spent nuclear fuel elements too small to have been located and removed during previous debris removal.

fully institutionalized – To incorporate into a formalized, structured system and be implemented and fully functional.

G

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.

ground truth – Direct physical observations that are used to test indirect interpretations.

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.

H

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 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.

I

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.

ion exchange resin – High molecular weight insoluble polymers containing functional groups capable of undergoing exchange reactions with ions in a solution with which it is in contact.

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 a 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.

L

legacy waste – Waste that was generated before the Hanford Site's nuclear materials production mission was terminated.

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.

M

material at risk – The inventory of radioactive material that could potentially be released to the environment from an accident.

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 the site.

mean (or average) – Average value of a series of measurements. The mean is computed using the following equation:

$$\text{mean} = \frac{\sum x}{n}$$

where n is the number of measurements, and $\sum x$ 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 or extremely or acutely hazardous waste that contains both a nonradioactive hazardous component and a radioactive component.

monitoring – As defined in [DOE O 458.1, Chg 3](#), the measurement of radiation levels, discharges or environmental releases, residual radioactive levels, quantities of radioactive material, or exposure to members of the public and the use of these measurement results to evaluate radiological discharges or releases or potential and actual dose resulting from exposures to radioactive material or radiation.

N

noble gas – Any of a group of chemically and biologically inert gases that includes argon, krypton, radon, 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.

O

off-site locations – Sampling and measurement locations outside the Hanford Site boundary.

on-site 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 problems associated with the site.

outfall – End of a drain or pipe that carries wastewater or other *effluent* into a ditch, pond, or river.

P

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.

phytoremediation – Use of plants to degrade or immobilize pollutants or toxins from the environment.

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 plutonium-239, which is produced by the *irradiation* of uranium-238. Routine analysis cannot distinguish between the plutonium-239 and plutonium-240 *isotopes*; hence, the term plutonium-239/240 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.

Q

quality assurance – All actions that provide confidence that an item or process meets or exceeds user requirements and expectations.

quality control – All 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*.

R

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*.

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), neutrons (A), and 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.

refractory – A material that has a high melting point (i.e., heat resistant).

refugium (refugia) – An area that has not experienced ecological changes that have affected surrounding regions, providing a habitat for species that were once more widespread.

relative percent difference (RPD) – A measure of the precision of the measurement of a sample (S) and its duplicate (D). The formula is:

$$RPD = \left(\frac{|S - D|}{\left(\frac{S + D}{2} \right)} \right) \times 100$$

rem – A unit of dose equivalent and total 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 intended to manage and dispose of *Toxic Substances Control Act*-regulated polychlorinated biphenyl (PCB) waste not addressed suitably within the regulations. The risk-based disposal approval process applies to any person wishing to sample, clean up, or dispose of waste in a manner other than as prescribed in [40 CFR 761](#). For PCB *remediation* waste, the requirements for a risk-based disposal approval are specified in [40 CFR 761.61\(c\)](#). 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*.

S

shrub-steppe – A drought-resistant shrub and grassland ecosystem.

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 O 458.1, Chg 3](#), 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 determining effects, if any, on the local environment.

T

tank farm – A group of underground waste storage tanks.

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*.

total uranium – The sum of concentrations of the *isotopes* uranium-234, uranium-235, and uranium-238.

transuranic element – An element with an atomic number greater than 92, 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).

tritium – The heaviest radioactive *isotope* of hydrogen (hydrogen-3) with a 12.3-year half-life.

U

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 the Hanford Site, the unconfined *aquifer* is the uppermost aquifer and is most susceptible to contamination from site operations.

V

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.

W

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.

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Appendix B**Useful Information**

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B. Useful Information

The following information is provided to assist the reader in understanding this report. Included in this Appendix is information on scientific notation; units of measure, radioactivity, and radiological dose; chemical and elemental nomenclature; understanding data tables and data uncertainty; understanding graphs; and an explanation of select mathematical symbols. Definitions of technical terms can be found in Appendix A.

B.1 Public Reading Rooms

University of Washington
Government Publications Division
Suzzallo & Allen Libraries
P.O. Box 352900
Seattle, WA 98195-2900
(206) 543-4164
www.catalog.kub.wa.edu

Washington State University, Tri-Cities
US DOE Public Reading Room
Consolidated Information Center, Rm 101-L
2770 University Drive
Richland, WA 99352
(509) 372-7443
<http://reading-room.labworks.org>

Portland State University
Government Information
Branford Price Millar Library
1875 SW Park Ave
Portland, OR 97207-1151
(503) 725-4542
<http://library.pdx.edu/governmentinformationservice.html>
and http://library.pdx.edu/public_comment.html#hanf

Gonzaga University, Foley Center
East 502 Boone
Spokane, WA 99258-0001
(509) 313-3847
<http://www.gonzaga.edu/Academics/Libraries/Foley-Library/Departments/Special-Collections/default.asp>

Hanford Health Info Archive (through Gonzaga):
<http://www.gonzaga.edu/Academics/Libraries/Foley-Library/Departments/Special-Collections/Collections/Hanford-Health-and-Information-Archives/default.asp>

B.2 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, under using scientific (E notation), 1×10^9 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 a value given is 2.0×10^3 (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 2.0×10^{-5} (or 2.0E-05), the decimal point should be moved five places to the **left** so that the result would be 0.00002.

B.3 Units of Measure

The primary units of measure used in this report follow the International System of Units and are metric. Table B.1 summarizes and defines the terms and corresponding symbols (metric and non-metric). A conversion table is provided in Table B.2.

Table B.1. Units of Measure

Symbol	Name
Temperature	
°C	degree Celsius
°F	degree Fahrenheit
Time	
d	day
hr	hour
min	minute
sec	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 × 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 × 10 ⁻² m)
ft	foot
in.	inch
km	kilometer (1 × 10 ³ m)
m	meter
mi	mile
mm	millimeter (1 × 10 ⁻³ m)
μm	micrometer (1 × 10 ⁻⁶ m)
Area	
ha	hectare (1 × 10 ⁴ m ²)
km ²	square kilometer
mi ²	square mile
ft ²	square foot
Mass	
g	gram
kg	kilogram (1 × 10 ³ g)
mg	milligram (1 × 10 ⁻³ g)
μg	microgram (1 × 10 ⁻⁶ g)
lb	pound

Table B.2. Conversion Table

Multiply	By	To Obtain
cm	0.394	in.
m	3.28	ft
km	0.621	mi
kg	2.205	lb
L	0.2642	gal
m ²	10.76	ft ²
ha	2.47	acre
km ²	0.386	mi ²
m ³	35.31	ft ³
m ³	1.308	yd ³
pCi	1,000	nCi
μCi/mL	109	pCi/L
Ci/m ³	1012	pCi/m ³
mCi/cm ³	1015	pCi/m ³
nCi/m ²	1.0	mCi/km ²
Ci	3.7 × 10 ¹⁰	Bq
pCi	0.037	Bq
rad	0.01	Gy
rem	0.01	Sv
ppm	1,000	ppb
°C	(°C × 9/5) + 32	°F
oz	28.349	g
ton	0.9078	tonne

Multiply	By	To Obtain
in.	2.54	cm
ft	0.305	m
mi	1.61	km
lb	0.454	kg
gal	3.785	L
ft ²	0.093	m ²
acre	0.405	ha
mi ²	2.59	km ²
ft ³	0.0283	m ³
yd ³	0.7646	m ³
nCi	0.001	pCi
pCi/L	10 ⁻⁹	μCi/mL
pCi/m ³	10 ⁻¹²	Ci/m ³
pCi/m ³	10 ⁻¹⁵	mCi/cm ³
mCi/km ²	1.0	nCi/m ²
Bq	2.7 × 10 ⁻¹¹	Ci
Bq	27	pCi
Gy	100	rad
Sv	100	rem
ppb	0.001	ppm
°F	(°F - 32) ÷ 9/5	°C
g	0.035	oz
tonne	1.1	ton

B.4 Radioactivity Units

Much of this report provides data on levels of radioactivity in various environmental media. Radioactivity in this report is usually discussed in units of **curies (Ci)**, with conversions to **becquerels (Bq)**, the International System of Units measure (Table B.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., pCi/L). 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 B.4 includes selected conversions from curies to bequerels.

Table B.3. Radioactivity Unit Conversions

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 disintegrations/sec (dps).

Table B.4. Radioactivity Units

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel (2.7×10^{-11} Ci)
mCi	millicurie (1×10^{-3} Ci)	mBq	millibecquerel (1×10^{-3} Bq)
μCi	microcurie (1×10^{-6} Ci)	kBq	kilobecquerel (1×10^3 Bq)
nCi	nanocurie (1×10^{-9} Ci)	MBq	megabecquerel (1×10^6 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)		

B.5 Radiological Dose Limits

Regulatory dose limits, both public and occupational regulatory dose limits, are set by federal (i.e., U.S. Environmental Protection Agency [EPA], U.S. Nuclear Regulatory Commission [NRC], and U.S. Department of Energy [DOE]) and state agencies to limit cancer risk (Table B.5). Other radiation dose limits are applied to limit other potential biological effects with workers' skin and lens of the eye.

Table B.5. Radioactivity Units

Annual Radiation Dose Limits	Agency
Radiation Worker - 5,000 mrem	NRC, occupationally exposed
General Public - 100 mrem	NRC, member of the public
General Public - 25 mrem	NRC, D&D all pathways
General Public - 10 mrem	EPA, air pathway
General Public - 4 mrem	EPA, drinking water pathway

D& D = decontamination and decommissioning.

B.6 Radiological Dose Units

Radiological dose in this report is usually written in terms of total effective dose (equivalent) and reported numerically in units of millirem (mrem), with the metric units millisievert (mSv) or microsievert (μ Sv) following in parenthesis or footnoted.

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 1.0 mrem (10 mSv) 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 Sv) would likely cause temporary radiation sickness in some exposed individuals. An acute dose of over 500 rem (5 Sv) would soon result in death in approximately 50% of those exposed. Exposure to lower amounts of radiation (10 mrem [100 μ Sv] 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 310 mrem (3.1 mSv; National Council on Radiation Protection and Measurements 2009). Medical and dental X-rays and air travel add to this total. Table B.6 includes selected conversions from rem to sievert.

Table B.6. Radiological Dose Units Conversions

μ Sv 0.01	μ Sv 0.1	μ Sv 1	μ Sv 10	μ Sv 100	mSv 1	mSv 10	mSv 100	Sv 1
1	10	100	1	10	100	1	10	100
μ rem	μ rem	μ rem	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 term **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 B.6 also can be used to convert grays to rads.

The **roentgen (R)** is a measure of exposure to electromagnetic radiation (i.e., gamma and x-radiation). 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 B.7.

Table B.7. Radiation Dose or Exposure Units

Symbol	Name
mrad	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
μ rem	microrem (1×10^{-6} rem)
Sv	sievert (100 rem)
mSv	millisievert (1×10^{-3} Sv)
μ Sv	microsievert (1×10^{-6} Sv)
nSv	nanosievert (1×10^{-9} Sv)
R	roentgen
mR	milliroentgen (1×10^{-3} R)
μ R	microroentgen (1×10^{-6} R)
Gy	gray (100 rad)
mGy	milligray (1×10^{-3} rad)

Additional information on radiation and dose terminology can be found in Appendix A. A list of the radionuclides discussed in this report, their symbols, and their half-lives are included in Table B.8.

Table B.8. Radionuclides and Half-Lives

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
³ H	tritium	12.35 yr	¹⁰³ Ru	ruthenium-103	39.28 d	U	natural uranium	~4.5 × 10 ⁹ (a)
⁷ Be	beryllium-7	53.3 d	¹⁰⁶ Ru	ruthenium-106	368.2 d	²³³ U	uranium-233	1.585 × 10 ⁵ yr
¹⁴ C	carbon-14	5,730 yr	¹¹³ Sn	tin-113	115.1 d	²³⁴ U	uranium-234	2.445 × 10 ⁵ yr
⁴⁰ K	potassium-40	1.28 × 10 ⁹ yr	¹²⁵ Sb	antimony-125	2.77 yr	²³⁵ U	uranium-235	7.038 × 10 ⁸ yr
⁵¹ Cr	chromium-51	27.704 d	¹²⁹ I	iodine-129	1.57 × 10 ⁷ yr	²³⁷ Np	neptunium-237	2.14 × 10 ⁶ yr
⁵⁴ Mn	manganese-54	312.5 d	¹³¹ I	iodine-131	8.04 d	²³⁸ U	uranium-238	4.468 × 10 ⁹ yr
⁵⁵ Fe	iron-55	2.7 yr	¹³⁴ Cs	cesium-134	2.062 yr	²³⁸ Pu	plutonium-238	87.74 yr
⁵⁹ Fe	iron-59	44.529 d	¹³⁷ Cs	cesium-137	30.0 yr	²³⁹ Pu	plutonium-239	2.4065 × 10 ⁴ yr
⁵⁹ Ni	nickel-59	7.5 × 10 ⁴ yr	¹³⁷ mBa	barium-137m	2.552 min	²⁴⁰ Pu	plutonium-240	6.537 × 10 ³ yr
⁶⁰ Co	cobalt-60	5.271 yr	¹⁵² Eu	europium-152	13.33 yr	²⁴¹ Pu	plutonium-241	14.4 yr
⁶³ Ni	nickel-63	96 yr	¹⁵⁴ Eu	europium-154	8.8 yr	²⁴² Pu	plutonium-242	3.763 × 10 ⁵ yr
⁶⁵ Zn	zinc-65	243.9 d	¹⁵⁵ Eu	europium-155	4.96 yr	²⁴¹ Am	americium-241	432.2 yr
⁸⁵ Kr	krypton-85	10.72 yr	²¹² Pb	lead-212	10.64 hr	²⁴³ Am	americium-243	7,380 yr
⁹⁰ Sr	strontium-90	29.12 yr	²²⁰ Rn	radon-220	55.6 sec	²⁴³ Cm	curium-243	28.5 yr
⁹⁰ Y	yttrium-90	64.0 hr	²²² Rn	radon-222	3.8235 d	²⁴⁴ Cm	curium-244	18.11 yr
⁹⁵ Zr	zirconium-95	63.98 d	²³² Th	thorium-232	1.405 × 10 ¹⁰ yr	²⁴⁵ Cm	curium-245	8,500 yr
⁹⁹ Tc	technetium-99	2.13 × 10 ⁵ yr						

*Natural uranium is a mixture dominated by uranium-238; thus, the half-life is approximately 4.5 × 10⁹ years.

B.7 Chemical and Elemental Nomenclature

Many of the chemical contaminants discussed in this report are listed in Table B.9, along with their chemical (or elemental) names and their corresponding symbols.

Table B.9. 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		

B.8 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 also can 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.

B.9 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.

B.10 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 the nominal detection limit.

B.11 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. 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.

B.12 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, 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 \pm statistical uncertainty or when the data do not follow a bell-shape (i.e., normal) distribution. Figure B.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.

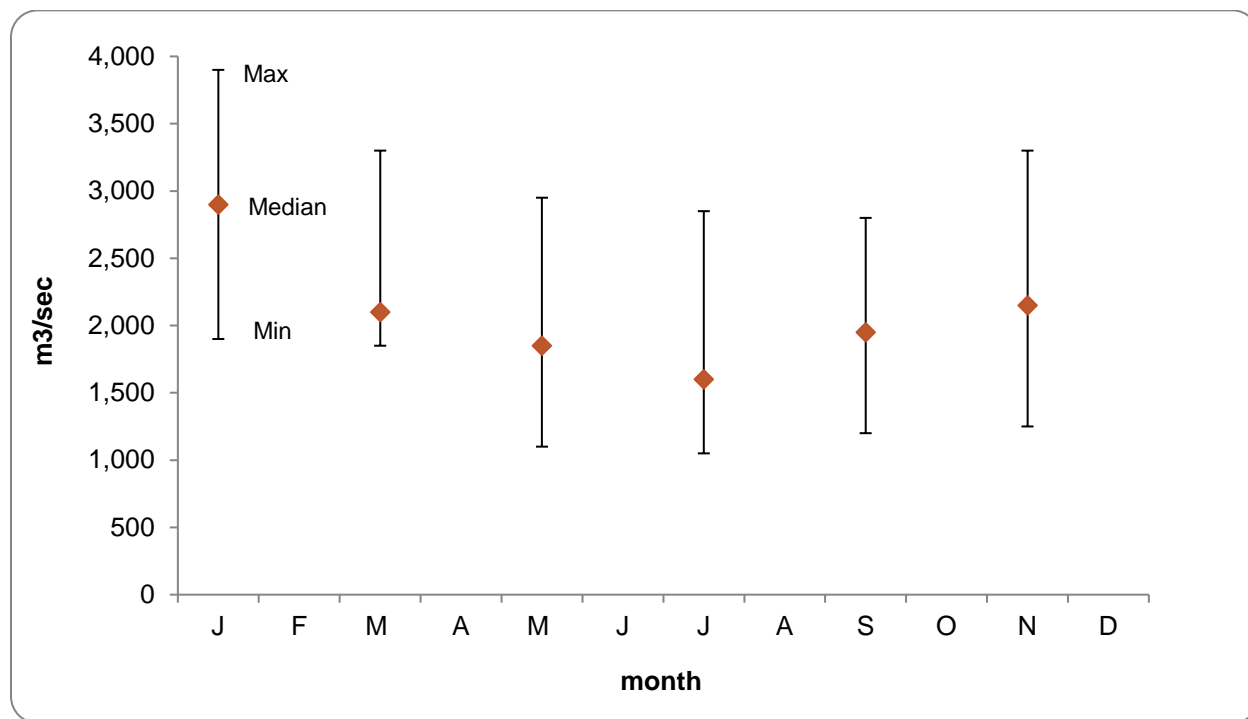


Figure B.1. Maximum, Median, and Minimum Values Graphical Representation

B.13 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.

B.14 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 (\leq or \geq) indicates that the actual value is less than or equal to or greater than or equal to the number given, respectively.

B.15 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 may be 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 g/L would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 g/L (Figure B.2). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure B.3).

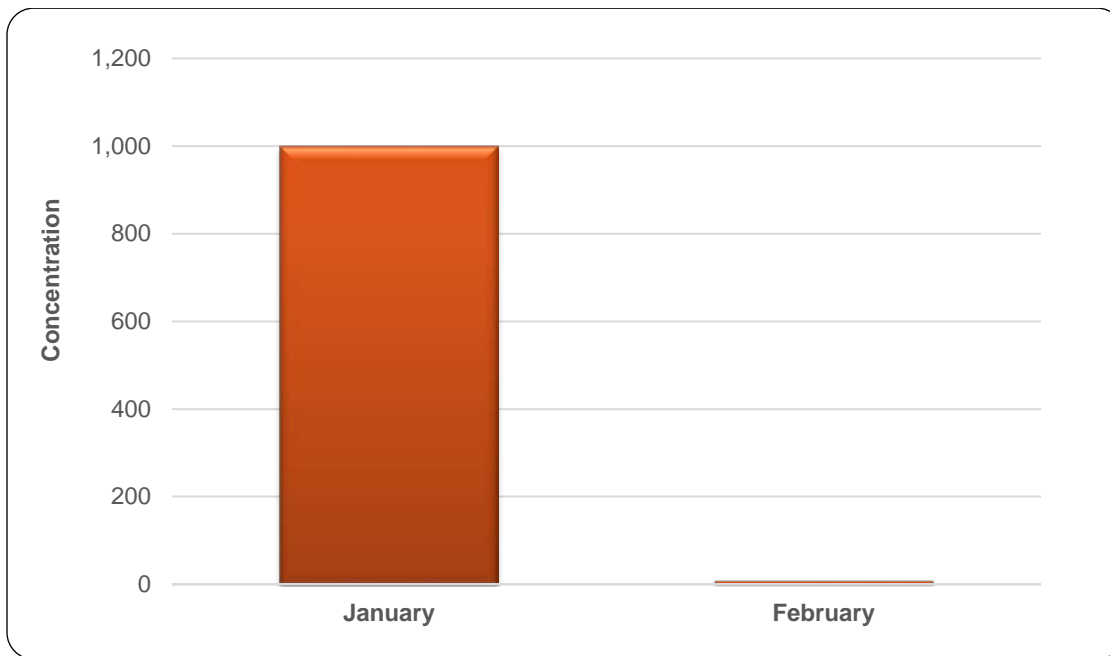


Figure B.2. Data Plotted Using a Linear Scale

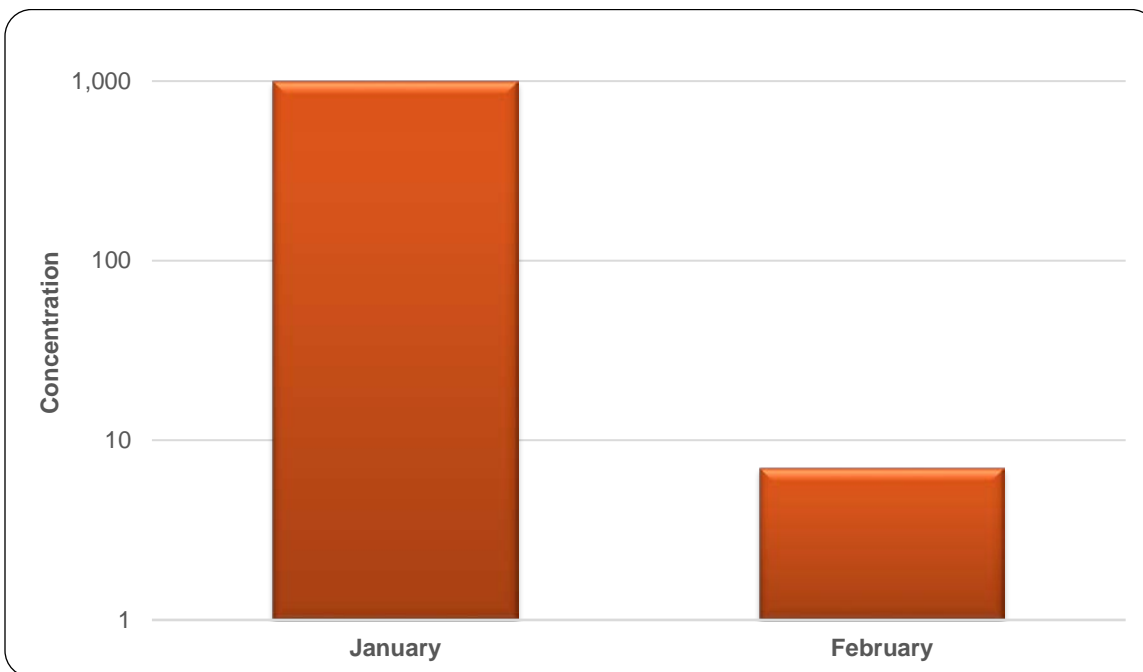


Figure B.3. Data Plotted Using a Logarithmic Scale

The mean (average) and median (defined earlier) values seen in graphics 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 standard error of the mean) in the reported value. 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.* For example, in Figure B.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 (e.g., 2 and 3) may actually be quite similar when compared statistically.

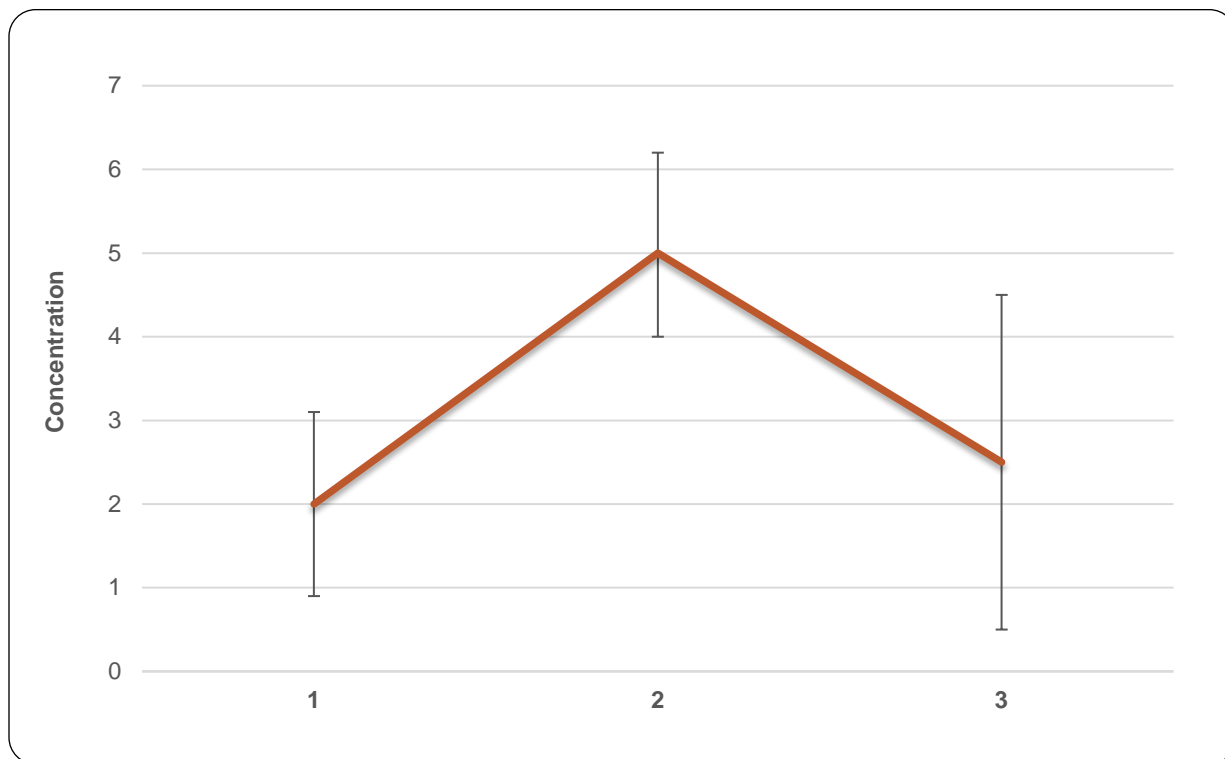


Figure B.4. Data with Error Bars Plotted Using a Linear Scale

*Assuming the data are normally distributed.

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Appendix C

Additional Monitoring Results

C. Additional Monitoring Results C.1

Tables

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C. Additional Monitoring Results

ME Hoefer, CJ Perkins

This appendix contains additional information on monitoring results and supplements data summarized in the main body of the report.

Table C.1. Radionuclide Concentrations in West Lake Sediment

Radionuclide	2015		2010–2014		
	No. of Samples	Concentration (pCi/g)* Result†	No. of Samples	Concentration (pCi/g)* Average‡	Maximum†
Antimony-125	4	6.1E-04 ± 2.3E-02§	5	5.6E-03 ± 5.2E-02§	3.6E-02 ± 4.6E-02§
Cesium-134	4	4.1E-02 ± 2.7E-02§	5	4.8E-02 ± 6.0E-02§	4.0E-02 ± 4.0E-02§
Cesium-137	4	3.4E-01 ± 4.9E-02	5	9.5E-01 ± 9.1E-01	1.7E+00 ± 1.6E-01
Cobalt-60	4	1.1E-02 ± 1.2E-02§	5	-3.0E-03 ± 9.0E-03§	5.3E-03 ± 1.7E-02§
Europium-152	4	2.5E-02 ± 2.8E-02§	5	4.6E-03 ± 6.7E-02§	5.4E-02 ± 8.0E-02§
Europium-154	4	-2.7E-02 ± 3.6E-02§	5	-1.3E-02 ± 1.0E-01§	4.7E-02 ± 6.0E-02§
Europium-155	4	6.8E-02 ± 3.8E-02	5	3.2E-02 ± 7.0E-02§	8.5E-02 ± 8.6E-02§
Gross Alpha	4	9.0E+00 ± 3.7E+00	5	8.1E+00 ± 7.9E+00	12.2E+00 ± 3.1E+00
Gross Beta	4	29.2E+00 ± 2.4E+00	5	2.32E+01 ± 12.8E+00	2.7E+01 ± 6.4E+00
Potassium-40	4	19.3E+00 ± 1.7E+00	5	1.5E+01 ± 9.3E+00	1.9E+01 ± 2.0E+00
Ruthenium-106	4	-1.5E-04 ± 1.5E-01§	5	-2.3E-02 ± 2.5E-01§	1.2E-01 ± 1.5E-01§
Strontium-90	4	4.5E-02 ± 3.1E-02§	5	2.6E-01 ± 3.4E-01§	4.9E-01 ± 9.7E-02§
Technetium-99	4	4.8E-01 ± 3.2E-01§	5	-1.7E-01 ± 3.8E-01§	3.9E-02 ± 3.7E-01§
Uranium-234	4	4.1E+00 ± 5.5E-01	5	3.2E+00 ± 5.0E+00	7.6E+00 ± 1.1E+00
Uranium-235	4	2.9E-01 ± 7.8E-02	5	1.6E-01 ± 1.9E-01	3.2E-01 ± 8.9E-02
Uranium-238	4	4.2E+00 ± 5.5E-01	5	3.0E+00 ± 4.4E+00	6.8E+00 ± 1.0E+00

*1 pCi = 0.037 Bq

†Result and maximum values are ± total propagated analytical uncertainty (2 Sigma).

‡Averages are ±2 standard deviations of the mean. Average values calculated using reporting limit values for all results at or below minimum detectable concentrations.

§Result was below detection limit.

Table C.2. Radionuclide Concentrations in West Lake Seep Water

Radionuclide	2015			2012–2014			DOE-Derived Concentration Guides/Standards	WA State Ambient Surface Water Quality Standard§
	No. of Samples	Concentration*		No. of Samples	Concentration*			
		Average†	Maximum‡		Average†	Maximum‡		
		pCi/L			pCi/L			
Tritium	1	††	41E+00 ± 15.0E+01	2	43.3E+01 ± 51.1E+01	6.9E+02 ± 20.8+01	2,000,000	20,000§**
Uranium-234	1	††	25.0E+01 ± 40.0E+00	3	19.4E+01 ± 18.6E+01	26.3E+01 ± 38.1E+00	500	—
Uranium-235	1	††	1.9E+01 ± 1.3E+01	3	9.7E+00 ± 9.4E+00	13.8E+00 ± 4.3E+00	600	—
Uranium-238	1	††	1.9E+02 ± 33.4E+00	3	18.2E+01 ± 17.5E+01	25.0E+01 ± 69.2E+00	600	—
*1 pCi = 0.037 Bq †Averages are ±2 standard deviations of the mean. ‡Maximum values are ± total propagated analytical uncertainty. §WAC 246-290 and 40 CFR 141. Dashes indicate no concentration guides available. **WAC 173-201A-250 and EPA-570/9-76-003. ††Average values are not calculated when only one sample was analyzed; 2012 West Lake Seep Water did not have tritium analyses performed.								

Table C.3. Radionuclide Concentrations in West Lake Surface Water

Radionuclide	2015			2012–2014			DOE-Derived Concentration Guides/ Standards	WA State Ambient Surface Water Quality Standard§
	No. of Samples	Concentration*		No. of Samples	Concentration*			
		Average†	Maximum‡		Average†	Maximum‡		
		pCi/L			pCi/L			
Tritium	4	22.3E+00 ± 14.3E+01	12.2E+01 ± 12.5E+01	3	4.8E+01 ± 6.9E+01	9.6E+01 ± 14.9+01	2,000,000	20,000§**
Uranium-234	4	43.0E+01 ± 14.0E+02	16.5E+02 ± 23.3E+00	3	34.8E+02 ± 53.9E+02	65.8E+02 ± 10.7E+02	500	—
Uranium-235	4	2.3E+01 ± 7.4E+01	8.7E+01 ± 1.5E+01	3	13.2E+01 ± 20.3E+01	24.8E+01 ± 93.7E+00	600	—
Uranium-238	4	40.9E+01 ± 13.4E+02	15.7E+02 ± 22.3E+01	3	33.5E+02 ± 52.2E+02	63.8E+02 ± 10.4E+02	600	—
*1 pCi = 0.037 Bq								
†Averages are ±2 standard deviations of the mean.								
‡Maximum values are ± total propagated analytical uncertainty.								
§WAC 246-290 and 40 CFR 141. Dashes indicate no concentration guides available.								
**WAC 173-201A-250 and EPA-570/9-76-003.								

Table C.4. Concentrations of Select Radionuclides (pCi/m³)* in On-site Air Samples

Radionuclide	Site	2015					2010–2014				EPA Table 2**,††
		Number of Samples	Detections†	Average‡	Maximum§	Sampler	Number of Samples	Detections†	Average‡	Maximum§	
gross α	100-K Area	188	185	1.7E-03 \pm 2.5E-03	7.8E-03 \pm 1.3E-03	N534	1100	1032	1.1E-03 \pm 1.4E-03	6.8E-03 \pm 9.9E-04	2.0E-02
	200-East	565	562	1.8E-03 \pm 2.5E-03	7.6E-03 \pm 1.1E-03	N532	2724	2615	1.3E-03 \pm 1.5E-03	6.6E-03 \pm 1.1E-03	
	200-West	614	613	1.8E-03 \pm 2.6E-03	9.9E-03 \pm 1.4E-03	N165	3062	2915	1.3E-03 \pm 1.7E-03	1.4E-02 \pm 2.0E-03	
	300 D4	151	139	1.0E-03 \pm 1.4E-03	4.3E-03 \pm 8.0E-04	N918	774	703	8.5E-04 \pm 1.1E-03	4.1E-03 \pm 8.0E-04	
	618-10 BG	108	108	1.5E-03 \pm 1.9E-03	7.5E-03 \pm 1.7E-03	N548	434	407	1.2E-03 \pm 2.3E-03	1.6E-02 \pm 2.3E-03	
	ERDF	135	135	1.4E-03 \pm 1.9E-03	5.8E-03 \pm 9.7E-04	N963	650	611	1.1E-03 \pm 1.4E-03	5.5E-03 \pm 9.2E-04	
gross β	100-K Area	188	188	1.8E-02 \pm 2.1E-02	5.4E-02 \pm 5.3E-03	N534	1102	1101	1.7E-02 \pm 2.4E-02	1.5E-01 \pm 1.2E-02	9.0E+00
	200-East	565	565	1.7E-02 \pm 2.0E-02	7.3E-02 \pm 6.1E-03	N967	2724	2723	1.7E-02 \pm 2.2E-02	1.2E-01 \pm 9.0E-03	
	200-West	614	614	1.7E-02 \pm 2.1E-02	7.5E-02 \pm 6.2E-03	N304	3062	3061	1.6E-02 \pm 2.2E-02	1.0E-01 \pm 2.3E-02	
	300 D4	151	151	2.0E-02 \pm 2.0E-02	4.9E-02 \pm 4.6E-03	N903	779	779	2.0E-02 \pm 2.7E-02	1.1E-01 \pm 1.2E-02	
	618-10 BG	108	108	2.1E-02 \pm 2.6E-02	1.0E-01 \pm 1.8E-02	N548	434	433	1.7E-02 \pm 2.5E-02	1.1E-01 \pm 9.0E-03	
	ERDF	135	135	1.7E-02 \pm 1.9E-02	4.7E-02 \pm 8.0E-03	N518	650	649	1.5E-02 \pm 2.0E-02	7.6E-02 \pm 5.8E-03	
⁹⁰ Sr	100-K Area	14	0	-6.4E-05 \pm 6.2E-04	7.5E-04 \pm 6.3E-04	N576	94	10	1.2E-05 \pm 8.6E-04	3.1E-03 \pm 9.4E-04	1.9E-02
	200-East	42	0	-2.5E-05 \pm 5.0E-04	6.3E-04 \pm 6.4E-04	N499	210	37	4.5E-05 \pm 3.9E-04	1.7E-03 \pm 5.7E-04	
	200-West	46	0	-8.9E-05 \pm 4.4E-04	5.2E-04 \pm 4.1E-04	N555	239	24	-1.5E-05 \pm 3.2E-04	5.5E-04 \pm 4.7E-04	
	300 D4	12	0	1.4E-04 \pm 8.8E-04	1.0E-03 \pm 8.3E-04	N557	61	2	-2.8E-05 \pm 3.6E-04	4.1E-04 \pm 3.0E-04	
	618-10 BG	8	2	1.6E-04 \pm 3.0E-04	4.7E-04 \pm 2.6E-04	N548	40	4	-5.4E-06 \pm 5.0E-04	3.7E-04 \pm 3.2E-04	
	ERDF	10	0	-4.1E-05 \pm 2.4E-04	1.0E-04 \pm 1.6E-04	N482	50	5	1.1E-05 \pm 2.9E-04	3.3E-04 \pm 3.6E-04	
¹³⁷ Cs	100-K Area	14	0	6.8E-05 \pm 3.6E-04	4.0E-04 \pm 4.6E-04	N535	94	27	3.0E-04 \pm 2.8E-03	1.3E-02 \pm 4.0E-03	1.9E-02
	200-East	42	0	9.0E-05 \pm 4.1E-04	6.6E-04 \pm 6.2E-04	N973	210	41	2.6E-04 \pm 2.7E-03	1.9E-02 \pm 6.2E-03	
	200-West	46	0	3.8E-05 \pm 4.4E-04	6.1E-04 \pm 3.8E-04	N966	239	25	5.6E-05 \pm 3.1E-04	7.6E-04 \pm 3.8E-04	
	300 D4	12	0	7.3E-05 \pm 3.4E-04	4.4E-04 \pm 5.1E-04	N904	62	3	8.8E-05 \pm 3.7E-04	6.5E-04 \pm 5.1E-04	
	618-10 BG	8	0	-5.4E-06 \pm 1.8E-04	1.0E-04 \pm 1.3E-04	N549	40	4	6.8E-05 \pm 4.7E-04	1.2E-03 \pm 4.0E-04	
	ERDF	10	0	4.1E-05 \pm 2.3E-04	2.5E-04 \pm 3.5E-04	N963	50	5	6.2E-05 \pm 2.1E-04	4.0E-04 \pm 4.5E-04	
²³⁸ Pu	100-K Area	13	0	4.4E-06 \pm 2.0E-05	3.9E-05 \pm 5.5E-05	N900	90	0	1.9E-06 \pm 1.3E-05	2.9E-05 \pm 3.3E-05	2.1E-03
	200-East	36	0	-2.8E-07 \pm 5.4E-06	4.0E-06 \pm 3.8E-06	N972	204	3	8.3E-07 \pm 7.1E-06	2.2E-05 \pm 2.2E-05	
	200-West	38	0	-9.1E-07 \pm 6.3E-06	8.0E-06 \pm 7.5E-06	N165	229	8	1.3E-06 \pm 9.5E-06	3.7E-05 \pm 1.9E-05	
	300 D4	11	0	1.2E-06 \pm 1.6E-05	1.4E-05 \pm 5.3E-05	N919	59	4	1.7E-06 \pm 1.0E-05	2.3E-05 \pm 2.8E-05	
	618-10 BG	8	0	7.6E-06 \pm 1.6E-05	2.4E-05 \pm 2.9E-05	N580	40	2	3.2E-06 \pm 1.7E-05	4.6E-05 \pm 2.2E-05	
	ERDF	9	0	-1.6E-06 \pm 2.4E-06	-3.5E-07 \pm 3.5E-06	N518	50	0	1.0E-06 \pm 6.1E-06	8.5E-06 \pm 9.1E-06	
^{239/240} Pu	100-K Area	12	0	-1.0E-06 \pm 1.6E-05	1.1E-05 \pm 1.7E-05	N578	92	31	1.2E-05 \pm 4.5E-05	1.7E-04 \pm 7.0E-05	2.0E-03
	200-East	42	0	5.9E-07 \pm 7.0E-06	1.1E-05 \pm 1.8E-05	N973	204	18	1.5E-06 \pm 4.6E-06	1.2E-05 \pm 6.9E-06	
	200-West	44	2	5.8E-06 \pm 4.3E-05	1.2E-04 \pm 3.7E-05	N165	237	71	1.6E-05 \pm 1.1E-04	4.5E-04 \pm 1.6E-04	
	300 D4	11	0	-2.8E-06 \pm 1.5E-05	7.7E-06 \pm 3.5E-05	N918	59	0	1.1E-06 \pm 5.4E-06	1.2E-05 \pm 1.2E-05	
	618-10 BG	8	5	5.5E-05 \pm 1.0E-04	1.7E-04 \pm 9.3E-05	N548	40	22	6.9E-05 \pm 2.7E-04	6.8E-04 \pm 2.6E-04	
	ERDF	10	0	6.9E-07 \pm 1.1E-05	1.4E-05 \pm 3.8E-05	N518	50	18	6.0E-06 \pm 2.1E-05	6.1E-05 \pm 2.4E-05	
²³⁴ U	100-K Area	12	2	6.7E-06 \pm 6.6E-06	1.2E-05 \pm 1.7E-05	N534	78	47	9.7E-06 \pm 1.5E-05	4.7E-05 \pm 3.0E-05	7.7E-03
	200-East	42	12	1.0E-05 \pm 1.4E-05	2.6E-05 \pm 1.9E-05	N984	210	132	8.4E-06 \pm 1.0E-05	4.4E-05 \pm 2.0E-05	
	200-West	46	12	1.1E-05 \pm 1.4E-05	3.4E-05 \pm 3.9E-05	N965	239	150	2.3E-05 \pm 2.9E-04	2.2E-03 \pm 7.4E-04	
	300 D4	12	7	4.3E-05 \pm 5.4E-05	1.2E-04 \pm 7.6E-05	N919	61	50	3.9E-05 \pm 4.0E-05	8.8E-05 \pm 2.1E-05	

Table C.4. Concentrations of Select Radionuclides (pCi/m³)* in On-site Air Samples

Radionuclide	Site	2015					2010–2014				EPA Table 2**,††
		Number of		Average‡	Maximum§	Sampler	Number of		Average‡	Maximum§	
		Samples	Detections†				Samples	Detections†			
²³⁵ U	618-10 BG	8	3	2.8E-05 ± 5.5E-05	9.2E-05 ± 5.2E-05	N548	40	22	1.3E-05 ± 1.6E-05	3.0E-05 ± 1.5E-05	7.1E-03
	ERDF	9	2	1.2E-05 ± 1.9E-05	3.3E-05 ± 3.6E-05	N482	50	34	2.4E-05 ± 1.2E-04	4.3E-04 ± 1.7E-04	
	100-K Area	11	0	3.3E-06 ± 5.4E-06	9.7E-06 ± 1.8E-05	N534	73	8	2.0E-06 ± 8.1E-06	2.6E-05 ± 2.1E-05	
	200-East	39	0	3.2E-06 ± 8.5E-06	1.7E-05 ± 2.1E-05	N978	201	12	1.5E-06 ± 3.7E-06	7.3E-06 ± 7.4E-06	
	200-West	43	2	3.8E-06 ± 6.9E-06	1.2E-05 ± 1.4E-05	N457	230	24	3.5E-06 ± 3.1E-05	2.1E-04 ± 7.8E-05	
	300 D4	12	1	5.4E-06 ± 1.2E-05	1.8E-05 ± 4.0E-05	N557	56	10	3.2E-06 ± 5.1E-06	1.2E-05 ± 4.9E-06	
	618-10 BG	7	0	4.0E-06 ± 6.5E-06	8.0E-06 ± 1.2E-05	N549	35	2	1.8E-06 ± 7.5E-06	1.0E-05 ± 1.1E-05	
	ERDF	9	0	4.1E-06 ± 8.8E-06	1.3E-05 ± 2.8E-05	N517	46	6	3.1E-06 ± 1.5E-05	5.3E-05 ± 2.3E-05	
²³⁸ U	100-K Area	12	3	6.4E-06 ± 1.0E-05	1.7E-05 ± 9.3E-06	N578	78	45	7.8E-06 ± 1.1E-05	2.5E-05 ± 2.1E-05	8.3E-03
	200-East	41	11	1.0E-05 ± 1.3E-05	3.0E-05 ± 2.9E-05	N999	210	132	6.7E-06 ± 7.5E-06	2.3E-05 ± 1.1E-05	
	200-West	46	12	7.6E-06 ± 8.4E-06	1.5E-05 ± 8.7E-06	N956	239	153	1.9E-05 ± 2.6E-04	1.9E-03 ± 6.6E-04	
	300 D4	12	9	4.6E-05 ± 5.1E-05	9.3E-05 ± 6.5E-05	N919	61	54	3.7E-05 ± 4.0E-05	8.1E-05 ± 1.9E-05	
	618-10 BG	8	4	1.9E-04 ± 5.8E-04	7.6E-04 ± 2.6E-04	N548	40	27	2.1E-05 ± 5.6E-05	1.6E-04 ± 7.1E-05	
	ERDF	10	5	2.2E-05 ± 2.9E-05	5.3E-05 ± 7.9E-05	N518	49	34	2.2E-05 ± 1.0E-04	3.7E-04 ± 1.4E-04	
²⁴¹ Am	100-K Area	13	0	-1.8E-05 ± 8.1E-04	6.8E-04 ± 2.3E-03	N576	89	23	1.4E-05 ± 2.8E-04	7.3E-04 ± 7.3E-04	1.9E-03
	200-East	42	0	-9.6E-05 ± 1.8E-03	1.8E-03 ± 2.5E-03	N019	58	1	-3.0E-05 ± 1.1E-03	1.0E-03 ± 2.8E-03	
	200-West	46	0	-2.8E-04 ± 1.6E-03	1.6E-03 ± 2.7E-03	N441	54	8	-1.8E-04 ± 1.7E-03	2.4E-03 ± 2.3E-03	
	300 D4	10	0	5.4E-07 ± 8.2E-06	9.1E-06 ± 4.1E-05	N918	44	3	4.7E-05 ± 1.2E-03	1.9E-03 ± 2.7E-03	
	618-10 BG	8	3	2.6E-05 ± 5.4E-05	8.7E-05 ± 6.8E-05	N548	32	19	3.8E-05 ± 1.1E-04	2.4E-04 ± 9.4E-05	
	ERDF	4	0	-4.5E-04 ± 8.2E-04	1.3E-04 ± 1.3E-03	N963	4	0	-5.0E-04 ± 1.2E-03	2.9E-04 ± 2.6E-03	
²⁴¹ Pu	200-East	4	0	-5.6E-05 ± 8.3E-04	4.7E-04 ± 5.8E-04	N481	20	0	8.6E-05 ± 5.5E-04	7.7E-04 ± 1.1E-03	1.0E-01
	200-West	6	0	-2.6E-04 ± 7.1E-04	4.3E-04 ± 7.7E-04	N975	8	2	4.9E-04 ± 1.2E-03	1.5E-03 ± 8.8E-04	

BG=Burial Ground project; D4=deactivation, decontamination, decommissioning, and demolition; DOE=U.S. Department of Energy; EPA=U.S. Environmental Protection Agency; ERDF=Environmental Restoration Disposal Facility

*1 pCi = 0.037 Bq

†Number of samples with measurable concentrations of contaminant.

‡Average ± two standard deviations of all samples analyzed.

§Maximum ± analytical uncertainty

**DOE derived concentration guides are shown for gross alpha and gross beta

††EPA values are based on an effective dose equivalent of 10 mrem/yr (40 CFR 61, Appendix E, Table 2)

Table C.5. Concentrations of Selected Radionuclides (pCi/m³)* in Ambient Air Samples

Radionuclide	Site	2015					2010–2014				EPA Table 2**,††
		Number of Samples	Detections†	Average‡	Maximum§	Sampler	Number of Samples	Detections†	Average‡	Maximum§	
gross α	Onsite	550	506	1.1E-03 ± 1.8E-03	8.1E-03 ± 1.1E-03	N920	2602	2317	7.9E-04 ± 1.2E-03	6.8E-03 ± 9.9E-04	2.0E-02
	Perimeter	293	274	1.1E-03 ± 2.2E-03	7.7E-03 ± 1.2E-03	N934	1408	1256	7.9E-04 ± 1.2E-03	8.2E-03 ± 1.6E-03	
	Nearby Communities	188	180	1.1E-03 ± 1.7E-03	6.0E-03 ± 9.2E-04	N948	392	360	8.1E-04 ± 1.2E-03	4.2E-03 ± 8.3E-04	
	Distant Community	27	23	9.0E-04 ± 1.5E-03	3.1E-03 ± 6.4E-04	N909	128	105	7.0E-04 ± 1.2E-03	4.2E-03 ± 8.5E-04	
gross β	Onsite	550	550	2.1E-02 ± 2.4E-02	8.4E-02 ± 7.7E-03	N932	2609	2609	2.0E-02 ± 2.7E-02	1.3E-01 ± 1.0E-02	9.0E+00
	Perimeter	293	293	2.1E-02 ± 2.5E-02	7.6E-02 ± 7.5E-03	N937	1409	1409	2.0E-02 ± 2.5E-02	9.5E-02 ± 8.8E-03	
	Nearby Communities	188	188	2.2E-02 ± 2.6E-02	7.2E-02 ± 6.6E-03	N943	898	898	2.0E-02 ± 2.7E-02	1.6E-01 ± 1.6E-02	
	Distant Community	27	27	1.8E-02 ± 1.8E-02	4.5E-02 ± 4.1E-03	N909	128	128	1.8E-02 ± 2.4E-02	9.5E-02 ± 7.4E-03	
³ H	Onsite	125	52	6.9E+00 ± 1.1E+01	2.5E+01 ± 6.9E+00	P918	534	355	9.0E+00 ± 2.7E+01	1.1E+02 ± 1.1E+01	1.5E+03
	Perimeter	98	22	3.7E+00 ± 7.2E+00	1.7E+01 ± 5.0E+00	P937	446	232	6.2E+00 ± 2.0E+01	9.4E+01 ± 8.9E+00	
	Nearby Communities	28	6	5.2E+00 ± 2.2E+01	5.8E+01 ± 1.3E+01	P944	128	69	6.0E+00 ± 1.5E+01	4.8E+01 ± 1.1E+01	
	Distant Community	14	4	3.7E+00 ± 5.5E+00	9.9E+00 ± 4.0E+00	P909	65	26	5.1E+00 ± 2.1E+01	7.1E+01 ± 1.2E+01	
⁹⁰ Sr	Onsite	33	0	1.3E-05 ± 5.6E-04	9.7E-04 ± 7.9E-04	N918	135	2	1.4E-05 ± 2.0E-04	3.8E-04 ± 2.8E-04	1.9E-02
	Perimeter	18	0	4.2E-05 ± 6.2E-04	6.5E-04 ± 6.4E-04	N938	111	2	1.3E-05 ± 2.1E-04	4.2E-04 ± 3.3E-04	
	Nearby Communities	7	0	2.9E-05 ± 3.5E-04	4.0E-04 ± 5.0E-04	N945	39	1	3.9E-05 ± 3.3E-04	7.2E-04 ± 1.9E-04	
	Distant Community	2	0	-6.4E-05 ± 9.1E-05	-1.9E-05 ± 1.9E-04	N909	15	0	4.1E-05 ± 2.0E-04	2.8E-04 ± 2.5E-04	
¹³⁷ Cs	Onsite	40	0	7.8E-05 ± 3.7E-04	4.4E-04 ± 5.1E-04	N904	203	2	6.7E-05 ± 5.5E-04	1.2E-03 ± 1.0E-03	1.9E-02
	Perimeter	22	0	8.4E-05 ± 4.3E-04	6.0E-04 ± 6.3E-04	N907	145	3	8.9E-05 ± 1.4E-03	6.9E-03 ± 2.0E-03	
	Nearby Communities	14	0	8.0E-05 ± 2.5E-04	3.8E-04 ± 5.2E-04	N947	105	1	8.3E-05 ± 7.4E-04	1.2E-03 ± 7.0E-04	
	Distant Community	2	0	-2.6E-05 ± 5.2E-05	-3.3E-07 ± 3.3E-06	N909	16	0	1.1E-04 ± 7.0E-04	7.7E-04 ± 9.1E-04	
²³⁴ U	Onsite	27	20	4.2E-05 ± 4.0E-05	1.2E-04 ± 7.6E-05	N919	148	136	4.0E-05 ± 3.0E-05	8.8E-05 ± 2.1E-05	7.7E-03
	Perimeter	8	8	5.7E-05 ± 2.2E-05	6.9E-05 ± 2.7E-05	N936	68	61	4.7E-05 ± 3.9E-05	8.9E-05 ± 2.1E-05	
	Nearby Communities	11	11	5.7E-05 ± 2.0E-05	8.0E-05 ± 3.2E-05	N946	73	64	4.5E-05 ± 2.9E-05	8.7E-05 ± 1.9E-05	
	Distant Community	2	1	4.1E-05 ± 1.1E-05	4.6E-05 ± 2.2E-05	N909	15	13	3.7E-05 ± 3.1E-05	7.2E-05 ± 3.5E-05	
²³⁸ U	Onsite	27	24	4.5E-05 ± 3.4E-05	9.3E-05 ± 6.5E-05	N919	148	145	4.2E-05 ± 2.5E-05	8.7E-05 ± 5.8E-05	8.3E-03
	Perimeter	8	8	4.8E-05 ± 1.6E-05	6.2E-05 ± 2.6E-05	N935	68	64	5.1E-05 ± 3.7E-05	1.2E-04 ± 6.4E-05	
	Nearby Communities	11	11	5.5E-05 ± 1.8E-05	7.6E-05 ± 4.6E-05	N949	73	71	4.9E-05 ± 2.2E-05	8.0E-05 ± 6.9E-05	

Table C.5. Concentrations of Selected Radionuclides (pCi/m³)* in Ambient Air Samples

Radionuclide	Site	2015					2010–2014				EPA Table 2**,†,††
		Number of		Average‡	Maximum§	Sampler	Number of		Average‡	Maximum§	
		Samples	Detections†				Samples	Detections†			
^{239/240} Pu	Distant Community	2	1	3.4E-05 ± 4.3E-05	5.6E-05 ± 2.5E-05	N909	15	14	3.8E-05 ± 2.0E-05	6.0E-05 ± 2.5E-05	2.0E-03
	Onsite	37	0	-1.4E-07 ± 1.9E-05	2.9E-05 ± 3.5E-05	N928	184	12	1.4E-06 ± 2.4E-05	1.6E-04 ± 5.2E-05	
	Perimeter	17	0	1.1E-06 ± 1.4E-05	1.8E-05 ± 1.9E-05	N938	103	4	7.8E-07 ± 1.1E-05	5.5E-05 ± 1.3E-05	
	Nearby Communities	8	1	-3.3E-06 ± 1.3E-05	7.4E-06 ± 4.3E-06	N945	53	5	4.9E-07 ± 3.9E-06	1.0E-05 ± 3.7E-06	
	Distant Community	2	0	2.4E-07 ± 3.9E-06	2.2E-06 ± 2.6E-06	N909	15	0	-5.6E-08 ± 2.6E-06	2.7E-06 ± 2.6E-06	
²⁴¹ Am	Onsite	2	0	-6.7E-05 ± 6.5E-05	-3.5E-05 ± 3.5E-04	N909	16	0	-7.2E-04 ± 3.1E-03	1.8E-03 ± 2.1E-03	1.9E-03
	Perimeter	14	0	-4.9E-05 ± 1.4E-03	1.2E-03 ± 2.3E-03	N946	105	0	-3.6E-04 ± 3.1E-03	5.1E-03 ± 5.3E-03	
	Nearby Communities	40	0	-1.3E-04 ± 1.4E-03	1.3E-03 ± 2.5E-03	N931	203	3	-5.0E-05 ± 2.1E-03	4.0E-03 ± 3.2E-03	
	Distant Community	22	0	-2.8E-04 ± 2.0E-03	1.2E-03 ± 1.6E-03	N941	145	0	-1.7E-04 ± 2.3E-03	3.3E-03 ± 4.1E-03	

*1 pCi = 0.037 Bq

†Number of samples with measurable concentrations of contaminant. Detection is defined as a value reported above the minimum detectable activity and above the total propagated analytical uncertainty.

‡Average ± two standard deviations of all samples analyzed.

§Maximum ± analytical uncertainty.

**DOE derived concentration guides are shown for gross alpha and gross beta.

††EPA values are based on an effective dose equivalent of 10 mrem/yr (40 CFR 61, Appendix E, Table 2).

Table C.6. Radionuclide Concentrations in Columbia River Water (Richland, WA)

Radionuclide†	2015				2010-2014				WA Ambient Surface Water Quality Standard§	
	Number of		Concentration*		Number of		Concentration*			
	Samples	Detects	Maximum	Average	Samples	Detects	Maximum	Average		
			(pCi/L)‡				(pCi/L)‡			
Composite System										
Strontium-90	13	0	4.83E-02 ± 3.63E-02	1.83E-02 ± 3.97E-02	60	0	5.58E-02 ± 3.70E-02	1.59E-02 ± 4.75E-02	8	
Tritium	13	13	4.18E+01 ± 7.30E+00	3.00E+01 ± 1.17E+01	62	60	1.08E+02 ± 1.70E+01	3.17E+01 ± 3.02E+01	20000	
Technetium-99	13	0	5.01E-01 ± 4.30E-01	1.32E-01 ± 3.81E-01	60	0	6.18E-01 ± 4.48E-01	2.06E-02 ± 4.88E-01	900	
Uranium-234	13	13	3.13E-01 ± 9.4E-02	2.73E-01 ± 4.62E-02	60	60	3.46E-01 ± 7.32E-02	2.60E-01 ± 7.35E-02	--**	
Uranium-235	13	5	7.81E-02 ± 3.46E-02	2.74E-02 ± 3.76E-02	60	18	3.70E-02 ± 2.43E-02	1.36E-02 ± 1.98E-02	--	
Uranium-238	13	13	2.55E-01 ± 6.15E-02	2.21E-01 ± 3.79E-02	60	0	2.90E-01 ± 6.46E-02	2.14E-01 ± 6.37E-02	--	
Continuous System										
Cesium-137	D†	12	0	6.09E-04 ± 1.44E-03	-3.67E-04 ± 1.41E-03	32	0	1.67E-03 ± 3.08E-03	-3.06E-05 ± 1.90E-03	200
	P†	12	0	3.82E-03 ± 3.05E-03	2.37E-04 ± 3.82E-03	32	0	5.98E-03 ± 4.71E-03	1.02E-03 ± 4.10E-03	
Plutonium-238††	D†	12	0	6.85E-05 ± 7.45E-05	-1.3E-06 ± 6.17E-05	11	0	8.71E-05 ± 9.27E-05	1.75E-05 ± 5.65E-05	600
	P†	12	0	1.64E-04 ± 1.67E-04	1.94E-05 ± 1.41E-04	11	1	3.59E-04 ± 1.57E-04	6.54E-05 ± 2.07E-04	
Plutonium-239/-240††	D†	12	0	6.31E-05 ± 8.33E-05	7.84E-06 ± 4.97E-05	11	0	3.12E-05 ± 1.06E-04	6.01E-06 ± 2.91E-05	--
	P†	12	0	7.02E-05 ± 2.47E-04	-5.17E-06 ± 2.24E-04	11	0	1.35E-04 ± 1.26E-04	3.41E-05 ± 1.09E-04	

*Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard deviations of the mean.

†Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on unfiltered water samples collected by the composite system (see Section 7.2).

‡1 pCi = 0.037 Bq

§WAC 173-201A-250 and EPA-570/9-76-003; WAC 246-290; 40 CFR 141.

**Dashes indicate no concentration guides available.

††Plutonium-238 and Plutonium 239/240 were analyzed quarterly in previous years resulting in less samples.

Table C.7. Radionuclide Concentrations in Columbia River Water (Priest Rapids Dam, WA)

2015						2010-2014						WA Ambient Surface Water Quality Standard§
Radionuclide†	Number of		Concentration*			Number of		Concentration*				
	Samples	Detects	Maximum	Average		Samples	Detects	Maximum	Average			
			(pCi/L)‡					(pCi/L)‡				
Composite System												
Strontium-90	13	0	3.34E-02 ± 2.95E-02	-1.41E-03 ± 4.27E-02		60	1	1.30E-01 ± 5.04E-02	1.82E-02 ± 5.19E-02		8	
Tritium	13	13	2.98E+01 ± 6.72E+00	1.65E+01 ± 1.12E+01		63	60	4.21E+01 ± 5.47E+01	1.82E+01 ± 1.16E+01		20000	
Technetium-99	13	0	6.01E-01 ± 4.18E-01	-1.06E-01 ± 4.79E-01		60	0	4.76E-01 ± 4.56E-01	-1.35E-02 ± 4.60E-01		900	
Uranium-234	13	13	3.23E-01 ± 5.92E-02	2.51E-01 ± 6.27E-02		60	60	3.18E-01 ± 7.18E-02	2.20E-01 ± 6.79E-02		--**	
Uranium-235	13	7	7.37E-02 ± 3.25E-02	2.88E-02 ± 3.97E-02		60	13	2.93E-02 ± 2.15E-02	1.02E-02 ± 1.52E-02		--	
Uranium-238	13	13	2.22E-01 ± 5.40E-02	1.94E-01 ± 3.58E-02		60	60	2.41E-01 ± 6.19E-02	1.81E-01 ± 5.82E-02		--	
Continuous System												
Cesium-137	D†	13	0	1.10E-03± 1.21E-03	2.85E-05 ± 1.3E-03	34	0	4.00E-03 ± 2.73E-03	4.92E-04 ± 1.89E-03		200	
	P†	12	0	5.14E-03 ± 2.94E-03	4.64E-04 ± 4.28E-03	33	0	3.84E-03 ± 4.00E-03	6.50E-04 ± 4.04E-03			
Plutonium-238	D†	13	0	5.35E-05 ± 6.97E-05	1.72E-06 ± 4.75E-05	11	0	4.46E-05 ± 7.36E-05	7.04E-06 ± 3.05E-05		600	
	P†	12	1	5.15E-04 ± 1.69E-04	1.74E-05 ± 3.76E-04	11	1	1.86E-04 ± 1.46E-04	2.96E-05 ± 1.12E-04			
Plutonium-239/-240	D†	13	0	8.76E-05 ± 7.32E-05	1.07E-05 ± 5.65E-05	11	0	2.54E-05 ± 6.30E-05	2.46E-06 ± 3.56E-05		--	
	P†	12	1	2.42E-04 ± 2.35E-04	4.37E-05 ± 1.56E-04	11	0	6.78E-05 ± 1.21E-04	9.56E-06 ± 7.83E-05			

*Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard deviations of the mean.

†Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on unfiltered water samples collected by the composite system (see Section 7.2).

‡1 pCi = 0.037 Bq

§WAC 173-201A-250 and EPA-570/9-76-003; WAC 246-290; 40 CFR 141.

**Dashes indicate no concentration guides available.

††Plutonium-238 and Plutonium 239/240 were analyzed quarterly in previous years resulting in less samples.

Table C.8. Radionuclide Concentrations in Columbia River Transect Water Samples

Transect/Radionuclide	No. of Detections	No. of Samples	Concentration*	
			Maximum	Average
pCi/L†				
Vernita Bridge (Hanford River Marker [HRM] 0.3)				
Strontium-90	0	9	0.45 ± 0.04	0.01 ± 0.05
Technitium-99	0	9	0.46 ± 0.39	0.15 ± 0.37
Tritium	9	9	19.0 ± 5.7	14.9 ± 4.8
Uranium-234	9	9	0.28 ± 0.07	0.24 ± 0.07
Uranium-235	6	9	0.06 ± 0.03	0.03 ± 0.03
Uranium-238	9	9	0.20 ± 0.05	0.17 ± 0.04
100—N Area (HRM 9.5)				
Strontium-90	0	5	0.03 ± 0.03	0.02 ± 0.03
Tritium	5	5	54.2 ± 9.0	22.1 ± 32.6
Uranium-234	5	5	0.26 ± 0.06	0.22 ± 0.05
Uranium-235	0	5	0.02 ± 0.02	0.01 ± 0.01
Uranium-238	5	5	0.18 ± 0.05	0.17 ± 0.01
Hanford Townsite (HRM 28.7)				
Strontium-90	0	5	0.018 ± 0.03	0.01 ± 0.008
Tritium	5	5	79.5 ± 12.3	30.9 ± 48.9
Uranium-234	5	5	0.24 ± 0.06	0.22 ± 0.04
Uranium-235	3	5	0.02 ± 0.02	0.01 ± 0.02
Uranium-238	5	5	0.19 ± 0.05	0.18 ± 0.02
300 Area (HRM 43.1)				
Strontium-90	0	6	0.04 ± 0.03	0.02 ± 0.02
Tritium	6	6	22.2 ± 5.7	15.9 ± 6.4
Uranium-234	6	6	0.30 ± 0.07	0.23 ± 0.10
Uranium-235	4	6	0.03 ± 0.02	0.02 ± 0.15
Uranium-238	6	6	0.23 ± 0.06	0.19 ± 0.04
Richland (HRM 46.4)				
Strontium-90	0	12	0.04 ± 0.03	-0.01 ± 0.05
Technitium-99	1	12	0.62 ± 0.38	0.33 ± 0.29
Tritium	12	12	24.9 ± 6.7	17.4 ± 8.0
Uranium-234	12	12	0.29 ± 0.11	0.25 ± 0.04
Uranium-235	5	12	0.06 ± 0.06	0.02 ± 0.03
Uranium-238	12	12	0.24 ± 0.05	0.20 ± 0.06
*Maximum and minimum values are ± total propagated analytical uncertainty (2 sigma).				
†1 pCi = 0.037 Bq				

Table C.9. Dissolved Metal Concentrations in Columbia River Transect Water Near the Hanford Site

Metal	No. of Samples	No. of Detections	Maximum (µg/L)	Minimum (µg/L)	Average (±2 standard deviation) (µg/L)		Minimum Detectable Concentrations	WA State Ambient Surface Water Quality Chronic Toxicity Level†
Vernita Bridge								
Antimony	9	0	—*	—	—	—	1	N/A
Arsenic	9	0	—	—	—	—	1.7	190
Beryllium	9	0	—	—	—	—	0.2	N/A
Cadmium	9	0	—	—	—	—	0.11	N/A
Chromium	9	0	—	—	—	—	2	10
Copper	9	9	0.64	0.45	0.54	0.13	0.35	6
Lead	9	0	—	—	—	—	0.5	1.1
Nickel	9	0	—	—	—	—	0.5	83
Selenium	9	0	—	—	—	—	1.5	5
Silver	9	0	—	—	—	—	0.2	N/A
Thallium	9	0	—	—	—	—	0.45	N/A
Uranium	9	9	0.57	0.47	0.51	0.073	0.067	N/A
Zinc	9	4	6.1	3.5	4.3	2.04	3.5	55
100-N Area								
Antimony	5	0	—	—	—	—	1	N/A
Arsenic	5	0	—	—	—	—	1.7	190
Beryllium	5	0	—	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	—	0.11	N/A
Chromium	5	0	—	—	—	—	2	10
Copper	5	5	0.57	0.5	0.53	0.047	0.35	6
Lead	5	0	—	—	—	—	0.5	1.1
Nickel	5	0	—	—	—	—	0.5	83
Selenium	5	0	—	—	—	—	1.5	5
Silver	5	0	—	—	—	—	0.2	N/A
Thallium	5	0	—	—	—	—	0.45	N/A
Uranium	5	5	0.5	0.47	0.48	0.02	0.067	N/A
Zinc	5	0	—	—	—	—	3.5	55
Hanford Townsite								
Antimony	5	0	—	—	—	—	1	N/A
Arsenic	5	2	1.8	1.7	1.73	0.078	1.7	190
Beryllium	5	0	—	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	—	0.11	N/A
Chromium	5	0	—	—	—	—	2	10
Copper	5	5	0.55	0.47	0.5	0.063	0.35	6
Lead	5	0	—	—	—	—	0.5	1.1
Nickel	5	0	—	—	—	—	0.5	83
Selenium	5	0	—	—	—	—	1.5	5
Silver	5	0	—	—	—	—	0.2	N/A
Thallium	5	0	—	—	—	—	0.45	N/A
Uranium	5	5	0.65	0.46	0.51	0.15	0.067	N/A
Zinc	5	0	—	—	—	—	3.5	55
300 Area								
Antimony	6	0	—	—	—	—	1	N/A
Arsenic‡	6	1	1.73	1.7	1.71	0.022	1.7	190
Beryllium	6	0	—	—	—	—	0.2	N/A
Cadmium	6	0	—	—	—	—	0.11	N/A
Chromium	6	0	—	—	—	—	2	10

Table C.9. Dissolved Metal Concentrations in Columbia River Transect Water Near the Hanford Site

Metal	No. of Samples	No. of Detections	Maximum (µg/L)	Minimum (µg/L)	Average (±2 standard deviation) (µg/L)		Minimum Detectable Concentrations	WA State Ambient Surface Water Quality Chronic Toxicity Level [†]
Copper	6	6	0.77	0.48	0.57	0.19	0.35	6
Lead	6	0	—	—	—	—	0.5	1.1
Nickel	6	0	—	—	—	—	0.5	83
Selenium	6	0	—	—	—	—	1.5	5
Silver	6	0	—	—	—	—	0.2	N/A
Thallium	6	0	—	—	—	—	0.45	N/A
Uranium	6	6	0.54	0.48	0.5	0.053	0.067	N/A
Zinc	6	0	—	—	—	—	3.5	55
Richland								
Antimony	12	0	—	—	—	—	1	N/A
Arsenic	12	0	—	—	—	—	1.7	190
Beryllium	12	0	—	—	—	—	0.2	N/A
Cadmium	12	0	—	—	—	—	0.11	N/A
Chromium	12	0	—	—	—	—	2	10
Copper	12	12	0.96	0.44	0.6	0.26	0.35	6
Lead	12	0	—	—	—	—	0.5	1.1
Nickel	12	0	—	—	—	—	0.5	83
Selenium	12	0	—	—	—	—	1.5	5
Silver	12	0	—	—	—	—	0.2	N/A
Thallium	12	0	—	—	—	—	0.45	N/A
Uranium	12	12	0.63	0.47	0.54	0.093	0.067	N/A
Zinc	12	6	5.2	3.5	4	1.2	3.5	55
<p>*Dashes indicate results at or below minimum detectable concentrations.</p> <p>[†]WAC 173-201A-240 and WAC 173-201A-250. Table 240(3) Toxic Substances Criteria for the protection of aquatic life. For hardness-dependent criteria, minimum USGS value of 47 mg CaCO₃/L was used for 1992–2000 water samples collected near Vernita Bridge. Ppm values are equivalent to reported µg/L concentrations shown.</p> <p>[‡]Single detected value.</p>								

Table C.10. Radionuclide Concentrations in Columbia River and Shoreline Sediment Near the Hanford Site

Sediment Location	Radionuclide	2015					2010–2014				
		No. of Samples	No. of Detects	Maximum Concentration*			No. of Samples	No. of Detects	Average Concentration*		
				pCi/g					pCi/g		
Adjacent to Locke Island†	Cesium-137	1	0	4.02E-03	±	1.70E-02	2	0	9.33E-03	±	2.14E-02
	Cobalt-60	1	0	6.25E-03	±	1.44E-02	2	0	-9.72E-03	±	1.82E-02
	Europium-152	1	0	-1.05E-02	±	3.60E-02	2	0	-1.42E-02	±	1.21E-02
	Europium-155‡	1	0	N/A			2	0	N/A		
	Plutonium-239/-240	1	0	5.49E-04	±	7.39E-04	2	0	2.40E-03	±	4.29E-03
	Uranium-234	1	1	1.47E+00	±	3.10E-01	2	2	1.35E+00	±	2.00E-02
	Uranium-235	1	1	8.84E-02	±	6.71E-02	2	2	9.11E-02	±	3.00E-04
Adjacent to Salvage Island†	Uranium-238	1	1	1.23E+00	±	2.74E-01	2	2	1.40E+00	±	9.00E-02
	Cesium-137	1	1	2.85E-02	±	1.84E-02	2	2	4.07E-02	±	8.80E-03
	Cobalt-60	1	0	7.05E-03	±	1.55E-02	2	0	5.48E-03	±	1.28E-02
	Europium-152	1	0	-7.95E-03	±	3.56E-02	2	0	-1.68E-02	±	-3.35E-02
	Europium-155‡	1	0	N/A			2	0	3.24E-02	±	5.60E-02
	Plutonium-239/-240	1	0	3.88E-04	±	6.48E-04	2	0	1.60E-03	±	3.37E-03
	Uranium-234	1	1	1.03E+00	±	2.39E-01	2	2	7.23E-01	±	1.07E-01
100-D Spring 102-1	Uranium-235	1	1	8.65E-02	±	6.56E-02	2	2	5.42E-02	±	1.82E-02
	Uranium-238	1	1	9.01E-01	±	2.18E-01	2	2	6.80E-01	±	1.51E-01
	Cesium-137	1	1	1.25E-01	±	1.95E-02	3	3	1.43E-01	±	9.35E-02
	Cobalt-60	1	1	6.17E-02	±	1.91E-02	3	0	9.27E-04	±	1.06E-02
	Europium-152	1	0	2.99E-02	±	2.98E-02	3	0	1.20E-02	±	5.98E-02
	Europium-155‡	1	0	N/A			3	0	4.25E-02	±	8.82E-03
	Plutonium-239/-240	1	1	2.29E-03	±	9.40E-04	3	1	8.62E-04	±	3.07E-03
100F Slough	Uranium-234	1	1	5.04E-01	±	9.04E-02	3	3	4.56E-01	±	1.33E-01
	Uranium-235	1	1	6.20E-02	±	3.61E-02	3	3	4.48E-02	±	1.69E-02
	Uranium-238	1	1	5.51E-01	±	9.41E-02	3	3	4.76E-01	±	4.20E-02
	Cesium-137	2	2	1.66E-01	±	2.74E-02	4	4	2.08E-01	±	4.74E-02
	Cobalt-60	2	0	-4.64E-04	±	1.07E-02	4	0	9.35E-03	±	1.68E-02
	Europium-152	2	0	1.21E-02	±	2.91E-02	4	0	5.09E-03	±	5.57E-02
	Europium-155	2	0	3.02E-02	±	4.23E-02	4	0	5.25E-02	±	4.21E-02
100-K Spring 63-1	Plutonium-239/-240	2	2	1.83E-03	±	7.65E-04	4	0	2.23E-03	±	2.56E-03
	Uranium-234	2	2	7.17E-01	±	1.67E-01	4	4	4.66E-01	±	1.61E-01
	Uranium-235	2	2	7.38E-02	±	5.61E-02	4	4	5.08E-02	±	2.45E-02
	Uranium-238	2	2	6.08E-01	±	1.51E-01	4	4	4.27E-01	±	2.43E-02
	Cesium-137	1	1	1.16E-01	±	2.55E-02	2	2	6.99E-02	±	8.62E-02
	Cobalt-60	1	0	-2.17E-03	±	1.48E-02	2	0	1.84E-03	±	2.27E-03
	Europium-152	1	0	-3.06E-02	±	5.15E-02	2	0	2.38E-02	±	5.09E-02
	Europium-155‡	1	0	N/A			2	0	5.70E-02	±	3.68E-02
	Plutonium-239/-240	1	1	2.47E-03	±	7.88E-04	0	0	N/A		
	Uranium-234	1	1	1.09E+00	±	1.50E-01	2	2	6.02E-01	±	2.28E-01
	Uranium-235	1	1	5.44E-02	±	3.14E-02	2	2	4.22E-02	±	1.37E-02
	Uranium-238	1	1	9.36E-01	±	1.34E-01	2	2	5.79E-01	±	2.22E-01

Table C.10. Radionuclide Concentrations in Columbia River and Shoreline Sediment Near the Hanford Site

Sediment Location	Radionuclide	2015				2010–2014			
		No. of Samples	No. of Detects	Maximum Concentration* pCi/g		No. of Samples	No. of Detects	Average Concentration* pCi/g	
Hanford Slough	Cesium-137	1	1	2.69E-01	± 6.29E-02	6	6	2.49E-01	± 4.41E-02
	Cobalt-60	1	0	-5.21E-03	± 3.18E-02	6	0	1.33E-03	± 5.49E-02
	Europium-152	1	0	3.16E-02	± 4.78E-02	6	0	4.12E-02	± 5.82E-02
	Europium-155†	1	0	N/A		6	0	4.43E-02	± 1.06E-01
	Plutonium-239/-240	1	1	2.49E-03	± 7.88E-04	6	3	2.89E-03	± 1.66E-03
	Uranium-234	1	1	7.47E-01	± 1.50E-01	6	6	1.31E+00	± 2.50E+00
	Uranium-235	1	1	9.23E-02	± 6.57E-02	6	5	7.86E-02	± 1.73E-01
	Uranium-238	1	1	7.84E-01	± 1.95E-01	6	6	7.52E-01	± 4.04E-01
McNary Dam	Cesium-137	2	2	2.59E-01	± 3.26E-02	10	10	2.31E-01	± 4.26E-02
	Cobalt-60	2	0	9.67E-03	± 1.62E-02	10	0	5.06E-03	± 4.20E-02
	Europium-152	2	0	3.42E-02	± 4.93E-02	10	0	5.18E-02	± 8.06E-02
	Europium-155†	2	0	N/A		10	0	8.71E-02	± 3.33E-02
	Plutonium-239/-240	2	2	9.22E-03	± 1.82E-03	10	7	9.00E-03	± 8.71E-03
	Uranium-234	2	2	1.38E+00	± 2.81E-01	10	10	1.45E+00	± 2.54E-01
	Uranium-235	2	2	9.54E-02	± 6.41E-02	10	10	7.57E-02	± 2.61E-02
	Uranium-238	2	2	1.32E+00	± 2.71E-01	10	10	1.23E+00	± 1.77E-01
Priest Rapids Dam	Cesium-137	2	2	2.46E-01	± 3.45E-02	10	10	2.75E-01	± 8.69E-02
	Cobalt-60	2	0	1.03E-02	± 1.53E-02	10	0	-6.87E-03	± 1.33E-02
	Europium-152	2	2	-2.42E-02	± 4.08E-02	10	10	-2.84E-03	± 8.31E-02
	Europium-155	2	0	3.76E-02	± 4.19E-02	10	0	6.84E-02	± 5.49E-02
	Plutonium-239/-240	2	2	1.00E-02	± 1.76E-03	10	10	9.76E-03	± 2.36E-03
	Uranium-234	2	2	1.34E+00	± 2.88E-01	10	10	1.18E+00	± 2.93E-01
	Uranium-235	2	2	9.96E-02	± 6.70E-02	10	10	6.60E-02	± 4.51E-02
	Uranium-238	2	2	1.09E+00	± 2.40E-01	10	10	1.08E+00	± 2.59E-01
White Bluffs Slough	Cesium-137	1	1	2.94E-01	± 3.66E-02	5	5	4.06E-01	± 1.09E-01
	Cobalt-60	1	0	4.60E-03	± 1.13E-02	5	0	4.32E-03	± 2.37E-02
	Europium-152†	1	0	N/A		5	0	1.06E-01	± 1.53E-01
	Europium-155†	1	0	N/A		5	0	8.31E-02	± 3.28E-02
	Plutonium-239/-240	1	1	3.76E-03	± 1.09E-03	5	2	3.05E-03	± 2.54E-03
	Uranium-234	1	1	7.36E-01	± 1.83E-01	5	5	9.15E-01	± 2.96E-01
	Uranium-235	1	1	1.15E-01	± 7.02E-02	5	5	4.51E-02	± 9.00E-03
	Uranium-238	1	1	7.98E-01	± 1.91E-01	5	5	8.78E-01	± 3.81E-01

*1 mg/kg = ug/kg divided by 1000

†Adjacent to Locke and Savage Island sediment was analyzed in 2013 and 2014 but testing did not include TOC analyses.

‡These samples were rejected by the analytical laboratory due to low abundance.

Table C.11. Dissolved Metal Concentrations in Columbia River Sediment Near the Hanford Site

Metal	Priest Rapids Dam (mg/kg dry weight)	Hanford Reach* (mg/kg dry weight)	McNary Dam (mg/kg dry weight)
Antimony	1.46–1.79	0.52–5.5	0.79–0.98
Arsenic	10.2–12.2	2.4–8.2	9.6–10.5
Beryllium	1.27–1.40	0.45–1.28	1.4–1.6
Cadmium	4.1–6.5	0.16–2.1	1.3–1.6
Chromium	35.5–40.3	12.9–96.5	25.8–25.8
Copper	43.6–58.3	9.7–23.9	29.6–33.6
Lead	42.4–45.8	9.1–48.6	22.9–24.5
Mercury	0.12–0.13	0.01–0.05	0.007–0.087
Nickel	39.1–43.7	10.1–20.9	24.7–25.1
Selenium	9.2–9.6	0.72–8.5	9.2–9.8
Silver	0.25–0.31	0.12–0.74	0.29–0.31
Thallium	1.5–2.2	0.61–0.92	1.1–1.2
Zinc	428–547	47.0–362	215–257
No. of Samples	2	8	2
*100-F Slough (n=2), Hanford Slough (n=1), White Bluffs Slough (n=1), 100-D Spring 102-1 (n=1), 100-K 63-1 (n=1), Adjacent to Locke Island (n=1), Adjacent to Savage Island (n=1); where n = number of samples.			

Table C.12. Total Organic Carbon in Columbia River Sediment

Sediment Location	No. of Samples	2015 Concentration*		No. of Samples	2010-2014 Concentration*	
		Minimum mg/kg	Maximum mg/kg		Minimum mg/kg	Maximum mg/kg
Adjacent to Locke Island†	1	N/A	1.17E+03	0	N/A	N/A
Adjacent to Salvage Island†	1	N/A	2.24E+03	0	N/A	N/A
100-D Spring 102-1	1	N/A	2.37E+03	3	1.59E+03	5.87E+03
100F Slough	2	1.75E+03	2.61E+03	4	1.25E+03	2.52E+03
100-K Spring 63-1	1	N/A	1.39E+04	0	N/A	N/A
Hanford Slough	1	N/A	1.48E+04	6	5.29E+03	1.70E+04
McNary Dam	2	1.58E+04	1.80E+04	10	4.45E+03	2.42E+04
Priest Rapids Dam	2	2.47E+04	3.70E+04	10	1.47E+04	3.95E+04
White Bluffs Slough	1	N/A	1.68E+04	6	5.26E+03	3.37E+04

*1 mg/kg = ug/kg ÷ 1000

†Adjacent to Locke and Savage Island sediment was analyzed in 2013 and 2014 but testing did not include TOC analyses.

Table C.13. Radionuclide Concentrations in Columbia River Shoreline Seep Water

2015				2010–2014			WA State
Location/ Radionuclide	No. of Samples	No. of Detects	Concentration pCi/L*	No. of Samples	No. of Detects	Concentration pCi/L*	Ambient Surface Water Quality Standard (pCi/L)*†
			Maximum‡			Average§	
100-B Area (Spring 38-3)							
Strontium-90	1	0	-6.92E-02 ± 2.85E-02	5	0	2.68E-02 ± 3.89E-02	8
Tritium	1	1	6.27E+02 ± 1.87E+02	5	5	1.20E+03 ± 4.16E+02	20,000
100-B Area (Spring 39-2)							
Strontium-90	1	1	2.59E+00 ± 4.15E-01	2	2	1.88E+00 ± 4.60E-01	8
Tritium	1	1	1.90E+03 ± 4.09E+02	2	2	2.10E+03 ± 9.00E+01	20,000
100-D Area (Spring 110-1)							
Alpha (gross)	1	0	1.98E-01 ± 8.91E-01	6	1	1.32E+00 ± 2.33E+00	15
Beta (gross)	1	1	1.39E+00 ± 7.34E-01	6	3	5.94E+00 ± 6.77E+00	50
Strontium-90	1	1	2.70E-01 ± 6.99E-02	6	3	1.18E+00 ± 2.56E+00	8
Technetium-99	1	0	0.161 ± 0.446	4	0	2.49E-01 ± 5.22E-01	900
Tritium	1	1	3.40E+02 ± 1.51E+02	6	5	1.36E+03 ± 2.23E+03	20,000
Uranium-234	1	1	0.297 ± 0.0674	4	4	6.62E-01 ± 8.58E-01	—**
Uranium-235	1	1	2.61E-02 ± 1.94E-02	4	2	3.40E-02 ± 4.23E-02	—
Uranium-238	1	1	0.255 ± 0.0613	4	4	5.49E-01 ± 7.06E-01	—
100-F (Spring 207-1)							
Strontium-90	1	0	-2.38E-02 ± 2.38E-02	3	0	-9.23E-03 ± 4.58E-02	8
Tritium	1	1	352 ± 154	3	3	539 ± 298.77528	900
100-H Area (Spring 152-2)							
Tritium	1	0	1.67E+02 ± 1.17E+02	1	1	5.66E+02 ± 1.96E+02	900
100-K Area (Spring 63-1)							
Alpha (gross)	1	0	1.14E+00 ± 1.00E+00	4	2	2.35E+00 ± 2.45E+00	15
Beta (gross)	1	1	2.28E+00 ± 8.41E-01	4	4	1.22E+01 ± 1.09E+01	50
Carbon-14	5	3	3.41E+02 ± 7.01E+01	2	2	1.28E+03 ± 1.74E+03	2,000
Strontium-90	1	0	-2.87E-02 ± 2.56E-02	4	0	6.11E-03 ± 3.84E-02	8
Tritium	1	0	-6.42E-01 ± 1.24E+02	4	3	9.03E+02 ± 8.79E+02	20,000
100-N Area (Spring 8-13)							
Alpha (gross)	1	0	5.27E-02 ± 1.05E+00	5	1	3.29E+00 ± 7.27E+00	15
Beta (gross)	1	1	4.01E+00 ± 1.34E+00	5	2	5.39E+00 ± 1.25E+01	50
Strontium-90	1	0	1.02E-02 ± 1.49E-02	4	0	2.12E-02 ± 2.81E-02	8
Tritium	1	1	5.84E+03 ± 1.16E+03	5	5	2.56E+03 ± 2.84E+03	20,000
100-N Area (Spring 89-1)							
Strontium-90	1	1	1.66E+01 ± 2.60E+00	3	3	2.03E+01 ± 3.37E+01	8
Tritium	1	0	1.06E+02 ± 1.27E+02	3	3	8.83E+02 ± 1.01E+03	20,000
Hanford Town Site (Hanford Spring 28-2)							
Alpha (gross)	1	0	2.08E+00 ± 2.38E+00	4	0	2.78E+00 ± 1.39E+00	15
Beta (gross)	1	1	1.11E+01 ± 3.00E+00	4	4	3.29E+01 ± 1.89E+01	50
Tritium	1	1	5.75E+03 ± 1.14E+03	4	4	2.59E+04 ± 9.52E+03	20,000
300 Area (300 Area Spring 42-2 and 300 Area Spring DR 42-2)							
Alpha (gross)	3	3	4.79E+01 ± 7.15E+00	9	9	4.53E+01 ± 5.93E+01	15
Beta (gross)	3	3	2.99E+01 ± 4.28E+00	9	9	2.54E+01 ± 2.51E+01	50
Tritium	3	3	4.35E+03 ± 8.76E+02	9	9	4.29E+03 ± 1.44E+03	20,000
Uranium-234	3	3	3.00E+01 ± 3.98E+00	9	9	2.24E+01 ± 2.72E+01	—
Uranium-235	3	3	2.75E+00 ± 5.64E-01	9	9	1.81E+00 ± 2.28E+00	—
Uranium-238	3	3	2.97E+01 ± 5.05E+00	9	9	2.18E+01 ± 2.61E+01	—

*1 pCi = 0.037 Bq

†WAC 246-290, 40 CFR 141; WAC 173-201A-250; EPA-570/9-76-003; Appendix Table D.4

‡Maximum values are ± total propagated analytical uncertainty.

§Averages are ± 2 standard deviations of the mean. Maximum values ± total propagated analytical uncertainty reported as average if only one sample was collected.

**Dashes indicate no concentration guides available.

Table C.14. Metals and Anions in Columbia River Shoreline Seep Water

Location	Analyte	No. of Samples	Detects	Filtered/ Unfiltered*	Range (min-max) [†]	Unit	Regulatory Limit [‡]
100B	Metals						
	Antimony	2	0	Filtered	1.00E+00	µg/L	N/A
	Arsenic	2	2	Filtered	1.84E+00 - 2.10E+00	µg/L	190
	Cadmium	2	0	Filtered	1.10E-01	µg/L	0.59
	Chromium	2	1	Filtered	2.00E+00 - 1.19E+01	µg/L	10§
	Chromium	2	1	Unfiltered	2.00E+00 - 1.17E+01	µg/L	96**
	Copper	2	1	Filtered	3.50E-01 - 6.37E-01	µg/L	6
	Lead	2	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	2	0	Filtered	5.00E-01	µg/L	83
	Selenium	2	0	Unfiltered	1.50E+00	µg/L	5
	Thallium	2	0	Filtered	4.50E-01	µg/L	N/A
	Zinc	2	2	Filtered	2.37E+01 - 2.43E+01	µg/L	55
	Anion						
100D	Nitrate	2	2	Unfiltered	8.15E+02 - 3.52E+03	mg/L	45 ^{††}
	Metals						
	Antimony	1	0	Filtered	1.00E+00	µg/L	N/A
	Arsenic	1	0	Filtered	1.70E+00	µg/L	190
	Cadmium	1	0	Filtered	1.10E-01	µg/L	0.59
	Chromium	1	1	Filtered	3.54E+00	µg/L	10§
	Chromium	1	1	Unfiltered	3.82E+00	µg/L	96**
	Copper	1	1	Filtered	7.24E-01	µg/L	6
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	1	1	Filtered	7.82E-01	µg/L	83
	Selenium	1	0	Unfiltered	1.50E+00	µg/L	5
	Thallium	1	0	Filtered	4.50E-01	µg/L	N/A
	Zinc	1	1	Filtered	1.56E+01	µg/L	55
	Anion						
100F	Nitrate	1	1	Unfiltered	4.65E+03	mg/L	45 ^{††}
	Metals						
	Antimony	2	0	Filtered	1.00E+00	µg/L	N/A
	Arsenic	2	2	Filtered	3.39E+00 - 4.22E+00	µg/L	190
	Cadmium	2	1	Filtered	1.10E-01 - 3.19E-01	µg/L	0.59
	Chromium	2	2	Filtered	7.27E+00 - 1.14E+01	µg/L	10§
	Chromium	2	2	Unfiltered	7.48E+00 - 2.07E+01	µg/L	96**
	Copper	2	1	Filtered	3.50E-01 - 4.52E+00	µg/L	6
	Lead	2	1	Filtered	5.00E-01 - 5.16E+00	µg/L	1.1
	Nickel	2	1	Filtered	5.00E-01 - 1.77E+00	µg/L	83
	Selenium	2	1	Unfiltered	1.50E+00 - 1.63E+00	µg/L	5
	Thallium	2	0	Filtered	4.50E-01	µg/L	N/A
	Zinc	2	2	Filtered	1.51E+01 - 4.93E+01	µg/L	55
	Anion						
100H	Nitrate	2	2	Unfiltered	2.61E+04 - 3.59E+04	mg/L	45 ^{††}
	Metals						
	Antimony	1	0	Filtered	1.00E+00	µg/L	N/A
	Arsenic	1	1	Filtered	2.02E+00	µg/L	190
	Cadmium	1	0	Filtered	1.10E-01	µg/L	0.59
	Chromium	1	1	Filtered	2.84E+00	µg/L	10§
	Chromium	1	1	Unfiltered	2.96E+00	µg/L	96**
	Copper	1	1	Filtered	3.50E-01	µg/L	6
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	1	0	Filtered	5.00E-01	µg/L	83
	Selenium	1	0	Unfiltered	1.50E+00	µg/L	5
	Thallium	1	0	Filtered	4.50E-01	µg/L	N/A
	Zinc	1	1	Filtered	2.45E+01	µg/L	55
	Anion						
	Nitrate	1	1	Unfiltered	2.37E+03	mg/L	45 ^{††}

Table C.14. Metals and Anions in Columbia River Shoreline Seep Water

Location	Analyte	No. of Samples	Detects	Filtered/ Unfiltered*	Range (min-max) [†]	Unit	Regulatory Limit [‡]
100K	Metals						
	Antimony	1	0	Filtered	1.00E+00	µg/L	N/A
	Arsenic	1	0	Filtered	1.70E+00	µg/L	190
	Cadmium	1	0	Filtered	1.10E-01	µg/L	0.59
	Chromium	1	0	Filtered	2.00E+00	µg/L	10§
	Chromium	1	0	Unfiltered	2.00E+00	µg/L	96**
	Copper	1	1	Filtered	6.64E-01	µg/L	6
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	1	0	Filtered	5.00E-01	µg/L	83
	Selenium	1	0	Unfiltered	1.50E+00	µg/L	5
	Thallium	1	0	Filtered	4.50E-01	µg/L	N/A
	Zinc	1	1	Filtered	5.79E+01	µg/L	55
	Anion						
	Nitrate	1	1	Unfiltered	1.71E+03	mg/L	45 ^{††}
100N	Metals						
	Antimony	2	1	Filtered	1.00E+00 - 1.11E+00	µg/L	N/A
	Arsenic	2	2	Filtered	2.19E+00 - 8.69E+00	µg/L	190
	Cadmium	2	0	Filtered	1.10E-01	µg/L	0.59
	Chromium	2	1	Filtered	2.00E+00 - 6.59E+00	µg/L	10§
	Chromium	2	1	Unfiltered	2.00E+00 - 6.99E+00	µg/L	96**
	Copper	2	2	Filtered	5.13E-01 - 1.33E+00	µg/L	6
	Lead	2	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	2	0	Filtered	5.00E-01	µg/L	83
	Selenium	2	1	Unfiltered	1.50E+00 - 2.10E+00	µg/L	5
	Thallium	2	0	Filtered	4.50E-01	µg/L	N/A
	Zinc	2	2	Filtered	1.74E+01 - 2.04E+01	µg/L	55
	Anion						
	Nitrate	2	2	Unfiltered	3.25E+03 - 2.59E+04	mg/L	45 ^{††}
Hanford Townsite ^{‡‡}	Anion						
	Nitrate	1	1	Unfiltered	4.43E+03	mg/L	45 ^{††}
300 Area ^{‡‡}	Anion						
	Nitrate	3	3	Unfiltered	1.40E+04 - 2.08E+04	mg/L	45 ^{††}

*All dissolved concentrations are associated with filtered samples; all recoverable concentrations are associated with unfiltered samples.
[†]One value is shown if only one sample was collected or if the minimum and maximum concentrations were the same.
[‡]Ambient water quality criteria values or chronic toxicity unless otherwise noted (WAC 173-201A-240).
[§]Value for hexavalent chromium.
^{**}Value for trivalent chromium.
^{††}Washington State drinking water standard utilized (WAC 246-290).
^{‡‡}Hanford Townsite and 300 Area seeps did not have metals analyses performed during 2015.

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Appendix D

Dose Calculations

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D. Dose Calculations

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Dose calculations based on measured and/or estimated releases from stack emissions, liquid effluents, and contaminated soils were conducted for the public and biota. These dose calculations are summarized in Section 4.2. Details of the methods and assumptions used for modeling individual and population dose for the public are provided in Section D.1. Methods and assumptions related to the calculation of biota dose are provided in Section D.2.

D.1 Supporting Information for Calculation of Public Doses

The radiological dose that the public could have received in 2015 from the Hanford Site was calculated in terms of the *total effective dose*. The total effective dose is the sum of the effective dose equivalent from external sources and the committed effective dose equivalent for internal exposure, which are summarized here and described in more detail in DOE's Occupational Radiation Protection rule in [10 CFR 835](#). The committed effective dose equivalent is the sum of doses to organs and tissues that is weighted to account for the sensitivity of the organ or tissue to the effects of radiation and for the biological effectiveness of the type of radiation causing the dose. It is expressed in units of rem (Sv), or more typically the sub-unit mrem (mSv)[†] for individuals, and in units of person-rem (person-Sv) for the collective dose received by the total population within a 50-mi (80-km) radius of Hanford Site operations areas. This appendix describes how the doses summarized in Section 4.2 of this report were calculated.

Calculation of the total effective dose accounts for the long-term (50 yrs) internal exposure from radionuclides absorbed into the body during the current year. The committed effective dose equivalent is the sum of individual committed (50 yrs) organ doses multiplied by tissue weighting factors (International Commission on Radiological Protection [ICRP] 1991) that represent the contribution of each organ or tissue to a person's internal radiation dose. Internal organs also may 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.

Releases of radionuclides from Hanford Site facilities are frequently too small for their concentrations to be accurately measured in many of the off-site environmental media of interest. Even when present in measureable amounts, it can be difficult to distinguish the small Hanford Site contributions from levels attributable to fallout from historical nuclear weapons testing and from naturally occurring radionuclides such as uranium and its decay products. Therefore, Hanford-related environmental radionuclide concentrations were estimated from stack effluent measurements (air pathway doses) or river water measurements (water pathway doses) by using environmental transport models. The air dose calculations employ environmental transport modeling based on measurements made at the points of release (stacks and vents). The water pathway dose calculations are based on the difference in measurements of radionuclide concentrations in the Columbia River upstream and downstream of the Hanford Site.

The transport of radionuclides in the environment to points of exposure is predicted using mathematical models of the physical processes underlying the various exposure pathways. These models are used to calculate radionuclide levels in air, soil, and foods at off-site locations. Long-lived radionuclides deposited

[†]1 rem (0.01 Sv)=1,000 mrem (10 mSv).

on the ground by irrigation or airborne depositions become possible sources of external exposure and uptake by agricultural products. Radionuclides taken into the body by inhalation or ingestion may be distributed among different organs and tissues and retained in the body for various lengths of times. Agricultural, behavioral, and dosimetric models were applied to calculate radionuclide intakes and radiological doses to the public from annual-average radionuclide concentrations in the exposure media. Computer programs were used to implement these mathematical models using Hanford Site-specific dispersion and uptake parameters. These programs are incorporated in a master code—*GENII - The Hanford Environmental Radiation Dosimetry Software System, Version 2.10* ([PNNL-14583](#); [PNNL-14584](#); [PNNL-19168](#)), which employs the internal dosimetry methodology described in ICRP Publication 60 (ICRP 1991) and external dose coefficients described in Federal Guidance Report 12 ([EPA 1993](#)). GENII Version 1.485 ([PNL-6584](#), *The Hanford Environmental Radiation Dosimetry Software System*), which incorporated internal dosimetry methods of *International Commission on Radiological Protection Publication 30* (ICRP 1979a and 1979b) was used for dose calculations through 2008. GENII Version 2.10 is a Microsoft Windows®-based version that also incorporates some environmental modeling improvements (e.g., plume depletion during atmospheric transport) relative to Version 1.485. The modeling assumptions and radionuclide release data used in the GENII calculations are the primary focus of Section D.1. The ingestion and inhalation dose coefficients (ICRP 1991) and external dose coefficients ([EPA 1993](#)) used for the pathway dose calculations are described further in [PNNL-14584](#) and are not reproduced here.

In addition to the GENII calculations for assessing public doses, the computer program CAP88-PC (also known as CAP-88) was used to calculate an air pathway dose to a maximally exposed individual (MEI) for compliance with *Clean Air Act* standards, as required by the EPA through [40 CFR 61](#), Subpart H, from airborne radionuclide effluents (other than radon) released at DOE facilities. Air pathways calculations performed with the CAP-88PC computer code differ slightly from those performed in GENII. Technical details of the CAP88-PC calculations are provided in [DOE/RL-2016-10](#), *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2015*.

Calculations of radiological doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations. [DOE O 458.1](#) provides requirements for demonstrating compliance with the public dose limit of 100 mrem (1 mSv) total effective dose in a year. Relevant requirements include the following:

- Compliance may be demonstrated by calculating dose to the representative person or to the MEI
- Collective dose for members of the public should be calculated, and may be truncated, by distance (e.g., 50 mi [80 km])
- The representative person or MEI must include members of the public outside of controlled areas on DOE sites and off site
- Analytical models used to calculate dose must be codified or approved by DOE and must consider likely exposure pathways, including external radiation from air and soil, inhalation, and ingestion of water and terrestrial and/or aquatic foods
- Calculations of doses to the public from exposures resulting from both routine and unplanned activities must be performed using DOE-approved dose conversion factors
- Values of default or site-specific parameters used in the dose modeling must be included to document the calculations.

A summary of how the location of the off-site MEI was identified, and information on modeling assumptions and inputs to the GENII computer code used to conduct the MEI dose calculations is provided in Section D.1.1. Information supporting the calculation of collective off-site dose for members of the public using the GENII computer code is provided in Section D.1.2.

D.1.1 Maximally Exposed Individual Dose

The MEI is a hypothetical member of the public whose location and lifestyle make it unlikely that any actual individuals would receive higher doses. The location of the MEI can vary annually depending on 1) the relative contributions of the different operational areas to radioactive emissions released to the air, 2) the contribution of radionuclide releases to the Columbia River from Hanford Site facilities, and 3) variable differences in meteorology affecting wind dispersion. The following potentially significant exposure pathways are considered for identifying the location of this hypothetical individual and calculating radiation dose:

- Inhalation of airborne radionuclides
- External exposure from submersion in airborne radionuclides
- Ingestion of foodstuffs contaminated by radionuclides deposited on vegetation and the ground by airborne deposition and/or irrigation water drawn from the Columbia River downstream of the Hanford Site
- Incidental ingestion of soil and external exposure to ground contaminated by airborne deposition and/or irrigation water
- Ingestion of drinking water drawn from the Columbia River
- Consumption of fish from the Hanford Reach of the Columbia River
- Recreational activities along the Hanford Reach of the Columbia River, including fishing, hunting, boating, swimming, and exposure to sediments during shoreline activities.

Determination of the Location of the MEI. Based on experience since 1990 from environmental transport modeling and environmental surveillance monitoring, four locations (Section 4, Figure 4.2) are considered for identifying the location of the MEI. The distinguishing characteristics of these locations are described in the following paragraphs.

Riverview MEI. The Riverview area is across the Columbia River from the City of Richland. Because of its location, an individual in the Riverview area has the potential to receive the maximum exposure to waterborne effluent from Hanford Site facilities as well as some contribution from exposure to airborne emissions from the 300 Area. The Riverview location is where a small population of West Pasco residents obtain their drinking water from the river via a community water system; therefore, the domestic drinking water pathway is applied to this location. Columbia River water from just downstream of the Hanford Site is also withdrawn for irrigation of small gardens and farms at Riverview.

Ringold MEI. The Ringold area is along the eastern shoreline of the Columbia River 16 mi (26 km) east of separations facilities in the 200 Areas. 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. In addition, it is assumed that some individuals in the Ringold area may irrigate their crops with water from the Columbia River downstream of where contaminated groundwater originating from the 100 and 200-East Areas enters the river. For identifying the MEI, Hanford Site contributions to irrigation water at Ringold are

protectively evaluated using the same downstream concentrations employed for Riverview. Domestic drinking water at Ringold is not obtained from the Columbia River so this exposure pathway is incomplete.

Sagemoor MEI. An individual in the Sagemoor area, located 0.87 mi (1.4 km) directly across the Columbia River from the 300 Area, frequently receives maximum exposure to airborne emissions from the 300 Area. However, domestic water at this location comes from wells rather than from the river; as a result, wells on the eastern side of the Columbia River are not impacted by radionuclides of Hanford Site origin. Because the farms located across from the 300 Area obtain irrigation water from the Columbia River upstream of the Hanford Site, irrigation-related exposure pathways are likely incomplete at this location. However, because some individuals may obtain much of their food from local agriculture, Columbia River irrigation pathways agricultural dose has been historically assigned to the Sagemoor area MEI. This practice protectively but unrealistically sums the location-specific air deposition component of food-related dose with the irrigation component from another location. The added contribution of radionuclides in the Riverview area irrigation water maximizes the calculated dose from the air and water pathways combined.

Horn Rapids Road MEI. Meteorological conditions in 2012 through 2015 resulted in a more southerly direction of wind dispersion than has been observed in past years. As a result, air concentrations related to 300 Area emissions were modeled to be slightly higher at a location just to the south of the Hanford Site boundary than at the Sagemoor location across the Columbia River to the east. Buildings in this area historically have been associated with commercial and industrial activities. However, in recent years, residences also have been constructed near the southern boundary of the Hanford Site south of the 300 Area. Residences in this area obtain drinking water from the City of Richland, which has an intake on the Columbia River downstream of the Hanford Site; therefore, the domestic drinking water pathway is applied to this location. Additionally, some agriculture in this area occurs on leased property that receives irrigation water from the Battelle pumping station on the Columbia River just below the 300 Area.

During the period of plutonium production at the Hanford Site, Ringold was commonly the location of the MEI. Because of the shift in Hanford Site operations from nuclear weapons production to the current mission of managing waste products, cleaning up legacy waste, 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. For the past two decades, the hypothetical MEI has been associated with air emissions from the 300 Area.

Because the hypothetical MEI at all locations is assumed to potentially receive dose from consumption of foods raised using Columbia River irrigation water, the identification of the location of the MEI is based on the highest projected dose among the following air pathways: at Ringold (200 Area sources), Sagemoor (300 Area sources), Horn Rapids Road (300 Area sources) plus drinking water pathways dose, and Riverview (300 Area sources) plus drinking water pathways dose.

For 2015, air-pathways radiological dose calculations conducted using CAP88-PC in support of *Clean Air Act* requirements and GENII Version 2.10 have identified Horn Rapids Road as the location with the highest MEI dose. Air pathways calculations performed with the GENII computer code indicate that Sagemoor and Horn Rapids Road air pathways MEI doses in 2015 are similar (0.12 mrem at Sagemoor and 0.15 mrem at Horn Rapids Road). Unlike the Sagemoor receptor the MEI at Horn Rapids Road receives additional dose from the drinking water pathway. Both Sagemoor and Horn Rapids Road MEI GENII results are shown in Section 4, Figure 4.4 for comparison.

MEI location coordinates relative to Hanford Site operating areas are entered in the GENII computer code to specify the location for the air pathways dose calculations. For Sagemoor, these coordinates are:

100 Area: 26.874 km Easting, 30.064 km Northing	300 Area: 1.35 km Easting, 0.26 km Northing
200 Area: 24.954 km Easting, 20.814 km Northing	400 Area: 7.909 km Easting, 6.739 km Northing

For Horn Rapids Road, these coordinates are:

100 Area: 29.1 km Easting, -29.1 km Northing	300 Area: 0 km Easting, -1.80 km Northing
200 Area: 22.6 km Easting, -22.6 km Northing	400 Area: 7.92 km Easting, -7.92 km Northing

Water and Air Release Inputs Used In GENII Version 2.10. As discussed in Section 4.2, the environmental data needed to perform the GENII dose calculations for the water pathways are differences in the measured upstream and downstream radionuclide concentrations in the Columbia River. The radionuclide releases to the Columbia River that are assumed to be the source of these differences are assigned to the 200 Areas, but area assignment does not affect the dose results. Measured emissions of radionuclides in stack releases are used in the GENII air pathways dose calculations. These air and water pathways data must be processed for input to the GENII computer code. GENII accepts inputs for environmental releases using dimensions of activity (e.g., Cu or Bq) per time for both water and air pathways.

Direct liquid effluent releases from outfalls in the 100 Areas were historically used to characterize contributions from the 100 Areas. The last operating outfall, 1908-K in the 100-K Area, ceased operations at the end of March 2011; therefore, no annual releases were identified from the 100 Areas in 2015. Liquid effluent discharges related to historical Hanford operations are known to enter the Columbia River by groundwater discharge at certain locations along the site shoreline from the 100-B/C Area downstream to the 300 Area. The impact of these discharges was evaluated as the difference between near-shore river water radionuclide concentrations downstream of the Hanford Site (monthly samples collected at the Richland Pump house, sampling location label RICH.PMPHS HRM46.4) and upstream samples collected below the Priest Rapids Dam (monthly samples collected at sampling location label PRIEST RAPIDS-RIVER). Some radionuclides are measured in both filtered samples (in solution) and in samples that capture suspended particulates (adhered to resin). These data were evaluated both separately and summed.

One-tailed paired t-tests and nonparametric Wilcoxon Rank Sum (WRS) tests were used to determine whether average downstream sample concentrations were statistically greater than upstream average concentrations. The results of statistical tests were used in conjunction with supporting information such as known releases from groundwater plumes to the river and historical observations in river water to identify Hanford-related contaminants. The paired t-test is more powerful than the ordinary t-test when the values in the pairs correlate, or when the concentrations measured downstream tend to correlate to those upstream. The WRS test has less power than the t-test when the data originate from a normal distribution, but the assumptions under which the statistical results are valid are not as restrictive. A p-value of 0.05 is commonly used as the threshold of statistical significance, but a larger, less restrictive value may be used when other factors support evidence of a release. Likewise, when a contaminant does not have any known Hanford Site sources a smaller threshold could be appropriate to identify radionuclides for the dose assessment.

Both statistical tests identified tritium and uranium-238 as potentially Hanford-related contaminants to include in the 2015 water-pathways dose assessment using a p-value of 0.05. Concentrations of uranium-

234 were greater downstream, but p-values were slightly higher than 0.05 for both the t-test and WRS. Uranium-234 is retained as a potentially Hanford-related contaminant for the 2015 dose assessment because the higher downstream concentrations are considered plausibly site-related, particularly in light of the uranium-238 results. Although uranium-235 might be expected to co-occur with both uranium-234 and uranium-238, yearly average uranium-235 concentrations were higher upstream than downstream and therefore uranium-235 is not included in the water pathways dose assessment calculations. Two additional radionuclides included in the 2015 water pathways dose calculations are cesium-134 and strontium-90. Neither radionuclide was measured at concentrations above detection limits. In both cases, the t-test p-values were below 0.05 and the WRS p-values were slightly greater than 0.05. Strontium-90 is known to be a component of groundwater plumes impacting the Columbia River and is included for that reason, even though it was not detected in the river water samples. Current Hanford Site-related cesium-134 releases have not been identified to the Columbia River, and its relatively short half-life of approximately 2 years suggests that its presence related to historical Hanford operations is unlikely. In addition, cesium-134 was not detected in any samples; nevertheless, it has been protectively included in the water pathways dose calculations.

	paired t-test	p-value Wilcoxon Rank Sum
Tritium	0.0000060	<0.0003
Uranium-238	0.0020	0.0067
Uranium-234	0.070	0.057
Cesium-134	0.023	0.057
Strontium-90	0.033	0.065

Table D.1 summarizes the mean annual differences in downstream and upstream concentrations, and calculated annual releases for the 2015 GENII water pathways dose calculations.

Table D.1. Liquid Effluent Radionuclide Releases for GENII Dose Calculations

Radionuclide	Upstream	Downstream	Difference
Columbia River Annual-Average Radionuclide Concentrations (pCi/L)*			
Cesium-134	1.2E-03	3.1E-03	1.9E-03
Strontium-90	1.1E-04	1.7E-02	1.7E-02
Tritium	1.7E+01	3.0E+01	1.3E+01
Uranium-234	2.5E-01	2.7E-01	2.0E-02
Uranium-238	1.9E-01	2.2E-01	2.6E-02
Calculated Radionuclide Releases (Ci/year)†			
Cesium-134	NA	NA	1.9E-01
Strontium-90	NA	NA	1.7E+00
Tritium	NA	NA	1.3E+03
Uranium-234	NA	NA	2.1E+00
Uranium-238	NA	NA	2.6E+00
Thorium-234‡	NA	NA	2.6E+00
Protactinium-234m‡	NA	NA	2.6E+00
NA=not applicable; radionuclide releases calculated based on difference between annual-average downstream and upstream concentrations.			
*1 pCi=0.037 Bq			
†Calculated as the product of the difference in downstream and upstream radionuclide concentrations and the 2015 annual-average river flow rate of 3,177 m ³ /sec at Priest Rapids Dam and the number of seconds in a year.			
‡These short-lived progeny of uranium-238 were protectively assumed to be in secular equilibrium at the time of discharge. Refer to Section 7.0 for information on Columbia River surface water sampling.			

Radioactive air emissions based on monitoring of stacks in the 100, 200, 300, and 400 areas were used as the basis for the GENII air pathways dose calculations. Stack emissions are measured for specific radionuclides related to the operations at each emissions point. During the dispersion time from the stack to an off-site exposure location there is opportunity for ingrowth of short-lived radioactive progeny that are included in the GENII radionuclide inventory. A protective upper-bound dispersion time of 15 hrs was estimated based on the longest dispersion distance in the collective dose calculations 50 mi (80 km) and an assumed (4.9 ft/sec [1.5 m/sec]) average wind speed. The highest short-term (15-hr ingrowth period) concentrations of short-lived progeny that have a separate dose conversion factor were included in the GENII air emissions inventory to address their potential contribution to the inhalation dose. Ingrowth of longer-lived progeny in soil and other environmental media is accounted for within GENII.

In addition to measurement of specific radionuclides, gross alpha and gross beta measurements are also made on emissions from each operating area. Following the precedent of the *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2015* (DOE/RL-2016-10), measurements of gross alpha and gross beta radiation in stack emissions were protectively added to the measured emissions of plutonium-239/-240 and cesium-137, respectively, to ensure that contributions from any unmeasured operations-related radionuclides are incorporated in the estimated doses. These specific radionuclides were selected based on their historical association with releases in these operating areas and because air pathways calculations indicate dose is highest for these radionuclides among the group of plausible candidates of alpha- and beta-emitting radionuclides. Annual radionuclide air releases used in the GENII air pathways dose calculations are summarized in Table D.2.

Table D.2. Air Pathways Radionuclide Stack Emissions for GENII Modeling

Radionuclide	100 Area	200 Areas (Ci)	300 Area	400 Area
Hydrogen-3 (elemental tritium)	NA	NA	133	NA
Hydrogen-3 (tritiated water vapor)	NA	NA	282	1.8E-03
Carbon-14	NA	NA	1.2E-04	NA
Sodium-22	NA	NA	NA	1.4E-09
Krypton-85	NA	NA	5.8E-07	NA
Stontium-90	2.3E-06	1.0E-04	2.2E-07	NA
Yttrium-90†	3.4E-07	1.5E-05	3.3E-08	NA
Technetium-99	NA	NA	4.1E-06	NA
Ruthenium-106	NA	2.6E-06	1.9E-09	NA
Iodine-129	NA	2.3E-04	NA	NA
Cesium-134	NA	NA	NA	NA
Cesium-137‡	1.7E-05	2.9E-04	7.2E-06	1.3E-06
Barium-137m†,‡	1.7E-05	2.9E-04	7.2E-06	1.3E-06
Europium-152	NA	NA	1.8E-09	NA
Europium-154	NA	NA	1.2E-08	NA
Gadolinium-153	NA	NA	7.0E-11	NA
Radon-219	NA	NA	6.2E+00	
Lead-211†	--	--	1.1E-02	
Bismuth-211†	--	--	1.9E-03	
Thallium-207†	--	--	8.7E-05	
Radon-220	NA	NA	385	NA
Lead-212†	--	--	5.5E-01	NA
Bismuth-212†	--	--	4.6E-01	NA
Radon-222	NA	NA	NA	NA

Table D.2. Air Pathways Radionuclide Stack Emissions for GENII Modeling

Radionuclide	100 Area	200 Areas	300 Area	400 Area
	(Ci)			
Radium-226	NA	NA	4.1E-10	NA
Actinium-227	NA	NA	1.8E-09	NA
Uranium-232	NA	NA	5.4E-09	NA
Uranium-233	NA	NA	1.8E-08	NA
Neptunium-237	NA	NA	1.4E-08	NA
Plutonium-238	5.1E-07	5.4E-07	3.8E-08	NA
Plutonium-239/240§	1.5E-05	6.3E-05	7.8E-08	2.5E-07
Plutonium-241	2.0E-05	1.6E-05	6.7E-07	NA
Americium-241	3.4E-06	4.6E-06	1.2E-09	NA
Americium-243	NA	NA	4.5E-08	NA
<i>Neptunium-239†</i>	--	--	7.6E-09	NA
(gross alpha)	1.1E-05	4.0E-05	7.2E-08	2.5E-07
(gross beta)	1.3E-05	2.5E-04	5.3E-06	1.3E-06

NA=Not available or not detected. No stack emissions reported for this radionuclide.

*Radionuclides in *italic font* are short-lived progeny of the parent listed above that may ingrow during air dispersion to off-site locations.

†Values of these short-lived progeny are the highest activity calculated within an estimated 15-hr dispersion time period to an exposure point within a 50-mi (80-km) distance.

‡Values include the addition of gross beta activity.

§Values include the addition of gross alpha activity.

Exposure Parameter Values Used in GENII Version 2.10. GENII Version 2.10 requires input values for numerous parameters used in the environmental transport and human exposure models. Important parameters affecting the movement of radionuclides within agricultural exposure pathways such as animal dietary parameters, irrigation rates, crop yield, growing periods, and holdup periods are listed in Table D.3. The plant, animal, and aquatic foods transfer factors used for the pathway dose calculations are documented in [PNNL-14584](#) and are not reproduced here.

The off-site radiological dose is related to the extent of external exposure to or intake of radionuclides released from Hanford Site operations that become incorporated in exposure media such as air, water, soil, sediment, and various foodstuffs. Tables D.4 through D.6 provide the values for the diet, residency, and river recreation parameters for the MEI and collective dose (average individual) calculations.

Meteorological Data Used in GENII Version 2.10. GENII Version 2.10 employs an atmospheric dispersion model to calculate annual-average air concentrations and deposition rates at downwind locations based on site-specific radionuclide air emissions measurements and meteorological data ([PNNL-14583](#)). The 2015 meteorological data used in the GENII air dispersion modeling were gathered at monitoring stations in the 100 Area (station 13; 100-N), 200 Area (station 21; Hanford Meteorological Station), 300 Area (Station 11; 300 Area), and 400 Area (station 9; Fast Flux Test Facility [FFTF]). With the exception of the 200 Area, all meteorological data were obtained at a height of 33 feet (10 m). In the 200 Area, where some active stacks are 200 ft (61 m) in height, the meteorological data used were collected at 200 ft (61 m).

Table D.3. Agricultural Pathway Parameters for Hanford Site Dose Calculations

Medium	Vegetables					Poultry	Beef	Milk	Hay (beef cattle, milk cows)	Pasture (milk cows)	Grains (beef cattle, poultry)
	Leafy	Root	Fruits	Cereals	Eggs						
Holdup time; day (MEI)	1	5	5	180	1	1	15	1	100	0	180
Holdup time; day (population)	14	14	14	180	18	34	34	4	100	0	180
Growing period; day	90	90	90	90	NA	NA	NA	NA	45	30	90
Yield; kg/m*	1.5	4	2	0.8	NA	NA	NA	NA	2	1.5	0.8
Irrigation rate; cm/yr	77	88	77	†	NA	NA	NA	NA	103	103	†
Irrigation period; month	6	6	6	†	NA	NA	NA	NA	6	6	†
Water intake; L/year	NA	NA	NA	NA	0.3	0.3	50	60	NA	NA	NA
Food intake; kg/day	NA	NA	NA	NA	0.12	0.12	68/68‡	55/55§	NA	NA	NA
Contaminated fraction of diet*	NA	NA	NA	NA	1.0	1.0	0.25/0.75‡	0.25/0.75§	NA	NA	NA
Livestock soil intake; kg/day	NA	NA	NA	NA	0.0	0.0	0.0	0.375**	NA	NA	NA
Holdup=time between harvest and consumption; MEI=maximally exposed individual; NA=not applicable											
*Pertains to animal feed; 100% of animal water is assumed contaminated surface water.											
†No irrigation is assumed to occur for cereal crops or grains.											
‡First value pertains to grains, and second value pertains to hay.											
§First value pertains to hay, and second value pertains to pasture grass.											
**Calculated as 0.5 kg soil/day while grazing × 0.75 diet fraction of pasture grass.											

Table D.4. Consumption Parameters for Hanford Site Dose Calculations

Medium	Consumption Rate*	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Leafy vegetables	66 lbs (30 kg)/yr	33 lbs (15 kg)/yr
Root vegetables	485 lbs (220 kg)/yr	310 lbs (140 kg)/yr
Fruits	728 lbs (330 kg)/yr	140 lbs (64 kg)/yr
Cereals	180 lbs (80 kg)/yr	160 lbs (72 kg)/yr
Milk	71 gal (270 L)/yr	61 gal (230 L)/yr
Beef	180 lbs (80 kg)/yr	150 lbs (70 kg)/yr
Poultry	40 lbs (18 kg)/yr	19 lbs (8.5 kg)/yr
Eggs	66 lbs (30 kg)/yr	44 lbs (20 kg)/yr
Fish†	88 lbs (40 kg)/yr	--‡
Drinking water§	193 gal (730 L)/yr	116 gal (440 L)/yr
Inadvertent soil ingestion	1.17 oz (36.5 g)/yr	0.59 oz (18.3 g)/yr

*A transit time of 11 hrs from the release to receptor locations is assumed.

†A holdup time of 1 day is used for both MEI and population calculations.

‡Average individual consumption not identified; see text of Section D.1.2.

§A holdup time of 1 day is used for the Riverview calculations for identification of the location of the MEI.

Table D.5. Residency Parameters for Hanford Site Dose Calculations

Pathway	Exposure	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Air: Inhalation*, †	24 hrs/day, 365 days/yr	24 hrs/day, 365 days/yr
Air: external (submersion)†	24 hrs/day, 365 days/yr	24 hrs/day, 365 days/yr
Soil: external (ground shine)	12 hrs/day, 365 days/yr	8 hrs/day, 365 days/yr

*Inhalation rate, adult 1.0 m³/hr (35 ft³/hr).

†Dispersion time of 15 hrs is protectively assumed for ingrowth of short-lived progeny during transport (50 mi [80 km]) population dose radius and 4.9 ft/s (1.5 m/s) wind speed.

Table D.6. Columbia River Parameters for Hanford Site Dose Calculations

Activity and Pathway	Exposure*	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Shoreline: sediment; external	5.0 hrs/day, 100 days/yr†	1.7 hrs/day, 10 days/yr†
Boating: river water; external	2.0 hrs/day, 50 days/yr‡	0.1 hr/day, 50 days/yr‡
Swimming: river water; inadvertent ingestion§, external	2.0 hrs/day, 50 days/yr	0.2 hr/day, 50 days/yr

*A transit time of 11 hrs from the release to receptor locations is assumed.

†A shoreline width factor of 0.2 is used.

‡No shielding by the boat is assumed.

§Ingestion rate of 0.68 oz (0.02 L)/hr.

Because meteorological station 29 (100-K) has been inoperable since 2013, a meteorological file was compiled with data for 2003–2012, which represents a 10-yr average of daily meteorological data at this location. The 100 Area air pathways doses were calculated using this 10-yr average data file and using 2015 meteorological data from Station 13 at 100-N. The difference in dose results was approximately 7%. The 2015 100-N meteorological file, which is more applicable to local and regional air dispersion in 2015, was used for the MEI and population dose calculations. The negligible difference in dose using the 100-K

10-year average meteorological data file versus the 2015 100-N air station file indicates the selection of one or the other has little impact on the dose assessment results.

Hourly meteorological data from the monitoring stations described above were formatted for use in the GENII computer code. Five meteorological files, one for each of the Hanford Site operating areas and stations described above, were created. These files were referenced in the GENII Chronic Plume Air Module. A radial grid consisting of 16 directional sectors and 10 downwind distances was specified in the air module. The downwind distances were varied for each operating area to coincide with the distance to the MEI location, as defined by the Easting and Northing coordinates described above. For example, the finest resolution was entered for the distance from the 300 Area to the MEI location

D.1.2 Fifty-Mile (Eighty-Kilometer) Collective Population Dose

Regulatory limits have not been established for collective doses to a population; however, evaluation of the collective population doses to all residents within a 50-mi (80-km) radius of Hanford Site operations is required by [DOE O 458.1](#). The radiological dose received by the total population within 50 mi (80 km) of site operations areas was calculated to confirm adherence to DOE environmental protection policies, and provide information to the public. The 50-mi (80-km) collective dose is the sum of doses to all individual members of the public within 50 mi (80 km) of the four Hanford Site operations areas (100 Area, 200 Area, 300 Area, and 400 Area).

The same exposure pathways evaluated for the MEI (Section D.1.1) were used to calculate doses to the off-site population. The primary difference between the MEI and collective dose calculations is in the values selected for certain exposure parameters. As shown in Tables D.4, D.5, and D.6, exposure parameter values for the collective dose calculations reflect an average individual rather than an MEI.

In calculating the collective dose related to water-mediated exposure pathways (drinking water, irrigated foods, Columbia River recreation, and fish consumption), estimates were made of the off-site population size expected to be affected by each pathway. The assumptions of population size and the calculation of collective dose for each of these four exposure pathways are described in the following paragraphs.

Drinking Water. The Cities of Richland and Pasco obtain all or part of their municipal water directly from the Columbia River downstream from the Hanford Site; the City of Kennewick obtains its municipal water indirectly from wells adjacent to the river. Approximately 182,000 people residing in the Tri-Cities‡ are assumed to obtain all of their drinking water directly from the Columbia River or from impacted wells near to the river. Annual drinking water dose for an average individual is multiplied by the Tri-Cities population to calculate the collective drinking water dose.

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 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. Because these crops are widely distributed, any individual in the Tri-Cities is likely to receive only negligible potential exposure. Annual irrigated foods dose for an average individual is multiplied by the estimate population of 2,000 individuals to calculate the collective irrigated foods dose.

‡The Cities of Pasco, Kennewick, and Richland—known as the Tri-Cities—are located in southeastern Washington State. Population estimates from <http://quickfacts.census.gov/qfd/index.html>.

Columbia River Recreation. As described in Section 4.2 and Section D.1.1, these recreational activities include fishing, swimming, boating, and shoreline recreation. It was protectively assumed that all 182,000 individuals in the Tri-Cities participated in these recreational activities. Annual recreational dose for an average individual is multiplied by the Tri-Cities population to calculate the collective recreational dose.

Fish Consumption. Population doses from consuming fish obtained locally from the Columbia River were calculated from an estimated total annual catch of 33,000 lbs (15,000 kg) per year. It was protectively assumed that 100 percent of the annual catch was consumed by individuals in the Tri-Cities area. Population dose related to fish consumption was calculated as follows:

$$\text{Population dose (person-rem)} = \text{MEI dose (mrem)} \times 0.001 \text{ rem/mrem} \times (\text{annual catch [kg/yr]}/\text{IR_fish [kg/yr/person]}), \text{ where MEI dose=fish ingestion dose for the MEI; annual catch=15,000 kg fish/yr; IR_fish=individual fish ingestion rate used in the MEI calculation (40 kg/yr/person).}$$

Collective dose related to air-mediated exposure pathways was calculated based on the geographic distribution of the population residing within a 50-mi (80-km) radius of the Hanford Site operating areas, as shown in [PNNL-20631](#). These distributions are based on 2010 Bureau of the Census data and influence the population dose by providing estimates of the number of people exposed to radioactive air emissions and their proximity to the points of release.

The air pathways collective dose calculations are based on modeled radionuclide air concentrations and deposition rates downwind of the Hanford Site operating areas coupled with the geographic population distribution in these areas. Both meteorological and population distribution data are organized according to 16 directional sectors based on the four cardinal, four ordinal, and eight cross-wind directions (N, NNE, NE, ENE, etc.). These sectors were transformed into grids using concentric circles with radii of 1, 2, 3, 4, 5, 10, 20, 30, 40, and 50 mi. These radii correspond to the downwind distances specified in the GENII Chronic Plume Air Module. Population files were created based on the number of individuals located in each of the 160 grid segments centered on the 100, 200, 300, and 400 areas ([PNNL-20631](#)). These files were identified in the GENII Air Dose Report Module.

D.2 Calculation of Biota Doses

The RESRAD-BIOTA computer code was used to screen the 2015 radionuclide concentrations in water, sediment, soil, and tissues to see if they exceeded the established biota concentration guides. Biota concentration guides are concentrations published in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* that could result in a dose rate of 1 rad per day for aquatic biota or 0.1 rad per day for terrestrial organisms. Table D.7 presents water and sediment Tier 1 biota concentration guides for the radionuclides evaluated. Table D.8 presents the soil Tier 1 biota concentration guides for the radionuclides evaluated. Both internal and external doses to aquatic, riparian, and terrestrial animals and plants are included in the screening process. For with multiple media and radionuclides analyses, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to its corresponding biota concentration guide. 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 dose limit (sum of fractions more than 1.0), additional screening calculations are performed (Tiers 2 or 3) to evaluate accurate exposure of biota to radionuclides. The process may culminate in a site-specific assessment requiring additional sampling and study of exposure.

Table D.7. Biota Concentration Guides and Sediment to Water Partition Coefficients

Radionuclide	Water (pCi/L)*	Limiting Organism	Sediment (pCi/g)*	Limiting Organism	Default Kd (mL/g)†
Hydrogen-3	2.65E+08	Riparian animal	3.74E+05	Riparian animal	0.001
Carbon-14	6.09E+02	Riparian animal	5.90E+04	Riparian animal	0.001
Cobalt-60	3.76E+03	Aquatic animal	1.46E+03	Riparian animal	1000
Strontium-90	2.78E+02	Riparian animal	5.82E+02	Riparian animal	30
Technetium-99	6.67E+05	Riparian animal	4.22E+04	Riparian animal	5
Cesium-137	4.26E+01	Riparian animal	3.12E+03	Riparian animal	500
Plutonium-238	1.76E+02	Aquatic animal	5.73E+03	Riparian animal	2000
Plutonium-239/-240	1.87E+02	Aquatic animal	5.86E+03	Riparian animal	2000
Uranium-234	2.02E+02	Aquatic animal	5.27E+03	Riparian animal	50
Uranium-235	2.17E+02	Aquatic animal	3.73E+03	Riparian animal	50
Uranium-238	2.23E+02	Aquatic animal	2.49E+03	Riparian animal	50

*1 pCi=0.037 Bq. Biota concentration guides (pCi/g or pCi/L) from RESRAD-BIOTA v1.5.

†Kd=Water to Sediment Partition Coefficients (mL/g) from RESRAD-BIOTA v1.5.

Table D.8. Tier 1 Soil Biota Concentration Guides

Radionuclide	Soil (pCi/g)*	Limiting Organism
Strontium-90	2.25E+01	Terrestrial animal
Cesium-137	2.08E+01	Terrestrial animal
Plutonium-238	5.27E+03	Terrestrial animal
Plutonium-239/240	6.11E+03	Terrestrial animal
*1 pCi=0.037 Bq. Biota concentration guides (pCi/g) from RESRAD-BIOTA v1.5.		

In the initial (Tier 1) screening assessment, researchers compare maximum measured concentrations to the biota concentration guides. The maximum detected concentrations evaluated for aquatic biota dose assessment are presented in Table D.9. If the sum of fractions does not exceed one, no further analysis is required. However, if the sum of fractions does exceed one, a second analysis (Tier 2) is performed using average concentrations and the same Tier 1 biota concentration guides. For the aquatic biota dose assessment, paired sediment and water data are required. In the event that only one of these media was sampled, the other was calculated using an element-specific water to sediment partition coefficient. These coefficients are tabulated in Table D.7.

The sites for the aquatic biota dose assessment were grouped into upstream (Vernita sediment and river water samples), the 100 Areas (sediments from 100-K, 100-D, 100-F and White Bluff; river water from 100-K and 100-N; and seeps from 100-BC, 100-K, 100-N, 100-D, 100-H, 100-F), the Hanford Town Site (sediments from Hanford slough, Savage Island, and Locke Island; river water; and seep water from Hanford Spring); 300 Area (river water and springs), and downstream (sediments from McNary Dam and river water from the Richland Pump house).

Table D.9. Maximum Detected Concentrations Evaluated for Aquatic Biota Dose Assessment

Location Group	Radionuclide	Maximum Sediment (pCi/g)*	Maximum Water (pCi/L)*
Upstream	Hydrogen-3	—†	19
	Cesium-137	0.246	—
	Plutonium-239/-240	0.01	—
	Uranium-234	1.34	0.28
	Uranium-235	0.0996	0.0578
	Uranium-238	1.09	0.204
100 Areas	Hydrogen-3	—	5840
	Carbon-14	—	341
	Cobalt-60	0.0617	—
	Strontium-90	0.03‡	16.6
	Technetium-99	—	1.95
	Cesium-137	0.294	—
	Plutonium-239/-240	0.00376	—
	Uranium-234	1.09	0.297
	Uranium-235	0.115	0.0261
Hanford Townsite	Uranium-238	0.936	0.255
	Hydrogen-3	—	5750
	Cesium-137	0.269	—
	Plutonium-238	0.000549	—
	Plutonium-239/-240	0.00249	—
	Uranium-234	1.47	0.24
	Uranium-235	0.0923	0.0247
300 Area	Uranium-238	1.23	0.193
	Hydrogen-3	—	4350
	Uranium-234	—	30
	Uranium-235	—	2.75
Downstream	Uranium-238	—	29.7
	Hydrogen-3	—	24.9
	Technetium-99	—	0.621
	Cesium-137	0.259	—
	Plutonium-239/-240	0.00922	—
	Uranium-234	1.38	0.287
	Uranium-235	0.0954	0.033
	Uranium-238	1.32	0.24

*1 pCi=0.037 Bq

†Not detected or not measured.

‡Although strontium-90 was not detected in sediment, the maximum non-detect was substantially less than the estimated concentration based on Kd.

Radionuclides were selected for the aquatic biota dose assessment based primarily on their detection in sediment or water and graphical comparisons of on-site to upstream and downstream sample results (Figures D.1 to D.29). In addition, having known or suspected sources from DOE operations, the results for tissue samples compared to reference (i.e. upstream, generally at Vernita Bridge), and the known potential for bioaccumulation was also used to identify which radionuclides should be included in the dose assessment. Most of the detected radionuclides in water – hydrogen-3 (tritium), carbon-14, strontium-90, technetium-99, and isotopic uranium – could readily be associated with known groundwater plumes. Most of the remainder of the detected radionuclides could have sources from DOE operations but due to

relatively high soil-water partition coefficients (K_d) would most likely be associated with sediments instead of water. Cobalt-60, cesium-137, and isotopic plutonium were detected in sediments and may have sources from DOE operations. Although the magnitude of the sediment concentrations on site is sometime no greater than upstream, these radionuclides are included in the aquatic biota dose assessment. This is likely protective, as these radionuclides are not elevated above reference in tissues. Potassium-40 shows increased concentrations in sediment on site compared to both upstream and downstream levels. There were no differences in water or tissues potassium-40 concentrations between on-site and reference locations. There are also no groundwater plumes or other known DOE sources of potassium-40; therefore, potassium-40 was not included in the aquatic biota dose assessment.

As discussed in Section 4.2.6, biota doses were evaluated for Columbia River water and sediment and West Lake water and sediment, and soils (on site and off site). For West Lake, Tier 1 sum of fractions exceeded 1.0; therefore, Tiers 2 and 3 calculations were implemented using the mean water concentrations presented in Table D.10. The tiered screening process is further described in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* ([DOE-STD-1153-2002](#)).

Table D.10. West Lake 2015 Water Samples

Radionuclide	Water Concentration (pCi/L)		Sediment Concentration (pCi/g)	
	Maximum	Average	Maximum	Average
Cesium-137	—	—	0.335	0.317
Uranium-234	1650	393	4.14	4.12
Uranium-235	87.1	22.1	0.287	0.264
Uranium-238	1570	366	4.15	3.86
— Not detected or not measured. pCi=0.037 Bq.				

The Tier 1 and Tier 2 West Lake biota dose assessments were driven by the potential for dose from uranium isotopes in water and the assumed potential for these isotopes to accumulate in biota. Therefore, the Tier 3 West Lake biota dose calculations utilized site-specific information on bioaccumulation. As defined in [DOE-STD-1153-2002](#), bioaccumulation is the ratio of the contaminant concentration in the organism relative to the contaminant concentration in an environmental medium resulting from the uptake of the contaminant from one or more routes of exposure. The more relevant biota data collected from West Lake are the brine flies sampled in 2000 and 2007 ([PNNL-13487](#); [DOE/RL-2007-50](#)). Birds (avocets) were also sampled in 2000 and had lower concentrations than the brine flies ([PNNL-13487](#)). These birds are not year-round residents and thus have lower exposure and less potential for bioaccumulation at West Lake ([DOE/RL-2007-50](#), Appendix K).

The maximum concentration of any of the uranium isotopes in brine flies was 0.88 pCi/g for uranium-233/-234 in 2007. The minimum uranium-233/234 West Lake pond water concentration was 940 pCi/L in 2007. The bioaccumulation factor is calculated by dividing the biota concentration (in pCi/g) by the water concentration (in pCi/mL), because RESRAD-BIOTA assumes that aquatic bioaccumulation occurs from water to biota. Therefore, the maximum bioaccumulation factor for uranium would be less than one (0.88 divided by 0.94). Also, as presented in Table D.10 of the 2011 report ([DOE/RL-2011-119](#), *Hanford Site Environmental Report for Calendar Year 2011*), bioaccumulation factors for uranium isotopes based on the mean concentrations in flies and water were between 0.2 and 0.5. A bioaccumulation factor of one was used for the West Lake Tier 3 biota dose calculation as a somewhat protective measure of site-specific

uranium uptake into the food chain. This same approach was used in the 2011 ([DOE/RL-2011-119](#)) and 2012 ([DOE/RL-2013-18](#), *Hanford Site Environmental Report for Calendar Year 2012*) reports. The data supporting the site-specific bioaccumulation factor are presented in those reports. Table D.11 presents the Tier 3 biota concentration guides for isotopic uranium for both aquatic and riparian animals. These site-specific values were used in the RESRAD-BIOTA Tier 3 screening discussed in Section 4.2.6.

Table D.11. Tier 3 Biota Concentration Guides Calculated using RESRAD-BIOTA v1.5

Radionuclide	Water BCG (pCi/L)*		Sediment BCG (pCi/g)*	
	Aquatic Animal	Riparian Animal	Aquatic Animal	Riparian Animal
Uranium-234	202000	20200	3030000	5270
Uranium-235	217000	21700	110000	3790
Uranium-238	222000	22200	42900	2490

*1 pCi=0.037 Bq

Dose to terrestrial biota were evaluated using the near-field and far-field soil sample results. Table D.12 lists the maximum concentrations of strontium-90, cesium-137, plutonium-238, and plutonium-239/-240. These radionuclides were selected for the terrestrial biota dose assessment based on their detection in soil and graphical/statistical comparisons of soil/vegetation near-field to far-field sample results (Figures D.30 to D.40). In addition, having known or suspected sources from DOE operations, vegetation sample compared to soil results and the known potential for bioaccumulation were used to include or exclude radionuclides for the biota dose assessment.

Table D.12. Maximum Detected Concentrations Evaluated for Terrestrial Biota Dose Assessment

Location Group	Radionuclide	Maximum Soil (pCi/g)*
Near Field	Strontium-90	0.44
	Cesium-137	0.0016
	Plutonium-238	0.023
	Plutonium-239/240	0.053
Far Field	Strontium-90	14
	Cesium-137	0.14
	Plutonium-238	0.85
	Plutonium-239/240	1

*1 pCi=0.037 Bq

A summary of the basis for selection of radionuclides is provided in the following:

- Strontium-90 and cesium-137 soil and vegetation concentrations in near-field samples were statistically greater compared to far-field samples.
- Isotopic plutonium soil concentrations in near-field samples were statistically greater than far-field samples.
- Near-field potassium-40 soil and vegetation concentrations were not different from far-field concentrations. There are also no known DOE sources of potassium-40; therefore, potassium-40 was not included in the terrestrial biota dose assessment.

- There were no statistical differences of antimony-125, cesium-134, europium-155, and isotopic uranium near-field concentrations compared to far-field concentrations; therefore, these radionuclides were not included in the terrestrial biota dose assessment.

The biota dose assessment also included supplemental calculations using measured concentrations in tissues. Presented in Section 4.2.6, these supplemental calculations provide a more realistic estimate of biota dose compared to doses calculated using the protective bioaccumulation assumptions made in the Tier 1 dose assessments. Section 4.2.6 lists the detected tissue concentrations evaluated in these supplemental dose calculations. The tissue concentrations are used for the internal dose calculations, whereas external dose is estimated from the relevant soil, sediment, and water concentrations. Where available, mean concentrations rather than maxima were used in the supplemental external dose calculations to be consistent with DOE guidance for these Tier 3 dose calculations. Note that radionuclides were detected in mule deer bone and mulberry fruit and leaf tissues. However, the detection in bone was only from a reference site, and the detections in mulberry were similar on-site and reference locations. Detections of radionuclides in mule deer and mulberry were therefore not included in the supplemental dose calculations.

Appendix D: Dose Calculations

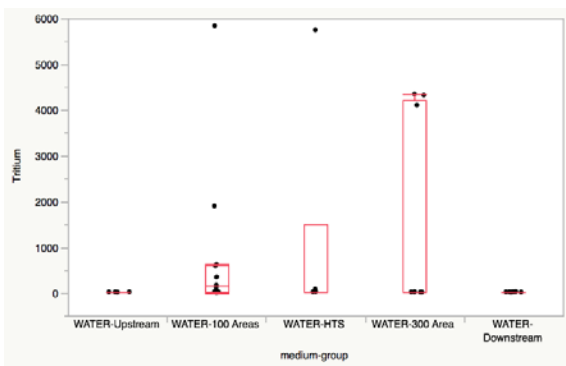


Figure D.1. Hydrogen-3 (tritium) concentrations in water

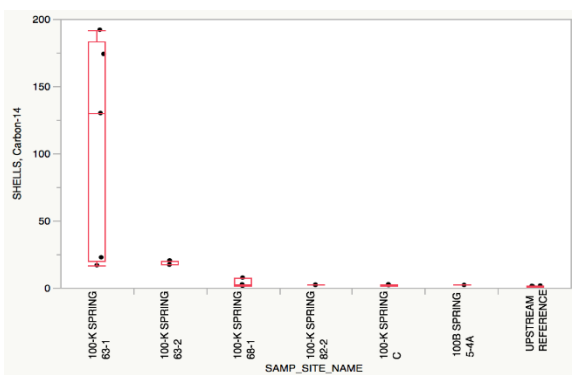


Figure D.2. Carbon-14 concentrations in clam shells

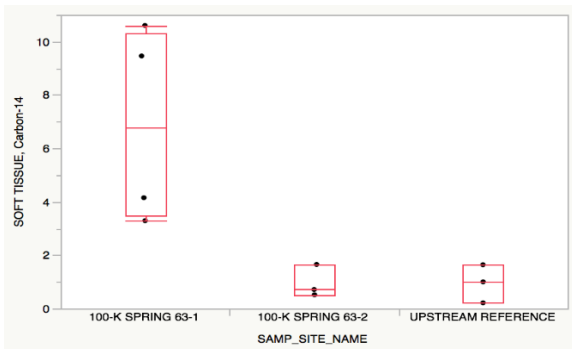


Figure D.3. Carbon-14 concentrations in clam shells

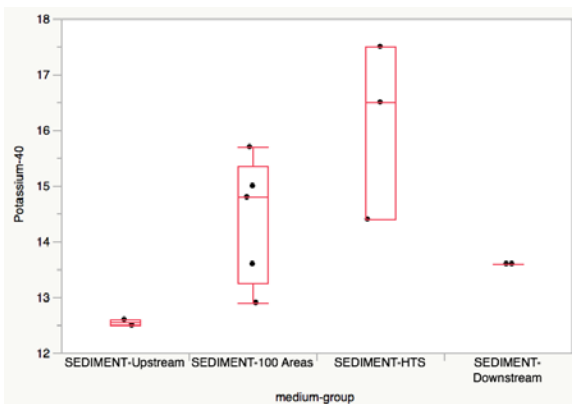


Figure D.4. Potassium-40 concentrations in sediment

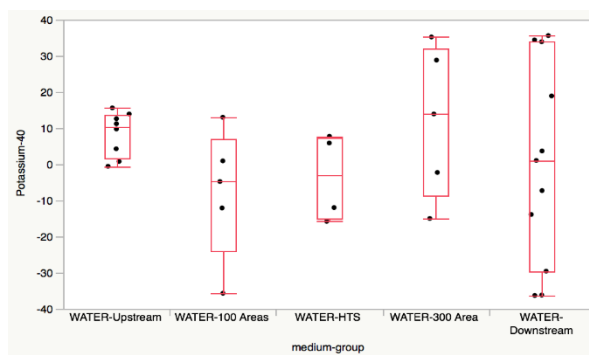


Figure D.5. Potassium-40 concentrations in water

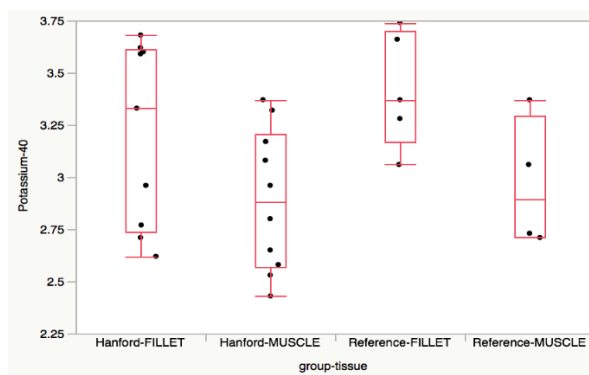


Figure D.6. Potassium-40 concentrations in tissues

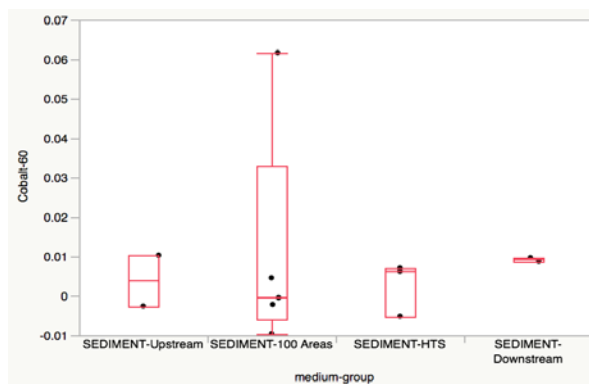


Figure D.7. Cobalt-60 concentrations in sediment

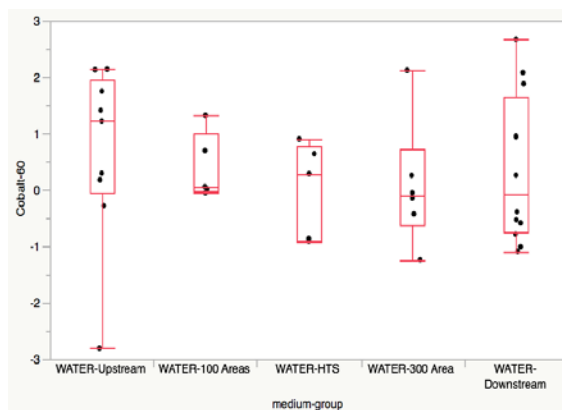


Figure D.8. Cobalt-60 concentrations in water

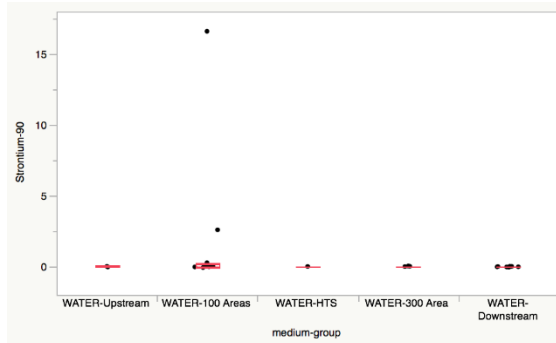


Figure D.9. Strontium-90 concentrations in water

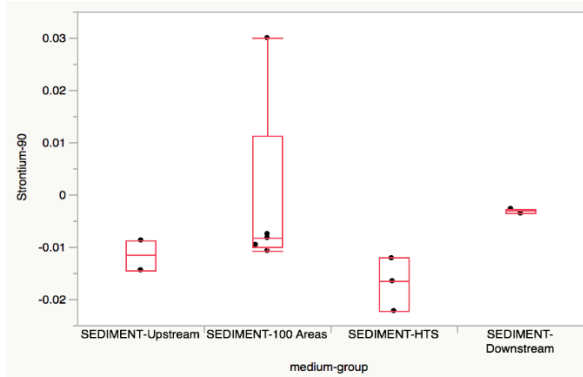


Figure D.10. Strontium-90 concentrations in sediment

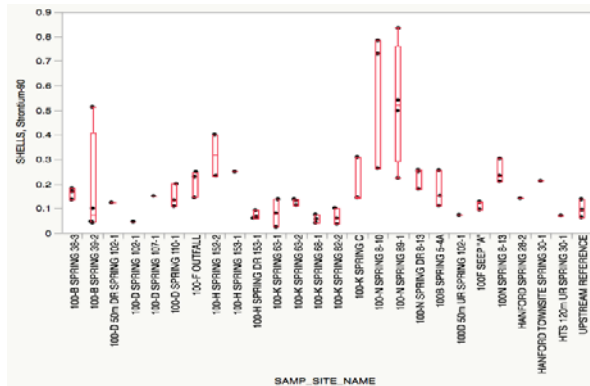


Figure D.11. Strontium-90 concentrations in clam shell

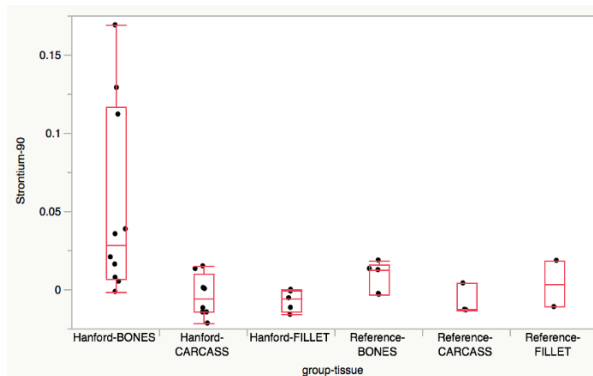


Figure D.12. Strontium-90 concentrations in tissues

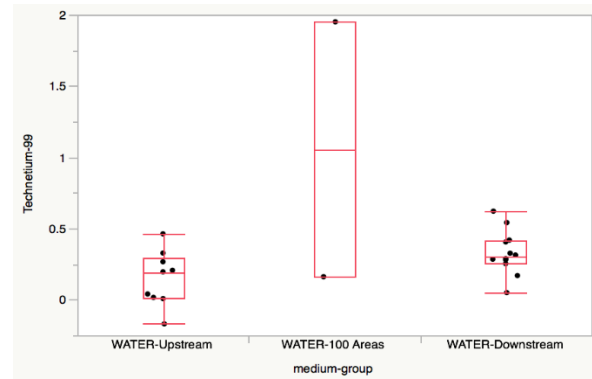


Figure D.13. Technetium-99 concentrations in water

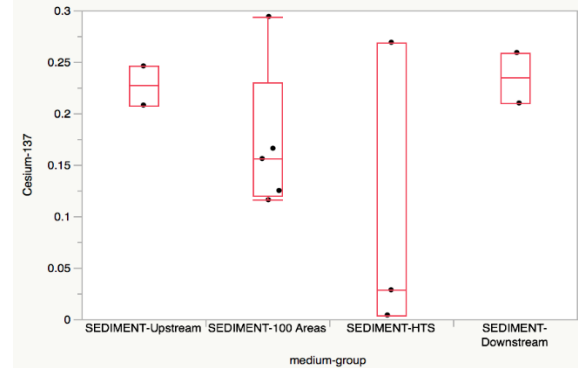


Figure D.14. Cesium-137 concentrations in sediment

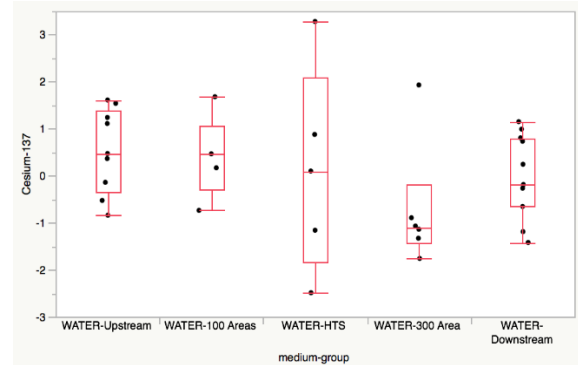


Figure D.15. Cesium-137 concentrations in water

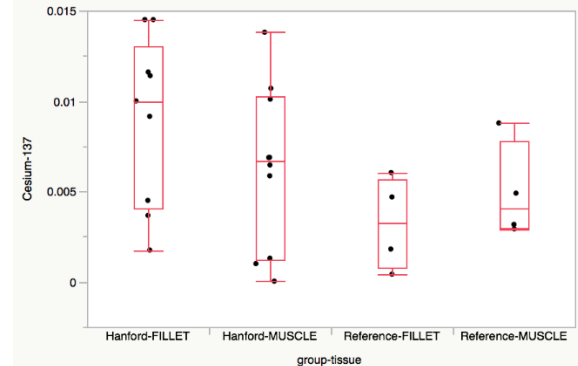


Figure D.16. Cesium-137 concentrations in tissues

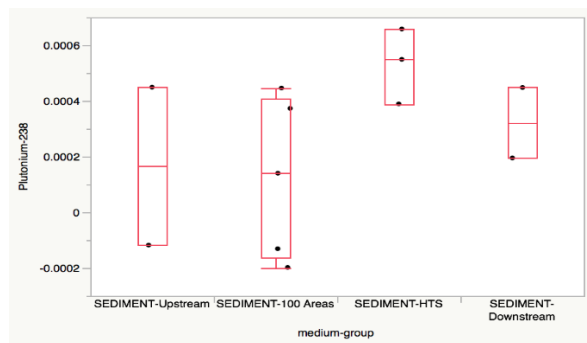


Figure D.17. Plutonium-238 concentrations in sediment

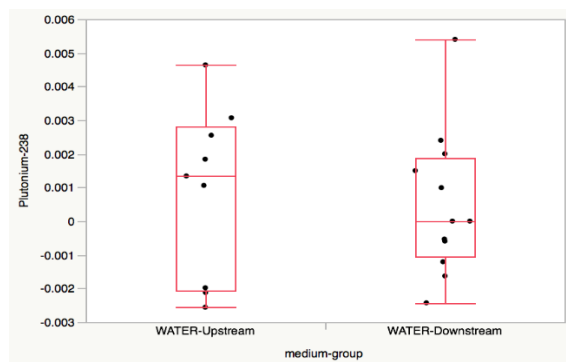


Figure D.18. Plutonium-238 concentrations in water

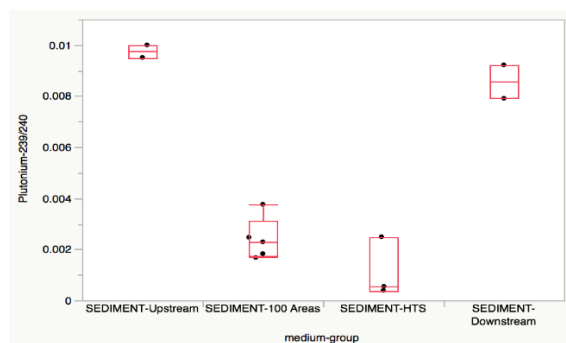


Figure D.19. Plutonium-239/240 concentrations in sediment

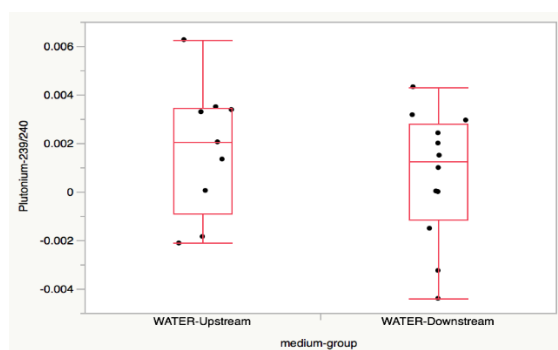


Figure D.20. Plutonium-239/240 concentrations in water

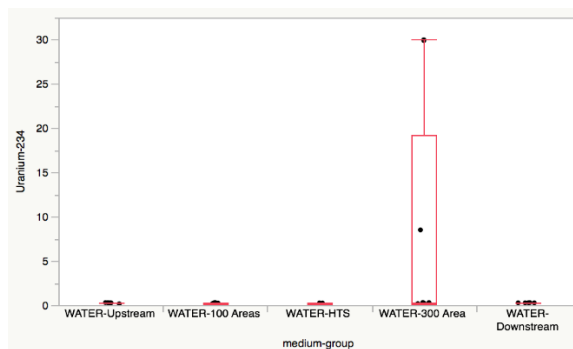


Figure D.21. Uranium-234 concentrations in water

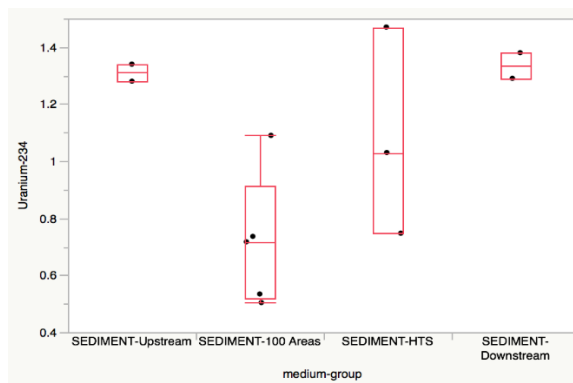


Figure D.22. Uranium-234 concentrations in sediment

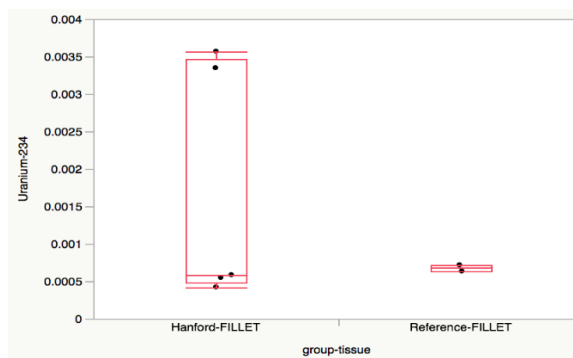


Figure D.23. Uranium-234 concentrations in tissues

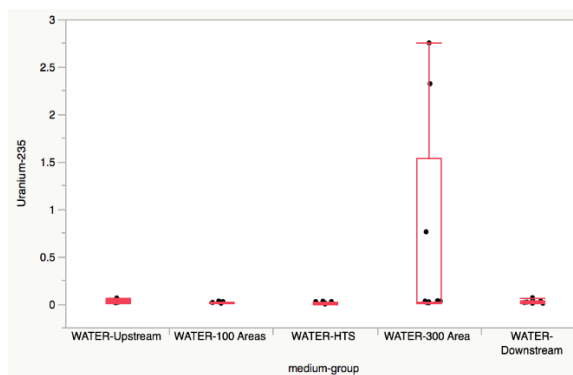


Figure D.24. Uranium-235 concentrations in water

Appendix D: Dose Calculations

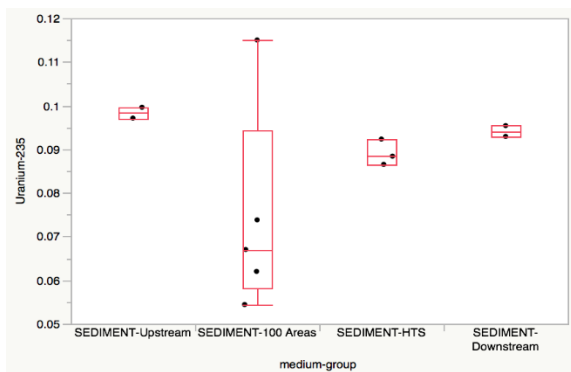


Figure D.25. Uranium-235 concentrations in sediment

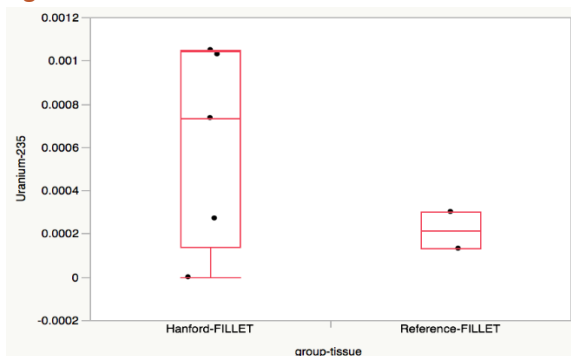


Figure D.26. Uranium-235 concentrations in tissues

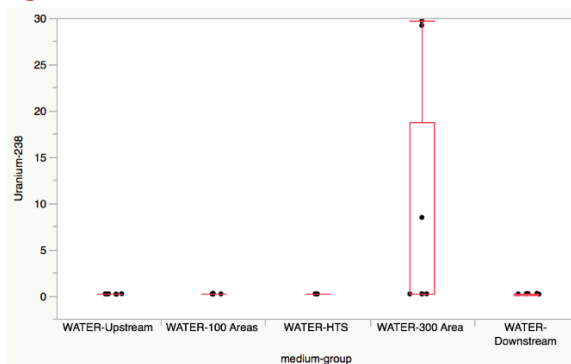


Figure D.27. Uranium-238 concentrations in water

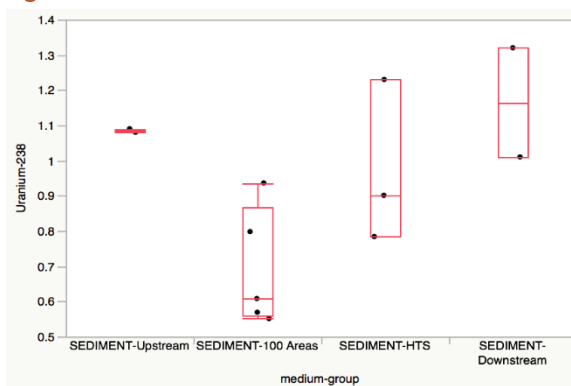


Figure D.28. Uranium-238 concentrations in sediment

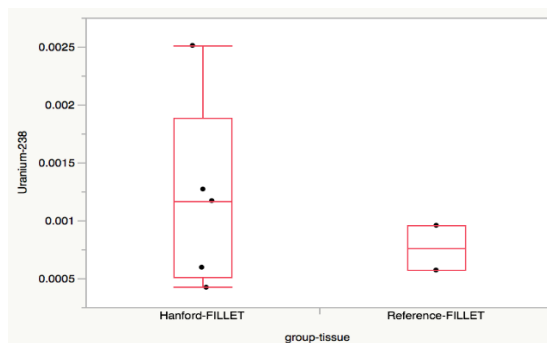


Figure D.29. Uranium-238 concentrations in tissues

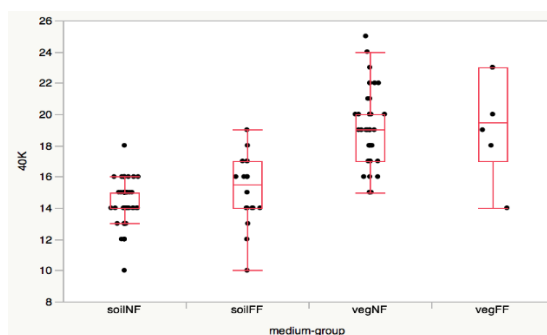


Figure D.30. Potassium-40 concentrations in soil and vegetation (veg) for near facility (NF) and far field (FF) samples

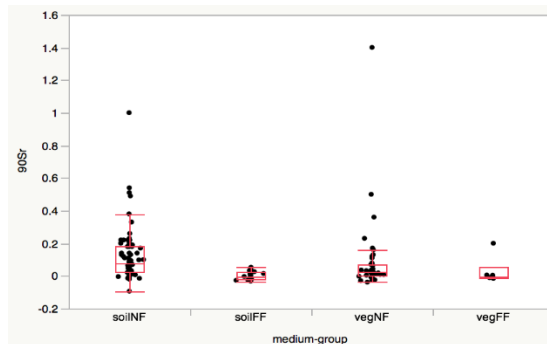


Figure D.31. Strontium-90 concentrations in soil and veg for NF and FF samples

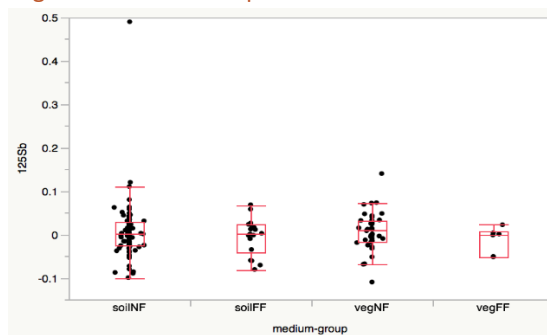


Figure D.32. Antimony-125 concentrations in soil and veg for NF and FF samples

Appendix D: Dose Calculations

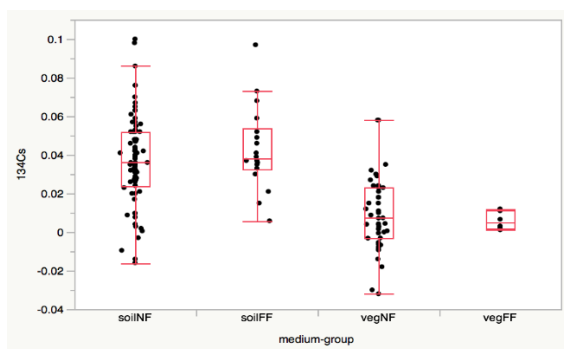


Figure D.33. Cesium-134 concentrations in soil and veg for NF and FF samples

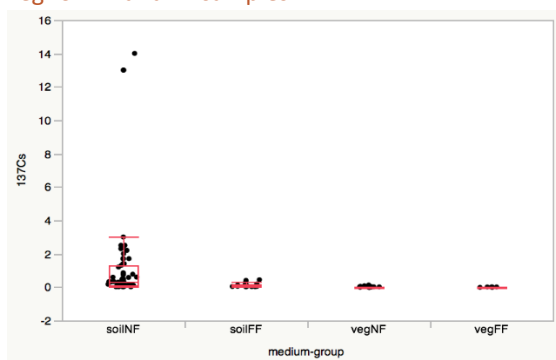


Figure D.34. Cesium-137 concentrations in soil and veg for NF and FF samples

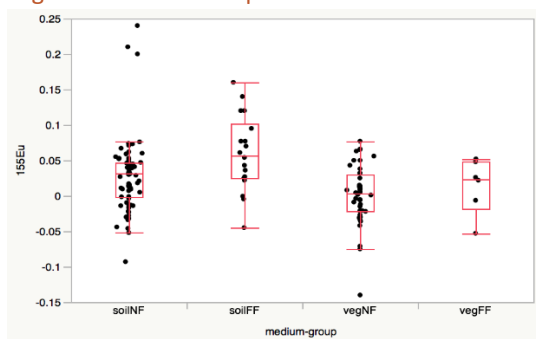


Figure D.35. Europium-155 concentrations in soil and veg for NF and FF samples

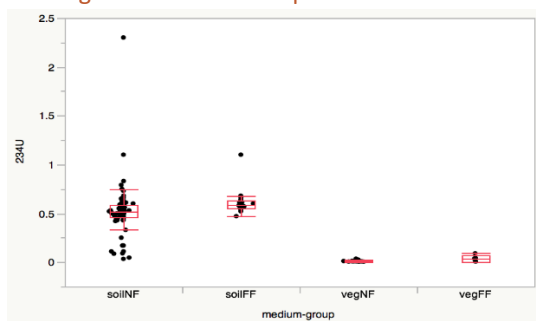


Figure D.36. Uranium-234 concentrations in soil and veg for NF and FF samples

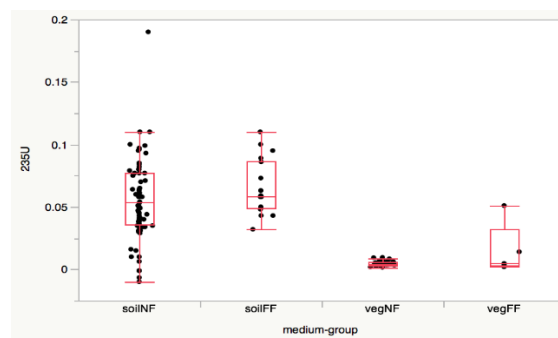


Figure D.37. Uranium-235 concentrations in soil and veg for NF and FF samples

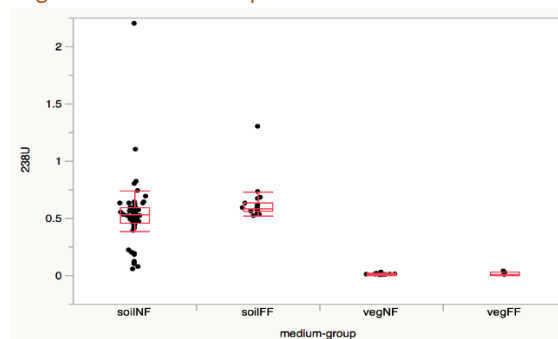


Figure D.38. Uranium-238 concentrations in soil and veg for NF and FF samples

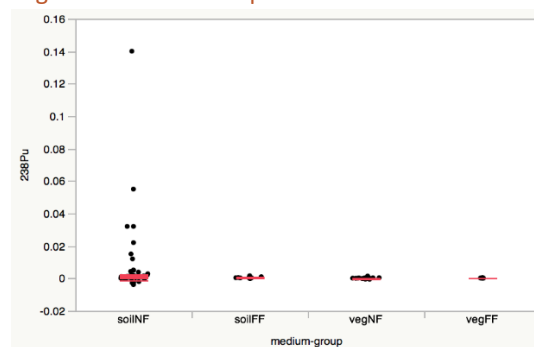


Figure D.39. Plutonium-238 concentrations in soil and veg for NF and FF samples

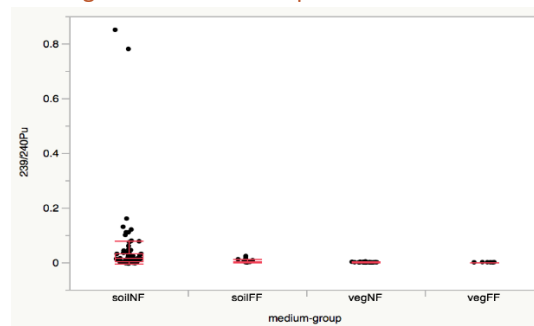


Figure D.40. Plutonium-238/240 concentrations in soil and veg for NF and FF sample