

Hanford Annual Site Environmental Report for Calendar Year 2017



Prepared for the
U.S. Department of
Energy, Richland
Operations Office



DOE/RL-2018-32, Rev. 0

A low-level stratus cloud blankets Rattlesnake Mountain; this is the start of the fall/winter rainfall season on the Hanford Site. The gray rabbitbrush (*Ericameria nauseosa*) and needle-and-thread grass (*Hesperostipa comata*) in the foreground are native species commonly seen growing on sandy soils in local shrub-steppe communities.



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September 2018

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



Richland Operations
Office

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EXECUTIVE SUMMARY

Since 1959, the U.S. Department of Energy (DOE) has annually published the Hanford Site Environmental Report in accordance with [DOE 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 Annual Site Environmental Report for Calendar Year 2017* is to inform the public, regulators, employees, and other stakeholders of environmental and operating performance during the year.

Hanford Site operations are affected and, in many cases, regulated by numerous federal and state agencies enforcing legal requirements that address environmental compliance, remediation, planning, preservation, and waste management. For example, the DOE has sole authority to take action on matters under the [Atomic Energy Act](#). In some cases, other federal agencies such as the Council on Environmental Quality, U.S. Environmental Protection Agency (EPA), and U. S. Fish and Wildlife Service have authority to regulate activities pursuant to the *National Environmental Policy Act*; [Comprehensive Environmental Response, Compensation, and Liability Act](#) (CERCLA); *Endangered Species Act*; and [Migratory Bird Treaty Act](#). The EPA has delegated authority to the State of Washington Departments of Ecology and Health to regulate activities in accordance with the [Resource Conservation and Recovery Act](#) (RCRA), [Clean Air Act](#), and [Clean Water Act](#). In still other cases, state laws for licensing and permitting apply to activities and have resulted in the Hanford Site Radioactive Air Emissions License, RCRA Permit, Air Operating Permit, and State Waste Discharge Permits.

In general, the laws, regulations, and other requirements applicable to Hanford Site operations include, but may not be limited to, those that address environmental quality; air quality and noise; water resources; hazardous waste and materials management; radioactive waste and materials management; ecological resources; cultural and paleontological resources; worker safety and health; radiological safety and radiation protection; transportation; emergency planning, pollution prevention, and conservation; and environmental justice. It is DOE's policy to carry out its mission in a sustainable manner to maximize energy and water efficiency; minimize chemical toxicity and harmful environmental releases; promote renewable and other clean energy development; and conserve natural, cultural, and ecological resources while sustaining assigned mission activities.

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.

ES.1 Section 1, Introduction

The DOE is responsible for the Hanford Site, one of the largest nuclear cleanup efforts in the world, managing the legacy of five decades of nuclear weapons production. Located in south-central Washington State within the semi-arid Pasco Basin of the Columbia Plateau, the Hanford Site encompasses approximately 581 mi² (1,505 km²) in Benton, Franklin, Adams, and Grant Counties (Figure ES-1). The Hanford Site was established in 1943 to produce plutonium for atomic weapons during World War II and the Cold War. The site has restricted public access and provides a buffer area around facilities formerly used for nuclear materials production, waste storage, and waste disposal.

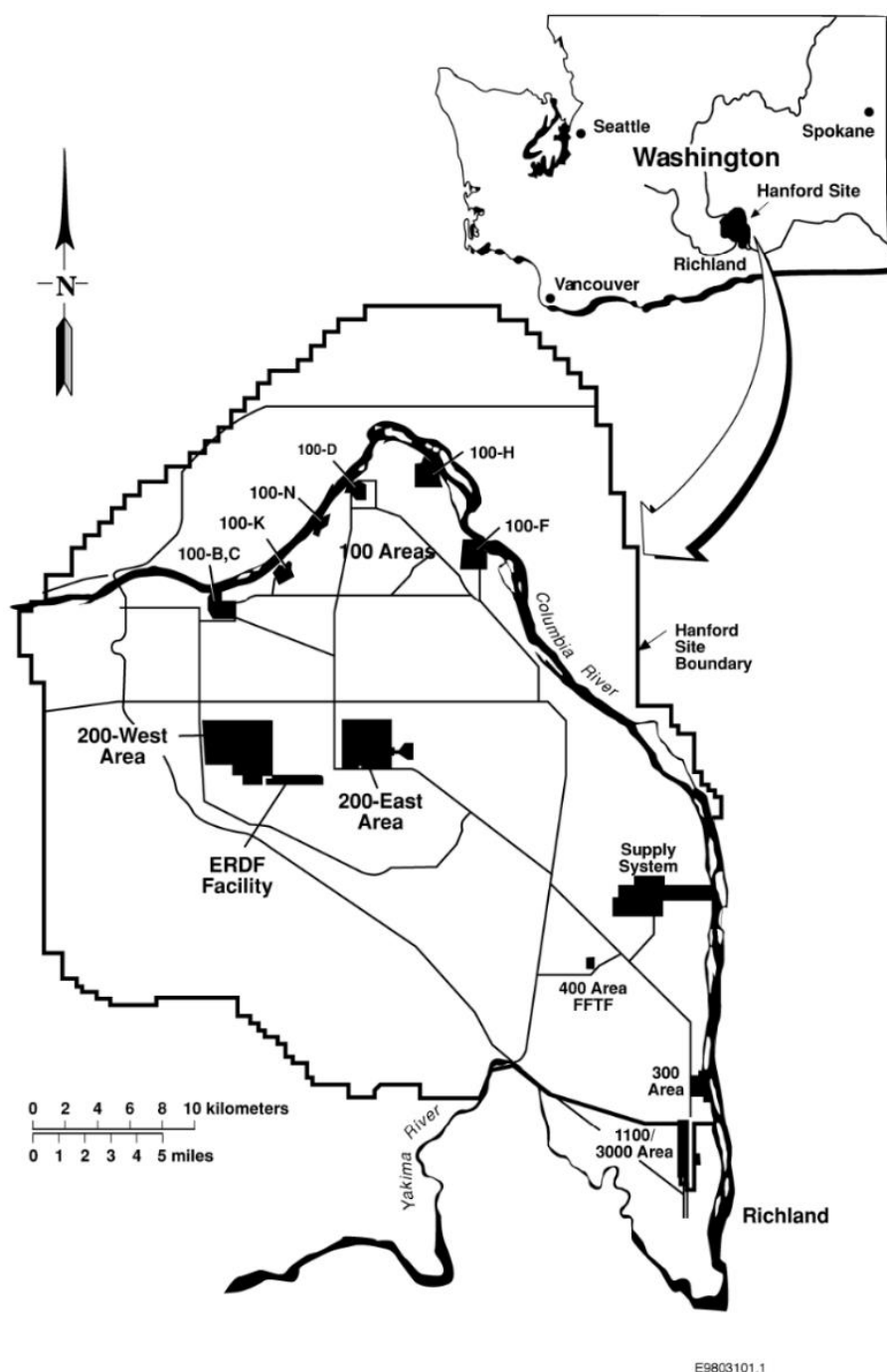


Figure ES-1. Location of the Hanford Site.

With the signing of the [*Hanford Federal Facility Agreement and Consent Order*](#) (Tri-Party Agreement [TPA]) in 1989 (Ecology et al. 1989) by the Washington State Department of Ecology (Ecology), EPA, and DOE (collectively, TPA agencies), the primary mission of the Hanford Site shifted from production to cleanup. 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 (i.e., waste storage, treatment, and disposal), and related scientific and environmental research and development of waste management technologies.

Cleanup of the Hanford Site is overseen by the U.S. Department of Energy, Richland Operations Office (DOE-RL) and Office of River Protection (DOE-ORP). The DOE-RL and the DOE-ORP manage the site through several contractors and their subcontractors. The DOE-RL 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 DOE-ORP was established by Congress in 1998 as a field office to manage the retrieval, treatment, and disposal of approximately 54.1 million gal (204.8 million 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 World War II and post-war production of nuclear weapons fuel. In support of this mission, DOE-ORP is responsible for the safe operation of the tank farms and associated 200 Area facilities and construction and operation of the Hanford Tank Waste Treatment Plant and Immobilization Plant (WTP) located in the Central Plateau.

The DOE, U.S. Fish and Wildlife Service, and Washington State Department of Fish and Wildlife each manage portions of the Hanford Reach National Monument. In 2000, President Clinton created the [Hanford Reach National Monument](#) (65 FR 37253). Over 300 mi² (777 km²) of riparian habitat and buffer lands surrounding active central Hanford lands were designated for management by the U.S. Fish and Wildlife Service.

The Manhattan Project National Historical Park, created in November 2015, is a partnership between DOE and the National Park Service. DOE continues to own, preserve, and provide public access to the five National Park facilities and areas at Hanford while the National Park Service is responsible for interpretation of the Manhattan Project story, as well as visitor services.

The DOE, Office of Science's Pacific Northwest Site Office manages science and technology facilities, programs, goals, and objectives at the Hanford Site. Its principal laboratory is the Pacific Northwest National Laboratory (PNNL), operated by Battelle Memorial Institute for DOE since 1965.

ES.2 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 laws and regulations, as well as 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 with applicable environmental regulations at the Hanford Site, including the EPA, Ecology, Washington State Department of Health (WDOH), City of Richland, and the Benton Clean Air Agency. The EPA and Ecology are the two main agencies who regulate Hanford Site cleanup as part of the TPA. In addition, the Defense Nuclear Facilities Safety Board (DNFSB) provides oversight of DOE work. Congress created the DNFSB as an independent agency within the Executive Branch to identify the nature and consequences of potential threats to public health and safety at DOE's defense nuclear facilities, to elevate such issues to the highest levels of authority, and to inform the public. During 2016, the DNFSB oversaw projects pertaining to each contractor at the Hanford Site. In addition, the TPA commits DOE to

comply with the remedial-action provisions of the CERCLA and the RCRA treatment, storage, and disposal (TSD) unit regulations and corrective-action provisions.

Tri-Party Agreement

From 1989 through December 31, 2017, a total of 1,314 TPA milestones were completed and 339 target dates were met. During 2017, 34 specific cleanup milestones were scheduled for completion; of those, 10 milestones were deleted, 22 milestones were completed on time, 1 milestone was missed, and 0 were in negotiation. In addition, one target date was met, zero target dates were deleted, and zero target dates were in negotiation.

Federal Facility Compliance Act

DOE provides mixed waste information annually as part of the Hanford Site Mixed Waste Land Disposal Restrictions Summary Reports pursuant to TPA Milestone M-026-01.

Regulatory Inspections

During calendar year (CY) 2017, 79 regulatory agency inspections were conducted at DOE facilities on the Hanford Site: Ecology conducted 45, WDOH 31, EPA (Region 10) 1, and the City of Richland 2. There were five RCRA Permit General Inspections of the 100, 200, 300, and 400 Areas, as well as the banks of the Columbia River by boat. These inspections were conducted by Hanford Site contractors with DOE oversight. Some of the agency inspections were conducted jointly between multiple agencies.

RCRA

The Ecology and EPA inspections focused on TSD unit compliance with the [Hanford Facility Dangerous Waste Permit](#) (Ecology 2012) and [WAC 173-303, "Dangerous Waste Regulations."](#) Generator activities, waste accumulation, and universal waste management areas were also inspected. During 2017, permit modifications were processed to change requirements for TSD units pursuant to WAC [173-303-830](#), "Permit Changes."

CERCLA

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. During CY 2017, [DOE/RL-2016-01, Hanford Site Fourth CERCLA Five-Year Review Report](#), addressing 2011 through 2015, was completed and received concurrence from EPA (2017).

Hanford Site Air Emission Sources

In 2017, the WDOH inspections focused on compliance of point and non-point emission units with the *Hanford Site Radioactive Air Emissions License #FF-01* (FF-01). Ecology inspections included discharge points (e.g., package boilers, emergency engines/generators, and tank farm ventilation systems) regulated under the Hanford Site Air Operating Permit. During 2017, regulatory agencies conducted 41 *Clean Air Act* inspections on the Hanford Site. There were no compliance actions involving airborne radioactive materials.

Environmental Occurrences

Per [DOE M 231.1-2, Occurrence Reporting and Processing of Operations Information](#), 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). On October 1, 2017, new Occurrence Reporting Criteria were established and implemented based on DOE O 232.2A, *Occurrence Reporting and Processing of Operations Information* and associated Supplemented Contract Requirements Document. In 2017, there were 31 documented occurrences of legacy contamination.

Emergency Planning and Community Right to Know Act

DOE/RL-2018-07, *2017 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory*, 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 50 hazardous chemicals that exceeded the reporting thresholds.

Pollution Prevention Program

The Hanford Site maintains a pollution prevention and waste minimization program that contributes to the achievement of sustainability goals. In 2017 1,358 metric tons of non-hazardous (i.e., plastic, aluminum, cardboard, paper, wood, and metal) and hazardous (i.e., antifreeze, batteries, bulbs, and oils) wastes were recycled through Hanford Site programs administered through the Mission Support Contract. Greenhouse gas emissions from employee commuting, business travel, offsite wastewater treatment, and contracted solid waste disposal are primarily dependent on work locations and the number of workers employed at the Hanford Site. There was a 23% reduction in Scope 1 and Scope 2 greenhouse gas emissions for the Hanford Site in fiscal year (FY) 2017. Reported greenhouse gas emissions for FY 2017 were 79,342 metric tons of carbon dioxide equivalent compared with 102,645 metric tons carbon dioxide equivalent from the FY 2008 baseline. There was a 31.2% reduction in Scope 3 greenhouse gas emissions for the Hanford Site in FY 2017 from the FY 2008 baseline; emissions in FY 2017 were 28,513 metric tons carbon dioxide equivalent, whereas emissions in FY 2008 were 41,426 metric tons carbon dioxide equivalent.

ES.3 Section 3, Environmental Management System

Environmental management performance measures objectives for 2017 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. The acquisition target for alternative fuel vehicles was not met in 2017. The alternative fuel use target was surpassed for FY 2017; however, the target for petroleum-based fuel use was missed. The target objectives for potable and non-potable water, renewable electric energy, facility fuel, facility energy, regulated waste reduction, sanitary waste reduction, and Electronic Product Environmental Assessment Tool acquisitions were met in FY 2017.

ES.4 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 2017 monitoring efforts are provided below.

External Radiation Monitoring

External radiation fields were monitored in 2017 at 125 environmental dosimeter (thermoluminescent dosimeter) locations near Hanford Site facilities and operations. Quarterly monitoring results were used individually or averaged to determine dose rates in a given area for a specific sampling period. The average dose rate levels measured in the operational areas during 2017 were comparable to the previous years' levels.

Radiological Clearance of Hanford Site Property

No property with anthropogenic (man-made) residual radioactivity above authorized limits was released from the Hanford Site in 2017.

Personal Property. More than 30,000 individual items of personal property were surveyed and verified to be free of residual radioactivity during 2017, allowing them to be released from the Hanford Site for unrestricted use by members of the public. Personal property consists mainly of materials and equipment; formal surveys are conducted on items such as power poles, transformers, miscellaneous electrical equipment, air conditioning units, industrial vehicles, excavation equipment, man lifts, and scaffolding. Verification surveys are also performed on common items such as electronics, pallets, batteries, office items, respiratory protection equipment, compressed gas cylinders, vehicles, tools, and physical security items. Some types of debris may be cleared to go to sanitary waste disposal sites. Scrap metal that has been confirmed to not have been in radiological areas can be verified as free of residual radioactivity and cleared for release from the Hanford Site.

Real Property. No real property (i.e., land and buildings) was cleared during 2017.

Granular Activated Carbon for Offsite Shipment and Regeneration. Approximately 100,100 lb (45,400 kg) of granular-activated carbon was shipped offsite in 2017 for regeneration.

Potential Radiological Doses to the Public and Biota

In 2017, scientists evaluated potential radiological dose to the public and biota resulting from modeled exposure to Hanford Site liquid effluents and airborne emissions to determine compliance with pertinent regulations and limits. The sources of radionuclide releases considered in the dose assessment included gaseous emissions from stacks and ventilation exhausts and contaminated groundwater seeping into the Columbia River. Potential doses were also evaluated based on measured concentrations of radionuclides in samples of Hanford Site drinking water, regional crops from near-by land, and fish from the Columbia River. Potential radiological doses from 2017 Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. The following radiological doses were assessed:

- Dose to a hypothetical maximally exposed individual (MEI) at an offsite location
- Collective dose to the population residing within 50 mi (80 km) of Hanford Site operation areas
- Dose from recreational activities (e.g., hunting and fishing)
- Dose to a worker consuming drinking water on the Hanford Site
- Dose to a visitor to the Manhattan Project National Historical Park
- Dose 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 onsite surface water bodies.

Additionally, air-pathway doses from stack and fugitive emissions to offsite and non-DOE Hanford Site employees 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,”](#) were summarized.

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 offsite individual would have received a higher Hanford-related dose. The dose to the MEI calculated in 2017 from Hanford Site operations was 0.22 mrem (2.2 μ Sv), which is 0.22% of the 100 mrem (1,000 μ Sv) annual public dose limit specified in DOE O 458.1. Many different exposure pathways are included in the dose calculations but inhalation and external exposure to radon isotopes and their radioactive progeny from 300 Area air emissions was the largest contributor. Collective dose was estimated for the entire population living within a 50-mi (80-km) radius of the air emissions sources and also individuals obtaining drinking water from the Columbia River downstream of the Hanford Site. A collective dose of 1.2 person-rem (0.012 person-Sv) was calculated as the sum of doses to all individual members of the exposed population.

Doses to a hypothetical individual were also calculated using measured concentrations of radionuclides in fish tissue and onsite drinking water. For recreational activities, a fish ingestion annual dose of up to 0.15 mrem (1.5 μ Sv) was estimated based on tissue samples of walleye and whitefish collected from the Hanford Reach of the Columbia River. An annual dose of up to 0.11 mrem (1.1 μ Sv) was calculated for ingestion of Hanford Site drinking water based on samples from the 400 Area, where water is supplied by groundwater wells. Lastly, annual doses were calculated for workers and visitors at the Hanford Townsite and White Bluffs Bank locations of the Manhattan Project National Historical Park (up to 0.00017 mrem (0.0017 μ Sv). Like the offsite MEI dose, these doses were far below the public dose limit.

To place this information into perspective, these doses were compared with those received by the U.S. population from other routinely encountered sources of radiation. The 2009 National Council on Radiation Protection and Measurements report *Ionizing Radiation Exposure of the Population of the United States* (NCRP 2009) estimated that the overall annual exposure to ionizing radiation for the average American is 620 mrem (6,200 μ Sv), approximately half of which is related to natural sources and the other half attributable primarily to medical procedures.

ES.5 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 2017 cleanup and remediation activities at the Hanford Site.

River Corridor

The River Corridor includes the Hanford Site 100, 300, and 400 Areas that border the Columbia River. Through 2017, 100 and 300 Area transitions to MSA Long-Term Stewardship are complete with the

exception of a portion of the 100-K Area that is under CH2M Plateau Remediation Contractor (CHPRC) management and a portion of the 300 Area under PNNL management.

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, and piping systems. In 2017, cleanup activities focused on completion of interim remedial actions in the 100-K Area. Waste generated from the cleanup of waste sites was disposed at the Environmental Restoration Disposal Facility (ERDF) in the 200 Areas.

100-K Area

Construction was completed on the Engineered Container Retrieval & Transfer System hardware in both the 105-K West Basin and Annex. Groundwater pump-and-treat operations continued. Remediation of waste sites to protect human health and the environment also continued.

100 Areas Facilities Decommissioning

As of 2017, all deactivation, decommissioning, decontamination, and demolition activities in the 100 Area, with the exception of 100-K 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. Decommissioning activities for the four main process buildings (234-5Z, 236Z, 242Z, and 291Z) at Plutonium Finishing Plant (PFP) were completed and demolition began in 2017. More than 1,500 roll-on/roll-off containers of rubble were removed from the PFP complex and taken to ERDF for final disposition.

300 Area Facilities Decommissioning

Current activities are focused on the remote excavation of the highly contaminated soil beneath the 324 Building B Cell and a portion of B Cell. Future activities in the 300 Area will address the remainder of the 324 facility, as well as the retained facilities and waste sites.

400 Area Facilities – Fast Flux Test Facility Deactivation

The Fast Flux Test Facility 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 offsite sources authorized to ship waste to the site. Active onsite solid waste facilities as of 2017 are described below.

Central Waste Complex. Located in the 200-West Area, the Central Waste Complex receives waste from Hanford Site sources and any offsite sources authorized by DOE to ship waste to the site for storage. Waste received includes low-level, transuranic, mixed low-level, and radioactive waste contaminated with polychlorinated biphenyls. Currently, the volume of waste stored in the Central Waste Complex Outside Storage Areas is approximately 198,126 ft³ (5,610 m³), with the remaining enclosed area storage totaling approximately 446,629 ft³ (12,647 m³).

T-Plant. The T-Plant Complex is located in the 200-West Area and provides solid waste treatment, storage, and decontamination services for the Hanford Site and offsite facilities. The T-Plant Complex is preparing to receive K-Basin sludge for storage.

Canister Storage Building. Located in the 200-East Area, this 42,000-ft² (3,902-m²) facility stores about 2,300 tons (2,086 metric tons) 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. The low-level burial grounds (LLBG) consist of eight separate burial areas regulated under the *Atomic Energy Act*. Two of the burial grounds are used for disposal of low-level waste and mixed waste (i.e., low-level radioactive waste with a dangerous waste component regulated by WAC 173-303). The first operational layer of waste packages in Trenches 31 and 34 has been covered with compacted gravel and soil; waste is currently being placed on the second waste layer. Trench 31 contains approximately 227,132 ft³ (6,432 m³) of waste in approximately 3,845 waste packages. Trench 34 contains approximately 186,758 ft³ (5,288 m³) of waste in 5,301 waste packages. In 2017, a total of 9,004 ft³ (255 m³) of waste was disposed of in Trenches 31 and 34. The LLBG Trench 94 received two defueled U.S. Navy reactor compartments in 2017.

Waste Receiving and Processing Facility. The Waste Receiving and Processing (WRAP) Facility is a treatment, storage, and disposal facility that began operations in 1997 with the mission to analyze, characterize, and prepare drums and boxes of low-level, mixed, and transuranic wastes for disposal. The WRAP complex is composed of the primary 2336W facility, the 2404-WB and 2404-WC storage buildings, and the High Energy Real Time Radiography and High Energy Neutron Counter.

Waste Encapsulation and Storage Facility. Located in the 200-East Area, the Waste Encapsulation and Storage Facility was constructed in 1970 and 1971 on the west end of B-Plant and became active in 1974. The Waste Encapsulation and Storage Facility is operating under interim status standards. Initial RCRA closure of Hot Cells A through F was achieved on April 10, 2017, through grouting these cells to fix any radioactive materials present.

Integrated Disposal Facility. The Integrated Disposal Facility (IDF) is an unused landfill located in the south-central part of the 200-East Area. The IDF is an expandable lined landfill (i.e., a double high-density polyethylene-lined trench with leachate collection and a leak detection system) with a process design capacity of 2.89 million ft³ (82,000 m³). The landfill is divided lengthwise into distinct east and west cells, one for disposal of low-level radioactive waste (the east cell) and the other for disposal of mixed waste (the west cell). The west cell is a permitted TSD facility under the Hanford Site RCRA Permit (WA7890008967). The landfill was constructed to accept low-level waste as well as mixed waste, such as vitrified low-activity waste (LAW) from the Waste Treatment Plant (WTP) and Demonstration Bulk Vitrification System (DBVS). Additionally, mixed waste generated by IDF operations will be disposed of in IDF. Work was conducted during CY 2017 to prepare and update a PA for the Integrated Disposal Facility (IDF).

Environmental Restoration Disposal Facility. The Environmental Restoration Disposal Facility (ERDF) began operations in 1996 and serves as the central disposal site for hazardous, low-level radioactive, and mixed low-level waste removed during Hanford Site CERCLA cleanup operations. The largest disposal facility in the DOE complex, DOE and its contractors have disposed 18.2 million tons (16.5 million metric tons) of contaminated material at the ERDF since the facility began operations in 1996.

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 Effluent Treatment Facility (ETF) treats liquid 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). Approximately 3.34 million gal (12.6 million L) of wastewater in LERF was treated at ETF in 2017.

200 Area Liquid Effluent Retention Facility. Across from the ETF, the Liquid Effluent Retention Facility (LERF) consists of three RCRA-compliant surface basins used to store aqueous waste. The volume of wastewater received for the LERF basin storage in 2017 was approximately 3.03 million gal (11.5 million L). The volume of wastewater being stored in the LERF at the end of 2017 was approximately 18.2 million gal (68.9 million L).

200 Area Treated Effluent Disposal Facility. Located east of the 200-East Area, the Treated Effluent Disposal Facility 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-ac (2-ha) disposal ponds. The volume of non-radioactive, non-dangerous waste is disposed to this facility in 2017 was approximately 96,212 million gal (803 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 2017, upgrades to the facility included a stack extension to vessel vent 296-A-22 and an upgrade to the process sampling station.

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. In 2017, progress continued in retrieving waste from the C Farm tanks and transferring it to newer, safer double-shell tanks (DST) to prepare to feed tank waste to the WTP. At the end of 2017 there were 28.7 million gal (108.6 million L) of waste in the single-shell tanks (SST). Waste volumes are provided in HNF-EP-1082. Table 5-5 summarizes the waste retrieved and stored in the SST system from 2010 through 2017.

Double-shell Tank System. The DST system includes 28 double-shell tanks located in the 200-East and 200-West Areas. The DST system is operating under interim status standards specified in the RCRA Permit (WA7890008967), Double-Shell Tank System Part A Form. At the end of 2017, there were 25.5 million gal (96.6 million L) of waste in the DSTs. Waste volumes are provided in HNF-EP-0182.

Underground Waste Storage Tanks and Associated Facilities Progress on DNFSB.

Throughout 2017, the DOE-ORP and its contractors met with and provided information to the DNFSB and its technical staff to answer questions regarding the following Hanford Site Tank Farm projects:

- Low Activity Waste Pretreatment System

- Maintenance Program
- Wireless Safety Instrumented System.

Single-Shell Tank Closure and Correct Measures Program. The Single-Shell Tank Closure and Corrective Measures Program is responsible for the closure of SST Waste Management Areas (WMAs), conducting performance assessments (PAs), and performing agreed upon interim measures in and around SST WMAs. Closure activities in CY 2017 focused on the development, submittal, and review of closure documents, and in conducting field and engineering activities to support WMA C Closure. Work was conducted during CY 2017 to prepare and update closure documents to meet the requirements of DOE O 435.1, *Radioactive Waste Management*, and the RCRA for WMA C, and prepare and update PAs for WMA C, and WMA A-AX. The WMA C and WMA A-AX PAs support closure of WMA C and WMA A-AX, respectively. In October 2017, construction of two SX Farm interim surface barriers began. The design for a third barrier was developed in CY 2017.

Hanford Tank 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. In 2017, Bechtel National Inc. (BNI) began executing against its new contract modifications, signed in December 2016 with DOE. These modifications prioritize finishing the LAW Facility, BOF, and Analytical Laboratory to feed waste directly from the Hanford Tank Farms to LAW under an approach called Direct Feed Low-Activity Waste.

Pretreatment Facility. In 2017, work continued to resolve the remaining technical decisions that have impacted design and construction at the Pretreatment Facility since 2012. The Pretreatment team completed final testing of the Standard High Solids Test Vessel pulse jet mixers and control systems. Significant progress on the technical decisions was made in 2017 with resolution of the last decisions anticipated in the second quarter CY 2018.

High-level Waste Facility. At this facility, high-level waste (HLW) is combined with materials in high-temperature melters, poured into waste containers to form a solid, immobilized glass form. In 2017, the HLW team completed the Facility Completion Plan and the Design and Operability Report. In September 2017, DOE-ORP approved HLW's Preliminary Design Safety Analysis. It also received three autosamplers for HLW.

Low-Activity Waste Facility. In 2017, WTP workers completed installation of the caustic scrubber, assembly of the two melters in LAW, and installation of the 48-ft (1,463-cm) elevation electrical bulk cable.

Analytical Laboratory. Once operational, the laboratory will process about 10,000 waste samples a year to support glass formulation and waste-form compliance.

Long-term Stewardship

The Hanford Site's Long-Term Stewardship (LTS) Program has responsibilities within the 220 mi² (570 km²) of the Hanford Site's River Corridor and bounded by 46 mi (74 km) of Columbia River shoreline; these responsibilities include managing post-cleanup obligations for 1,636 Waste Information Data System waste sites and 6 Manhattan Project Era production reactors that have been placed in interim safe storage. More than 24,000 cleanup and historic documents have been identified, indexed, and tagged as LTS records. In 2017, housekeeping tasks associated with the six reactors placed in interim safe storage were completed. External inspection of these structures continue to identify any potential

deterioration of the cocooned structure and improve protectiveness of human health and the environment. LTS assessed 229 waste sites with institutional controls.

Scientific and Technical Contributions to Hanford Site Cleanup

The PNNL scientific and technical contributions to cleanup at the Hanford Site are focused on applied science, technology development and maturation, and basic science contributions. These contributions are funded through the DOE-Environmental Management Offices of Soil and Groundwater Remediation and Tank Waste and Waste Processing, DOE-RL, CHPRC, DOE-ORP, Washington River Protection Solutions, and BNI.

ES.6 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. The outdoor ambient air is also monitored on the Hanford Site and offsite in nearby and distant communities.

Air Emissions

Small quantities of radionuclides and industrial air pollutants are emitted to the environment from the Hanford Site due to facility operations. Most facility radioactive air emission sources are sampled or monitored if they have the potential to emit radionuclides. The dose to the MEI calculated in 2017 from Hanford Site operations was 0.22 mrem (1.2 μ Sv), which is 0.22% of the 100 mrem (1,000 μ Sv) annual public dose limit specified in DOE O 458.1. Non-radioactive air pollutant emissions are estimated via sampling or chemical and material use. Pollutant emissions from all sources in 2017 were similar to emissions in 2016.

Ambient Air Monitoring

A network of continuously operating samplers at 59 locations across the Hanford Site was used during 2017 to monitor radioactive airborne materials in air near site facilities and operations. Generally, radionuclide levels measured in the 2017 air composite samples were similar to those measured in previous years. Notable exceptions to this were sample results from stations in the 200-West Area in the vicinity of the PFP demolition project. Air monitoring at the 618-10 Burial Ground project north of the 300 Area concluded in December 2017 with the completion of remediation activities.

Hanford Site and Offsite Ambient Air Monitoring

Airborne radionuclide samples were collected in 2017 by 37 continuously operating samplers at or in the vicinity of the Hanford Site. Generally, the 2017 air sample results showed very low radiological concentrations (Appendix C, Table C-3). Two stations showed a sample with radionuclide concentrations above their respective reporting threshold values (i.e., 10% of) of 40 CFR 61, Appendix E, 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 μ Sv)/yr from airborne radiological material if a person stayed in that location for a majority of the year. The values in 40 CFR 61, Appendix E, Table 2 are used as reporting thresholds to the WDOH, pursuant to Section 5.1.5.1, for those stations listed in Table 4-1 of the FF-01 license.

ES.7 Section 7, Water Monitoring

In 2017, water samples were collected and analyzed from different sources including Hanford Site drinking water systems, Columbia River surface water, sediment, and seep water; onsite pond water and sediment; offsite irrigation water; and liquid effluent.

Hanford Site Drinking Water Monitoring

Eight DOE-owned, contractor-operated public water systems supply drinking water to DOE facilities on the Hanford Site. MSA operates five of the public water systems. CHPRC operates two systems, and PNNL operates one system. The City of Richland supplies water to the 300 Area, Richland North Area, and Hazardous Materials Management and Emergency Response facility.

Routine radiological, chemical, physical, and microbiological monitoring of Hanford Site drinking water is performed regularly as mandated by EPA's Community Water System requirements. With the exception of the 300 Area water system, all of the DOE-owned Hanford Site systems were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels for 2017. Contaminant concentrations measured during the year were similar to those observed in recent years.

The 300 Area water system experienced a maximum contaminant level exceedance for disinfection by-products monitoring in the third and fourth quarters of 2017. Transition of the 300 Area operations and responsibilities from MSA to PNNL occurred on October 1, 2017. MSA assisted the PNNL Water Purveyor with the exceedance response, operational updates, and public notifications. MSA Water & Sewer Utilities continued to operate the water system under an inter-contractor work order agreement with PNNL for the remainder of CY 2017.

Columbia River Water Monitoring

Radionuclide concentrations measured in river water samples collected upstream and downstream of the Hanford Site in 2017 were similar to concentrations measured in recent years. Concentrations of radionuclides in samples collected at the City of Richland intake facility were slightly higher than in samples collected upstream at Priest Rapids Dam. Radiological contaminant concentrations were well below the DOE-derived concentration standards.

Radionuclide concentrations measured in cross-river, transect samples were, with one exception, similar to levels measured upstream at Priest Rapids Dam. The tritium concentration measured at the Hanford Townsite transect was higher than at Priest Rapids Dam or at any other transect. Strontium-90 concentrations in Hanford Reach transect samples were comparable to upstream reference concentrations. Strontium-90 concentrations measured in transect samples collected upstream and downstream of the Hanford Site during 2017 were below analytical detection limits. Uranium concentrations in all transect samples were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]).

Transect samples were also analyzed for inorganic and organic constituents. Copper, uranium, and zinc were detected in most samples at levels below the Washington State Ambient Surface Water Quality criteria for the protection of aquatic life. Organic contaminants trichloroethene and dichloroethene, attributable to past Hanford operations, were well below their respective EPA Drinking Water Standard.

Columbia River Sediment Monitoring.

Samples of Columbia River sediment were from locations upstream and downstream of the Hanford Site as well as at locations along the Hanford Reach. All samples were analyzed for radionuclides, anions, hexavalent chromium, metals, mercury, and total organic carbon. Analytical results for 2017 were comparable to previous years with cesium-137 and uranium isotopes consistently detected at most sediment collection locations.

Columbia River Seep Water

Samples of Columbia River shoreline seep water were collected along the Hanford Reach and analyzed for radiological, inorganic, and organic contaminants. Tritium concentrations were noticeably elevated in samples collected near the Hanford Townsite and at the 300 Area. These results are consistent with concentrations and plume maps reported by the Groundwater Monitoring program.

Pond Water and Sediment

West Lake is the only naturally occurring pond on the Hanford Site. Remotely located, it is most frequented by the indigenous wildlife. Water and sediment samples were analyzed for radiological contaminants and the 2017 concentrations were similar to previous years.

Offsite 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 irrigation systems on each side of the Columbia River. Radionuclide concentrations measured in 2017 were at similar levels measured in Columbia River transect water samples collected upstream of the Hanford Site.

Liquid Effluent Monitoring

Liquid effluent disposal is governed by applicable regulations and permits. In CY 2017 there were no liquid effluent discharges to the Columbia River and two permitted liquid effluent streams discharged to the ground. Sampling and analyses are performed to monitor effluent contaminants of concern. Discharge monitoring reports that contain contaminant data from these analyses are submitted to Ecology.

ES.8 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 and 200-West Areas in the central part of the site, and the 300 and 100 Areas along the Columbia River. Groundwater monitoring data and information about monitoring wells are available through the DOE Environmental Dashboard Application at <https://ehs.hanford.gov/eda>. A detailed discussion of groundwater monitoring results is available in DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2017*, and the interactive online report at <https://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports>.

ES.9 Section 9, Soil Monitoring

Surface soil samples are collected on the Hanford Site to evaluate long-term accumulation trends and provide baseline data used to quantify contaminant level changes due to fugitive or accidental releases of Hanford Site radiological materials. Soil samples for this effort have been collected annually for several decades. These samples are typically collected in the late-spring from locations on or adjacent to waste disposal sites, as well as from locations downwind, near, or within the boundaries of operating facilities and remedial action sites. Soil samples from offsite locations are collected every 3 to 5 years and were last collected in 2015. Offsite soil sampling is used for long-term trend analysis and is not used in dose model calculations. The sampling frequency of every 3 to 5 years is consistent with the guidance provided in [DOE-HDBK-1216-2015](#), *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

Analytical results for soil samples collected in 2017 at locations in the 200-East, 200-West, 300, 400, and 600 Areas were consistent with analytical results from previous years. While there are no specific DOE limits for radionuclide concentrations in soil, the 2017 onsite soil sample results were compared to other benchmarks including Hanford Site background concentrations ([DOE/RL-96-12](#)), dose-based limits for soil developed for a 1 mrem/yr dose threshold to an offsite member of the public ([DOE/RL-91-50](#)), and soil radiological preliminary remediation goals (PRGs) for the 200 Area outdoor worker exposure scenario. Generally, radionuclide concentrations in soil samples collected from the 200, 300, 400, and 600 Areas were near or below the Hanford Site background concentrations and well below the dose-based reporting limits for an offsite member of the public and the PRGs for the outdoor worker exposure scenario. The cesium-137 concentrations in the 200 Areas were slightly above the Hanford Site background level, but they were significantly lower than the PRGs for the 200 Area outdoor worker exposure scenario.

ES.10 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

Food and farm products (i.e., alfalfa, cherries, corn, leafy vegetables, melons, milk, potatoes, tomatoes, and wine must) were collected in 2017 at locations near the Hanford Site. Radionuclide concentrations in most food and farm product samples in 2017 were below the analytical laboratory detection levels; however, some potential Hanford Site-produced contaminants (e.g., tritium) were found at low levels in some samples. Data for potassium-40 and beryllium-7 are included to show the natural radioactive elements that exist in food products relative to concentrations of potential Hanford Site-produced contaminants.

Fish and Wildlife Monitoring

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during CY 2016 were walleye (*Sander vitreus*), mountain whitefish (*Prosopium williamsoni*), Canada goose (*Branta Canadensis*) and Nuttall's cottontail rabbit (*Sylvilagus nuttallii*). Most fish and wildlife samples are

collected on and around the Hanford Site and analyzed for human-pathway exposure every 2 to 3 years. Reference samples are obtained at locations determined not to be affected by Hanford Site effluents and emissions at least every 5 years.

Vegetation Monitoring

Native vegetation samples are collected on the Hanford Site to evaluate long-term accumulation trends and provide baseline data used to quantify contaminant level changes due to fugitive or accidental releases of Hanford Site radiological materials. Vegetation samples for this effort have been collected annually for several decades from locations on or adjacent to waste disposal sites, as well as from locations downwind, near, or within the boundaries of operating facilities and remedial action sites. Vegetation samples from offsite locations are collected every 3 to 5 years and were last collected in 2015. Offsite vegetation sampling is used for long-term trend analysis and is not used in dose model calculations. The sampling frequency of every 3 to 5 years is consistent with the guidance provided in [DOE-HDBK-1216-2015](#). Analytical results for vegetation samples collected in 2017 at locations in the 200-East, 200-West, 100-N, 300, 400, and 600 Areas were consistent with previous years.

Radiological Contamination. 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 23 vegetation samples surveyed during the 2017 investigations.

Vegetation Control. Approximately 4,689 ac (1,898 ha) were treated with herbicides in 2017 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

In 2017, only 1 ac (0.4 ha) across the Hanford Site was 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.

ES.11 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 applicable laws, regulations, and policies (including management plans) 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 2017, 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 ferruginous hawk nest monitoring, roadside bird surveys, burrowing owls, pollinators, ground squirrels, and bats.

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 threatened fish species (bull trout) has been 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. In addition, 13 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 31 state-level sensitive and candidate species of animals and 15 sensitive plant species occurring or potentially occurring on the Hanford Site.

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. In 2017, Hanford Site archaeologists completed 75 [National Historic Preservation Act of 1966](#) (NHPA) Section 106 cultural resources reviews. Thirty-three undertakings had the potential to affect cultural resources. Thirty-two projects affected historic buildings 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. Eight projects had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews. Two projects were reviewed and completed by Hanford Site archaeologists under an emergency declaration. A total of 2,723.03 ac (1,101.97 ha) of new ground was surveyed for cultural resources from NHPA Section 106 project-specific surveys.

Collection Management and Curation

The Hanford History Project provides professional curatorial and archival services for the management, conservation, and public access of the Hanford Collection, which consists of artifacts and multimedia relating to the Manhattan Project and Cold War Era. In addition to public outreach and education, Washington State University, Tri Cities (WSU-TC) provides 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. During 2017, 15 artifacts were evaluated for inclusion, picked up from Hanford Site facilities, and delivered to the Hanford History Project repository at WSU-TC, leaving 26 (3.5%) of the 743 tagged artifacts scheduled for collection between 2018 and 2048. Having transitioned the bulk of the Hanford Collection to the WSU-TC facility in 2016, tasks during 2017 consisted mainly of artifact cataloguing and archival processing. Additionally, 191 archival items staged at a secure Mission Support Alliance facility were reviewed for public release prior to being transferred to the Hanford History Project's repository for curation.

ES.12 Section 12, Quality Assurance

Quality assurance (QA) and quality control (QC) programs for the Hanford Site and offsite environmental surveillance were documented through project-specific QA plans and describe applicable QA elements.

Several types of field QC samples are collected to ensure the validity of the sampling procedures and the resulting sample data. The potential cross-contamination between samples during the sampling process is evaluated using trip blanks and equipment blanks. Additionally, field duplicates are collected to evaluate sample matrix heterogeneity and sample collection reproducibility. In 2017, field duplicate samples were collected and analyzed for air, soil, Columbia River water, natural vegetation, milk, wine, cherries, wildlife, irrigation water, sediment, and seep samples. The accepted method of evaluating the precision or reproducibility of duplicate samples is the calculation of the Relative Percent Difference. In 2017, Hanford Site Environmental Surveillance samples were sent to two laboratories (General Engineering Laboratories, LLC [GEL] and TestAmerica Richland Laboratory [TARL]). These laboratories participated in various independent QA and QC programs including the Mixed Analyte Performance Evaluation Program (MAPEP) and DOE Consolidated Audit Program.

GEL's MAPEP program results were nearly all acceptable. GEL received warnings in studies 36 and 37 for results with bias in the range of 20 to 30% for uranium-235, uranium-238, uranium total, and strontium-90, which are still considered acceptable. GEL received unacceptable results for bias greater than 30% for antimony and mercury. Unacceptable results such as these will be mitigated by future results and are not currently considered to be an unrecoverable problem under the MAPEP.

TARL's MAPEP results were nearly all acceptable. TARL received warnings in studies 36 and 37 for results with bias in the range of 20 to 30% for cesium-137, cobalt-60, uranium-238, uranium total, and technetium-99, which are still considered acceptable. TARL received unacceptable results for a false positive on nickel-63 and for a result biased by more than 30% for iron-55. Similar to the GEL results, these issues will be mitigated by future results and are not currently considered to be an unrecoverable problem under the MAPEP program.

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Acronyms

μS	microsiemens
μSv	microsievert
AEA	Atomic Energy Act of 1954
ALARA	as low as reasonably achievable
AR	Administrative Record
BNI	Bechtel National, Inc.
BOF	Balance of Facilities
BPA	Bonneville Power Administration
BRMP	Hanford Site Biological Resources Management Plan
C&D	construction and demolition
ca.	circa
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CGS	Columbia Generating Station
CHPRC	CH2M Plateau Remediation Company
CITS	Chemical Inventory Tracking System
CLUP	Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement
Council	Hanford Natural Resource Trustee Council
CSB	Canister Storage Building
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWC	Central Waste Complex
CY	calendar year
CX	categorically excluded
D4	deactivation, decommissioning, decontamination, and demolition
DFLAW	Direct Feed Low-Activity Waste
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DOE-EA	U.S. Department of Energy, Office of Enterprise Assessments
DOE-EM	U.S. Department of Energy, Office of Environmental Management
DOE-HQ	U.S. Department of Energy, Headquarters
DOE-ORP	U.S. Department of Energy, Office of River Protection

DOE-RL	U.S. Department of Energy, Richland Operations Office
DSA	Documented Safety Analysis
DST	double-shell tank
EA	environmental assessment
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
EMF	Effluent Management Facility
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act of 1986
EPEAT	Electronic Product Environmental Assessment Tool
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FFTF	Fast Flux Test Facility
FMEF	Fuels and Materials Examination Facility
FONSI	Finding of No Significant Impact
FY	fiscal year
GEL	General Engineering Laboratories, LLC
GIS	Geographic Information System
HAB	Hanford Advisory Board
HAMMER	Hazardous Materials Management and Emergency Response
HDPE	high-density polyethylene
HEPA	high-efficiency particulate air
HHP	Hanford History Project
HLW	high-level waste
HPMC	HPMC Occupational Medical Services
HRM	Hanford River Mile
HTO	tritiated water vapor
IAP	Injury Assessment Plan
IC	institutional control
ICRP	International Convention on Radiological Protection
IDF	Integrated Disposal Facility
IP	Implementation Plan

ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
LAW	low-activity waste
LERF	Liquid Effluent Retention Facility
LIGO	Laser Interferometer Gravitational-wave Observatory
LLBG	low-level burial grounds
LLRW	low-level radioactive waste
LLW	low-level waste
LTS	Long-Term Stewardship
MAPEP	Mixed Analyte Performance Evaluation Program
MBTA	<i>Migratory Bird Treaty Act of 1918</i>
MCO	Multi-Canister Overpacks
MEI	maximally exposed individual
MOA	Memorandum of Agreement
MSA	Mission Support Alliance
MSDS	Material Safety Data Sheet
NCO	NEPA Compliance Officer
NEPA	<i>National Environmental Policy Act of 1969</i>
NHPA	<i>National Historic Preservation Act of 1966</i>
NLOP	North Load-Out Pit
NRC	U.S. Nuclear Regulatory Commission
NRDA	Natural Resource Damage Assessment
NRDWL	Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill
PA	performance assessment
PCB	polychlorinated biphenyl
PEP	Project Execution Plan
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
PNSO	Pacific Northwest Site Office
PRG	preliminary remediation goal
PSRP	Public Safety and Resource Protection Program
PUREX	Plutonium Uranium Extraction Facility
QA	quality assurance

QC	quality control
RBDA	risk-based disposal approvals
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
REDOX	Reduction-oxidation
RESRAD	RESidual RADioactivity
ROD	Record of Decision
RPD	Relative Percent Difference
S&M	surveillance and maintenance
SARA	Superfund Amendments and Reauthorization Act
SDS	Safety Data Sheet
SDWA	<i>Safe Drinking Water Act of 1974</i>
SS	safety-significant
SST	single-shell tank
SVE	soil vapor extraction
SWL	Solid Waste Landfill
TARL	Test America Richland Laboratories
TLD	thermoluminescent dosimeter
TPA	Tri-Party Agreement
Tri-Cities	cities of Kennewick, Pasco, and Richland
TRIDEC	Tri-City Development Council
TSCA	<i>Toxic Substances Control Act</i>
TSD	treatment, storage, and disposal
TTP	transition and turnover package
USFWS	U.S. Fish and Wildlife Service
VPU	vertical pipe unit
WAI	Wastren Advantage, Inc.
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington State Department of Health
WESF	Waste Encapsulation and Storage Facility
WIPP	Waste Isolation Pilot Plant
WMA	waste management area
WRAP	Waste Receiving and Processing
WRPS	Washington River Protection Solutions, LLC

WSU-TC	Washington State University, Tri-Cities
WTP	Hanford Tank Waste Treatment and Immobilization Plant
Yakama Nation	Confederated Tribes and Bands of the Yakama Nation

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2017 Highlight

This section presents the following:

- A brief history of the Hanford Site.
- Highlights of Hanford Site contractors and their primary responsibilities.
- Description of the physical characteristics and attributes of the environment in and around the Hanford Site.
- Highlights of Hanford Site stakeholders and their involvement.
- Description of federal, state, and local regulatory agencies, as well as their roles at the Hanford Site.

1.0 Introduction

JR Draper

Since 1959, the U.S. Department of Energy (DOE) has published the Hanford Annual Site Environmental Report to inform the public, regulators, stakeholders, and other interested parties of the Site's environmental performance during the calendar year. This calendar year 2017 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. Annual environmental reports from previous years are available at <http://msa.hanford.gov/page.cfm/enviroreports>. The sections in this document include topics on:

- 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 onsite and offsite 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 2017 monitoring efforts are provided in the latest version of [DOE/RL-91-50, Hanford Site Environmental Monitoring Plan](#).

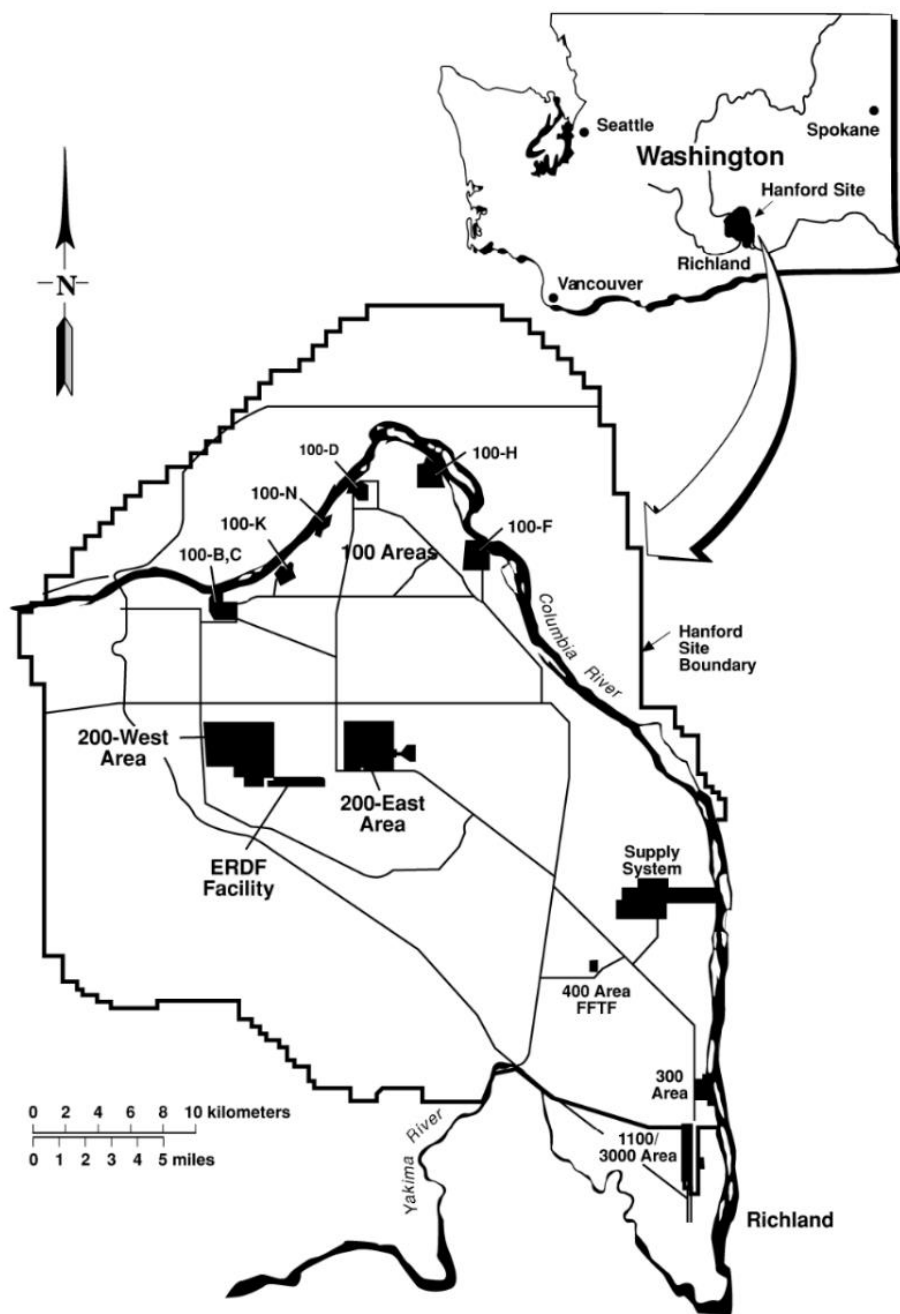
Section 1.0 provides information about the Hanford Site location and details the environmental setting, mission, management, primary operations and activities, and climate and meteorology as well as stakeholder involvement, the role of regional Tribal governments, and Hanford regulatory oversight.

1.1 Hanford Site Location

The Hanford Site encompasses approximately 581 mi² (1,505 km²) in Benton, Franklin, Adams, and Grant Counties, located in south-central Washington State within the semi-arid Pasco Basin of the Columbia Plateau (Figure 1-1). The Hanford Site stretches approximately 30 mi (50 km) north to south and about 24 mi (40 km) east to west, immediately north-northwest of the confluence of the Yakima and Columbia Rivers; the cities of Kennewick, Pasco, and Richland (the Tri-Cities); and the city of West Richland. The Columbia River flows 50 mi (80 km) through the northern part of the Hanford Site and, turning south, forms part of the Hanford Site's eastern boundary. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge are on the southwestern and western boundaries of the Hanford Site, and Saddle Mountain is on the northern boundary. The plateau of the central portion of the Hanford Site has two small east-west ridges: Gable Butte and Gable Mountain. Lands adjoining the Hanford Site to the west, north, and east are principally range and agricultural (WCH-520). With restricted public access, the diverse geographic features and land (Figure 1-2) provide a buffer for areas used for nuclear materials production, research, and ongoing waste storage and disposal.

The climate of south-central Washington is strongly influenced by the Pacific Ocean and the Cascade Range to the west. The Rocky Mountains to the east and the north are also an important influence on the climate of the region. Locally, the climate of the Hanford Site is influenced by the Yakima Ridge, Rattlesnake Hills, and Horse Heaven Hills to the west and south, and Saddle Mountain to the north (Figure 1-2). The relatively low annual average rainfall (6.3 in. [16 cm]) at the Hanford Site is caused in large part by the rain shadow created by the Cascade Range. Maritime influences are experienced in the Hanford Site area during the passage of strong, large-scale storm systems. Maritime air also penetrates into the region through gaps in the Cascade Range (such as the Columbia River Gorge). Continental influences are limited by the mountain ranges to the north and east of the Hanford Site. These mountains play a key role in protecting the region from the more severe winter storms and the extremely low temperatures associated with the modified arctic air masses that move southward through Canada. (WHC-SD-HWV-PSAR-001)

The Hanford Site lies within the interior, low elevation Columbia River Basin, which is within the shrub-steppe zone. The diversity of physical features across the Hanford Site contributes to a corresponding diversity of biological communities. The majority of the Hanford Site consists of shrub-steppe habitats, but valuable riparian, wetland, and aquatic habitats are associated with the Hanford Reach of the Columbia River. The Hanford Site also contains a diversity of other rare terrestrial habitats such as riverine islands, bluffs/cliffs, basalt outcrops, swales, and sand dunes. Both shrub-steppe and riparian habitats are considered "priority habitats" by the Washington State Department of Fish and Wildlife (WDFW) ([DOE/RL-96-32](#)). Some of these areas contain species considered rare and/or declining, or are of significant interest to federal, state, or Tribal governments.



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Figure 1-1. Location of the Hanford Site.

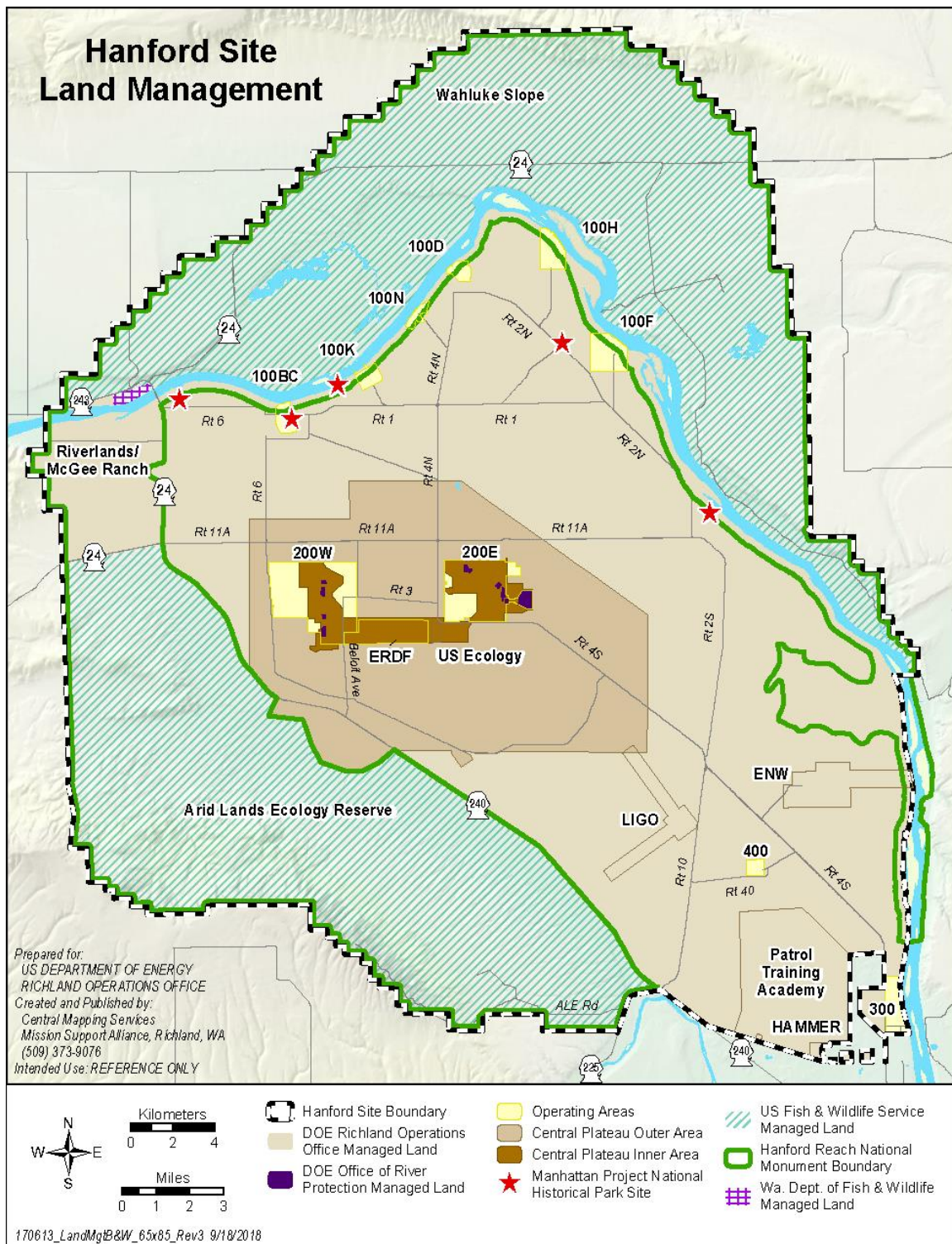


Figure 1-2. Detailed Geography of the Hanford Site, Hanford Reach National Monument, and U.S. Department of Energy Portions of the Hanford Site.

1.2 Hanford Site History and Mission

In February 1943, the federal government, under the authority of the War Powers Act, acquired 625 mi² (1,689 km²) of the mid-Columbia basin for the Hanford Site, known as the Hanford Engineer Works during the Manhattan Project, and offered resident compensation. Approximately 1,500 people living in towns and on farms from Priest Rapids to Richland were ordered to leave their homes and property. In some cases, landowners had only 30 days to move (Harvey 2000). Construction of the Hanford Site began in 1943 with nine plutonium production reactors operational along the Columbia River from 1944 to 1987. Research reactors, including the Fast Flux Test Facility (FFTF) that operated from 1982 to 1992, were located in the southern portion of the Hanford Site. Hundreds of other supporting buildings and extensive infrastructure was constructed to support the program to provide plutonium to fuel atomic weapons during World War II and the Cold War (Figure 1-3) and support research into nuclear energy. Hanford manufactured the uranium metal fuel for the nuclear reactors onsite. Five chemical process plants in the center of the Hanford Site processed 110,000 tons (100,000 metric tons) of irradiated fuel from the reactors, discharging an estimated 450 billion gallons of liquids to soil disposal sites and 54.1 million gallons (204.8 million L) of radioactive waste to 177 large underground tanks.



Figure 1-3. Construction of the Hanford Site Began in March 1943 and was Completed by April 1945.

With the end of the Cold War and the signing of the [*Hanford Federal Facility Agreement and Consent Order*](#) (Tri-Party Agreement [TPA]) in 1989 (Ecology et al. 1989) by the Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and DOE (collectively, TPA agencies), the mission focus shifted to developing new waste treatment and disposal technologies, characterizing and cleaning up the contamination from historical operations, and environmental remediation. The DOE is

responsible for one of the largest nuclear cleanup efforts in the world, managing the legacy of five decades of nuclear weapons production.

After more than two decades of cleanup, considerable progress has been made at Hanford, reducing risk to the health and safety of workers, the public, and the environment (Figure 1-4). Crews responsible for Hanford Site cleanup are dealing with several different kinds of waste in a number of different forms, with many of the wastes being potentially harmful to people and the environment. Precautions have been taken so that the waste does not contaminate the air, soil, groundwater, the Columbia River, the people who are doing the cleanup work, or the people and environment near the Hanford Site. 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 (i.e., 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 B Reactor and other Hanford Site structures are a part, focuses on historic preservation and public education.



Figure 1-4. H Reactor was the First Reactor Built after World War II. It was Operational from 1949 through 1965. In 2005, H Reactor Became the Fifth Hanford Facility to be Cocooned.

1.3 Primary Operations and Activities

The following is a list of the major DOE operational, administrative, research, and historically preserved areas in and around the Hanford Site.

1.3.1 100 Area

The 100 Area occupies 4 mi² (11 km²) and consists of six sites (100-B/C, 100-D/DR, 100-F, 100-H, 100-KE/KW, 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 built between 1943 and 1963. They were constructed next to the river because of the abundance of hydro-electric power and cooling water needed by the reactors during operation. None of the Hanford Site DOE reactors are in operation any more with the last reactor, the FFTF Reactor, being shut down in 1992. A commercial Nuclear Regulatory Commission-licensed reactor still operates on Hanford-leased land for the public utility Energy Northwest near the sand dunes along the Columbia River. Beginning in the 1990s, workers began the process of “cocooning” the DOE reactors. When a reactor is cocooned about 80% of the buildings and auxiliary structures that were needed to support the reactor during its operating days are demolished and removed. The remaining 20% of the reactor complex, including the core of the reactor itself, is enclosed in a cement and steel structure called a cocoon. This cocoon prevents radiation or contamination left over from the nuclear operations from escaping to the environment. Ultimately, 8 of the 10 reactors at Hanford will be cocooned. Reactors C, D, DR, F, H, and N are already cocooned, with K-East and K-West Reactors next in line to be cocooned. Every 5 years, Hanford crews enter these cocoons to ensure that the structure remains airtight and watertight. These cocoons will be in place over the reactors for approximately 75 years allowing the radiation within the reactors to safely decay to levels where it doesn’t pose a threat to the environment or the workers performing final demolition. Hanford engineers and scientists are already working on plans that will result in these cocooned reactors being removed from the area along the river following the 75-year life span of the cocoon. B Reactor will not be cocooned, it has been named a National Historic Landmark by the United States Department of the Interior and has been preserved as a museum. 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.

DOE operates five pump-and-treat facilities along the River Corridor. The KR4 system was the first system installed and began operation in 1997 and treats up to 330 gal/min. The KW system was the second system installed; it began remediating hexavalent chromium in the KW Reactor area in January 2007 and treats 330 gal/min. The third and newest system (KX) began operation in February 2009 and treats 600 gal/min. The KX system is used primarily to treat hexavalent chromium in groundwater near N Reactor Area. The DX and HX pump-and-treat systems were designed for hydraulic control and hexavalent chromium mass removal to protect the Columbia River. Both the DX and HX pump-and-treat systems include an extraction well network, transfer building (the DX system has two transfer buildings), a treatment building, and injection well network. The DX system was fully operational in December 2010, and the HX system was fully operational in October 2011. The DX and HX systems are designed to provide treatment capacities of 600 gal/min each. Details of the operations and results for these pump-and-treat facilities can be found in DOE/RL-2016-68, *Calendar Year 2016 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation*.

1.3.2 200 Areas

The 200 Areas at Hanford are known collectively as the Central Plateau. It is the part of the DOE Industrial Hanford Site that is the highest in elevation. There are three regions associated with the 200 Areas (the 200-East Area, the 200-West Area, and the 200-North Area); each are separated from each other by several miles. The 200 Areas make up about 75 mi² (194 km²) of the Hanford Site. The plateau surface is approximately 328 ft (100 m) above the level of the Columbia River and about 280 ft (85 m) above the underlying water table. The 200 Areas contain underground waste storage tanks and housed facilities known as separations plants that extracted plutonium from dissolved irradiated fuel. Some of the most hazardous chemical and nuclear wastes were put into 177 underground storage tanks spread out into 18 groups of tanks called tank farms. The storage tanks range in size from 50,000 gal (190,000 L) of capacity to more than 1 million gal (3.8 million L) of capacity. Currently at Hanford, some 54.1 million gal (204.8 million L) of chemical and nuclear waste remain stored in these tanks ([HNF-EP-0182](#)).

While much of Hanford's current mission revolves around the demolition of buildings and facilities, there are two construction projects underway in the 200 Areas that are critical to the safe removal of the solid and liquid wastes at Hanford. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is being built to process the millions of gallons of liquid waste currently being stored in the tank farms. The process is called vitrification, where the liquid wastes are mixed with glass making materials and then heated to form a red-hot, molten substance that is poured into steel cylinders. Once the material is cooled, the waste will have been captured in a glass form that is considerably more stable than liquid wastes are. These cylinders of vitrified waste will ultimately be sent to a national repository where they will be buried permanently in a specially approved and regulated facility. The Environmental Restoration Disposal Facility (ERDF) also is located on the Central Plateau between the 200-East and -West Areas. ERDF is a massive landfill that is regulated by the EPA. ERDF accepts materials that come from building demolition projects and waste site remediation at Hanford.

The 222-S Analytical Laboratory, a Hazard Category 3 nuclear facility, plays many roles, which include testing of waste compatibility and physical characteristics to support tank-to-tank waste transfers, performing corrosion rate studies and chemical testing to support tank corrosion inhibition, and providing input to the engineering specifications for each of the 242-A Evaporator campaigns. The laboratory also studies the physical and chemical characteristics of waste necessary to enable waste retrievals, provides data to support tank closure requirements, and supports the Vadose Zone Program.

The 242-A Evaporator is currently the only operating nuclear waste processing facility at Hanford. The Evaporator receives radioactive liquid wastes that are pumped through underground pipes from double-shell waste storage tanks on the Hanford Site. The mission of 242-A is to take that waste, referred to as "feed", and boil off as much of the liquids as possible. The remaining waste goes back into the waste storage tanks while the water products that were removed through the Evaporator operations is sent to other facilities for treatment and safe disposal.

The Canister Storage Building (CSB) is a large 42,000-ft² facility in Hanford's 200-East Area. The CSB stores about 2,300 tons of spent nuclear fuel packaged in approximately 400 multi-canister overpacks (MCOs). The MCOs are stored in 220 carbon steel tubes within a below grade concrete vault. The MCOs will be safely stored in the tubes until they are permanently placed in a National Repository.

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 also sent to the National Repository.

The 200-West Pump-and-Treat facility was constructed between 2010 and 2011 to remove contaminants of concern found in the Central Plateau groundwater. The 200-West pump-and-treat system is designed to treat contaminated groundwater and reduce the mass of carbon tetrachloride, total chromium (trivalent and hexavalent), nitrate, trichloroethene, technetium-99, and uranium. Following treatment, the water is re-injected into the aquifer to serve as a recharge source to promote flow-path control and provide hydraulic containment. The central facility can treat up to 2,500 gal/min of extracted groundwater using two parallel treatment trains. The extraction and injection well network is located throughout the Central Plateau.

1.3.3 300 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, hundreds of thousands of tons of raw uranium was sent to the 300 Area to be manufactured into fuel assemblies called “rods.” These fuel rods were ultimately placed into the 100 Area reactors where a nuclear chain reaction would change the nuclear properties of the uranium into the plutonium needed for atomic weapons. The 300 Area also served to provide scientists with the laboratory facilities where they could test their theories and conduct experiments on the most efficient ways to transform the uranium into plutonium and perform materials analysis and research. Several small nuclear reactors were operated in the 300 Area in support of research. Due to the many experiments that were conducted at the 300 Area, there are many areas of contamination. The Pacific Northwest National Laboratory (PNNL), working for the DOE Office of Science’s Pacific Northwest Site Office uses some of the buildings within the 300 Area under an agreement between the U.S. Department of Energy, Richland Operations Office (DOE-RL) and the Pacific Northwest Site Office (PNSO).

1.3.4 400 Area

The 400 Area is located northwest of the 300 Area and covers approximately 0.23 mi² (0.61 km²). This area includes the FFTF, the Maintenance and Storage Facility, and the Fuels and Materials Examination Facility (FMEF). Construction of FFTF was completed in 1978 and initial criticality was achieved in early 1980, with full power initiated in late 1980. Following an additional year of acceptance testing, FFTF operated successfully from 1982 to 1992 as a research facility providing the nuclear industry with advances in nuclear fuels, materials, and components; nuclear power plant operations and maintenance protocols; and reactor safety designs. During this time, FFTF also produced a wide variety of medical and industrial isotopes, made hydrogen-3 (tritium) for the U.S. fusion research program, and conducted cooperative international research work. In late 1993, DOE decided not to continue operating FFTF due to a lack of economically viable missions at that time and issued a shutdown (e.g., deactivation) order for the facility. Since that time, and after various delays temporarily stopping the deactivation work, FFTF completed deactivation activities and was placed in a long-term, low-cost surveillance and maintenance condition in 2009. The Maintenance and Storage Facility is periodically used to support mock ups of proposed work to ensure the workers have practiced using the tools and equipment in physical configurations they are likely to encounter doing specialized work. The FMEF was intended to be a support building for the FFTF and the future Liquid Fast-Breeder Reactor Program; the FMEF was never used in a nuclear capacity. When the nation abandoned the breeder reactor program, FMEF was also left without a mission and remains unused and largely vacant today.

1.3.5 600 Area

The 600 Area consists of Hanford’s roads, railroads, fire station, an old concrete batch plant site, the former townsites of Hanford and White Bluffs, the Hanford meteorology station, the Wahluke Slope, and the Arid Lands Ecology Reserve (including Rattlesnake Mountain).

The Laser Interferometer Gravitational-wave Observatory (LIGO) is located just north of the 400 Area and is designed to detect gravitational waves originating from black holes and other astronomical phenomena. LIGO is a scientific collaboration of the California Institute of Technology and the Massachusetts Institute of Technology funded by the National Science Foundation.

An area along the river and north of the 300 Area is leased by Energy Northwest for operation of a commercial nuclear plant called the Columbia Generating Station (CGS). CGS is the only commercial nuclear energy facility in the region. Construction of the CGS began in 1973 and power was first delivered to the region in 1984.

The 618-10 and 618-11 Burial Grounds are also located within the 600 Area. The burial grounds contain wastes that were generated by activities in the 300 Area of the Hanford Site. The 300 Area was used for developing and manufacturing reactor fuel and conducting laboratory research during Hanford's plutonium production mission. Some of the most hazardous wastes on the Hanford Site were disposed of in the 618-10 and 618-11 Burial Grounds. Cleanup of the 618-10 Burial Ground includes remediating 94 buried vertical pipe units (VPU) that contain radioactive and chemical waste. The VPUs were constructed of 55-gal (208-L) corrugated or solid steel drums welded together end-to-end. Some of the waste disposed in the VPUs was packaged in a variety of containers ranging in size from juice cans to paint buckets. Remediation of the 618-10 Burial Ground was completed at the end of fiscal year (FY) 2017. Nonintrusive characterization was completed in 2011 at the 618-11 Burial Ground.

1.3.6 1100 Area

The former 1100 Area is located between the 300 Area and Richland, covering 1.2 mi² (3.1 km²). It had no disposal locations for radioactive or mixed wastes but contained several sites for hazardous wastes (e.g., batteries and battery acid containing lead, sulfuric acid, and ethylene glycol or antifreeze). Following cleanup, EPA took the site off the National Priorities List in 1996. 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.

1.3.7 3000 Area

The former 3000 Area is located northeast of the 1100 Area and accommodated engineering and construction support facilities.

1.3.8 Richland North Area (offsite)

This area includes the DOE and DOE contractor facilities located between the 300 Area and the City of Richland that are not in the 1100 and 3000 Areas. Located in the Richland North Area is PNNL, a DOE National Laboratory operated by Battelle for DOE's Office of Science. PNNL conducts research for national security missions, nuclear materials stewardship, non-proliferation missions, the nuclear fuel life cycle, an energy production, and includes the DOE scientific user facility Environmental Molecular Sciences Laboratory. PNNL also supports the Hanford Site cleanup and River Corridor protection missions.

1.3.9 700 Area (offsite)

The 700 Area of the Hanford Site is located in downtown Richland. Called the Federal Building, DOE and site contractors occupy offices in the seven-story structure, although the majority of DOE offices are now located in the Stevens Center in North Richland near where the 1100 Area used to be located.

1.3.10 Volpentest Hazardous Materials Management and Emergency Response Federal Training Center

Hazardous Materials Management and Emergency Response (HAMMER) is a worker safety training facility and is used by Hanford Site contractors, federal and state agencies, Tribal governments, and private industry. HAMMER is owned by DOE and operated by MSA. HAMMER is comprised of modern classrooms, specialty-training areas, and numerous life-size training props that can be configured to create a variety of situations for industrial hazards (e.g., worksite scenarios, emergency response or incident command, and hazardous materials training) (Figure 1-5). HAMMER contracts with emergency response agencies and offers classes in fire suppression, hostage rescue, high-speed pursuit, and drug enforcement. 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.

HAMMER staff manages nationally recognized training and safety programs including:

- Construction Worker Safety Training
- Worker-Trainer Program
- National Training Center Safety and Health Courses
- Energy Infrastructure Protection and Emergency Response Program
- Domestic and International Border Security Training
- Military Training.



Figure 1-5. Workers in Training Remove a Cover from a Waste Container Used to Haul Waste to the Hanford Site's Environmental Restoration Disposal Facility.

1.3.11 Hanford Tank Waste Treatment and Immobilization Plant

Bechtel National, Inc. (BNI) is designing, constructing, and commissioning the world's largest radioactive waste treatment plant for the DOE. When complete, the WTP, also known as the Vit Plant, will process and stabilize 54.1 million gal (204.8 million L) of radioactive and chemical waste currently stored at the Hanford Site. The construction site spans 65 ac (26 ha) and includes four major nuclear facilities –

Pretreatment, Low-Activity Waste Vitrification, High-Level Waste Vitrification, and the Analytical Laboratory. The plant will use vitrification technology to stabilize the waste. Vitrification involves blending the waste with glass-forming materials and heating it to 2,100 °F (1,149 °C). The molten mixture is poured into stainless steel canisters to cool and solidify. In this glass form, the waste is stable in the environment and designed so the radioactivity will safely dissipate over hundreds to thousands of years.

1.3.12 Non-DOE Operations and Activities on Hanford Site-Leased Land

Energy Northwest operates a commercial nuclear power reactor at the CGS north of the 300 Area on 1,090 ac (440 ha). The CGS nuclear facility is the third largest electricity generator in Washington State and the only commercial nuclear energy facility in the region. Construction of the CGS began in 1973 and power was first delivered to the region in 1984. All of its output is provided to the Bonneville Power Administration at the cost of production under a formal net billing agreement in which Bonneville Power Administration pays the costs of maintaining and operating the facility.

The U.S. Ecology Washington operates a commercial low-level radioactive waste (LLRW) burial site located west of the 200-East Area on 99 ac (40 ha). The burial site serves commercial and government LLRW customers in the Northwest and Rocky Mountain compact regions: Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, Wyoming, Colorado, Nevada, and New Mexico.

West of the 400 Area, the California Institute of Technology and Massachusetts Institute of Technology jointly operate the LIGO sponsored by the National Science Foundation. LIGO is a national facility for gravitational-wave research, providing opportunities for the broader scientific community to participate in detector development, observation, and data analysis.

1.3.13 Non-DOE Nuclear Operations

AREVA NP, Inc. operates a commercial nuclear fuel fabrication facility adjacent to the DOE Hanford Site. The facility provides fuel products and related components and services for commercial pressurized water reactor and boiling water reactor customers worldwide.

The Perma-Fix Northwest Richland facility is a commercial treatment, storage, and disposal (TSD) facility located on 35 ac (14 ha) adjacent to the DOE Hanford Site. This facility receives, manages, and treats both LLRW and mixed LLRWs from the Hanford Site. Westinghouse Electric Company operates the Richland Service Center. The facility can be used for a variety of fabrication projects, chemical mixing, maintenance, repair of hot equipment, and laboratory testing.

1.3.14 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) in Benton, Franklin, Grant, and Adams Counties. 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 administrative units: Rattlesnake (Fitzner/Eberhardt Arid Lands Ecology Reserve), Columbia River Corridor, Ringold, Wahluke, and Saddle Mountain. The U.S. Fish and Wildlife Service (USFWS), WDFW, and DOE-RL manage portions of the monument. The DOE-RL 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 the CGS.

1.3.15 Manhattan Project National Historical Park

Established in November 2015, one of the nation's newest national parks is located in three areas of the United States (Oak Ridge, Tennessee; Los Alamos, New Mexico; and Hanford, Washington). These areas 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-World War II 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

Cleanup of the Hanford Site is overseen by two DOE offices, the DOE-RL and the U.S. Department of Energy, Office of River Protection (DOE-ORP). The DOE-RL and DOE-ORP 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 the Interior's National Park Service, acting as interpreter and offering visitor services and assistance with historical preservation.

The DOE-RL is 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 following is a list of DOE-RL's principal contractors and their respective responsibilities.

- Mission Support Alliance, LLC (MSA) was awarded the Mission Support Contract for the Hanford Site in 2009. MSA is a joint venture between Leidos 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 Hill 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, and remediation of 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.
- 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 8,000 Hanford workers. Besides providing medical monitoring and qualification-for-work exams, services also include operating and maintaining two clinical facilities, epidemiological studies of Hanford Site workers, and maintenance of the medical records of Hanford workers.

The DOE-ORP was established by Congress in 1998 as a field office to manage the retrieval, treatment, and disposal of approximately 54.1 million gal (204.8 million 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 World War II and post-war production of nuclear weapons fuel. In support of this mission, DOE-ORP is responsible for the safe operation of the tank farms and 200 Area facilities, and construction and operation of the WTP located in the Central Plateau. The following is a list of DOE-ORP's principal contractors and their responsibilities at the Hanford Site.

- Wastren Advantage, Inc. (WAI) was awarded the Laboratory Analytical and Testing Services contract in 2014. WAI operates, manages, and maintains the Analytical Services functions of the Hanford 222-S Laboratory. Technicians test some 25,000 samples of materials that come in from numerous projects on the Hanford Site.
- BNI was awarded the contract to design, construct, and commission the WTP in 2000. When complete, the WTP will process and stabilize radioactive and chemical waste currently stored at the Hanford Site. The WTP will cover 65 ac (26 ha) with four nuclear facilities (Pretreatment, High-Level Waste Vitrification, Low-Activity Waste Vitrification, and an Analytical Laboratory), as well as operations and maintenance buildings, utilities, and office space.
- Washington River Protection Solutions, LLC (WRPS) was awarded the Tank Operations Contract in 2008. It is WRPS' responsibility to maintain and operate the Tank Farms, 242-A Evaporator, and supporting Tank Farm infrastructure. WRPS is owned by AECOM and Atkins with AREVA as the primary subcontractor. WRPS is responsible for safely managing the underground waste storage

tanks and preparing the systems to feed waste to the WTP for immobilization. The waste is stored in 149 single-shell tanks and 28 double-shell tanks located in the 200 Areas. The 242-A Evaporator is located in the 200-East Area of the Hanford Site and is critical to the safe management of Hanford's tank waste. It began operating in 1977 to reduce the volume of waste stored in Hanford's underground tanks.

The DOE Office of Science manages DOE's science and technology programs, goals, and objectives at the Hanford Site. The principal contractor at the Hanford Site is PNNL, operated by Battelle Memorial Institute 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. PNNL is home to DOE's Environmental Molecular Sciences Laboratory, a national scientific user facility leading molecular-level discoveries for DOE's Office of Biological and Environmental Research.

1.5 Fire Protection and Management

RL Hibbs

Following the DOE complex-wide fires of 2000, DOE Headquarters instituted a moratorium on prescribed burning. In May 2001, field offices were granted approval authority for specific prescribed fire plans. Prescribed fire plans are designed to address areas along designated fire breaks that need improvement and accumulations of biomass fuels (e.g., tumbleweeds). In addition to fire break maintenance and fuel reduction, prescribed fire can be a valuable and cost effective tool for the ecosystem and the mitigation of noxious/invasive plant species.

The Hanford Fire Department vigorously pursues compliance, as directed by DOE, with all applicable environmental compliance regulations. Included in the prescribed fire plan are technical data for use by appropriate personnel for decision making in the fire environment with respect to prescribed fire application. The purpose of each prescribed fire plan is to identify specific accomplishable objectives and to ensure compliance for each type of fire application.

Site-specific burn plans are prepared in support of each application of prescribed fire. Prior to conducting prescribed burning, in accordance with approved plans, burn permits must be in place and [National Environmental Policy Act of 1969](#) (NEPA) documentation (including cultural and ecological resource reviews) must be completed.

In addition, the requirements for other applicable regulations must be followed pursuant to existing procedures (e.g., *Clean Air Act*, *Clean Water Act*). Each burn plan uses a Specific, Measurable, Achievable, Realistic, and Time (SMART) framework that is applied to all portions of the burn plan in order to ensure that fire application is appropriate.

Detailed information on Hanford Fire Department's prescribed burning activities is available in *HNF-44199, Hanford Fire Department 2018 Prescribed Fire Plan*.

1.6 Climate and Meteorology

GE Gutierrez, PJ Perrault

The Hanford Meteorology Station is located on the Hanford Site's 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. This data is used by a broad range of scientific and clean-up endeavors across site. 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 minutes. 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 1 tower that is 400 ft (121 m) high. Meteorological information collected at these stations includes wind speed, wind direction, temperature, precipitation, atmospheric pressure, dewpoint temperature, wet-bulb global temperature, solar radiation, relative humidity, and subsurface soil temperature; however, not all data are collected at all stations. Other specialized meteorological data such as cloud height, visibility, present weather, and freezing rain detection is collected at select sites.

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 to 7 mph (3 m/s), and highest during summer, averaging about 8 to 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 1-6 shows the 2016 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, 29, and 32 are 10 ft (3 m) tall, leading to small changes in wind data.

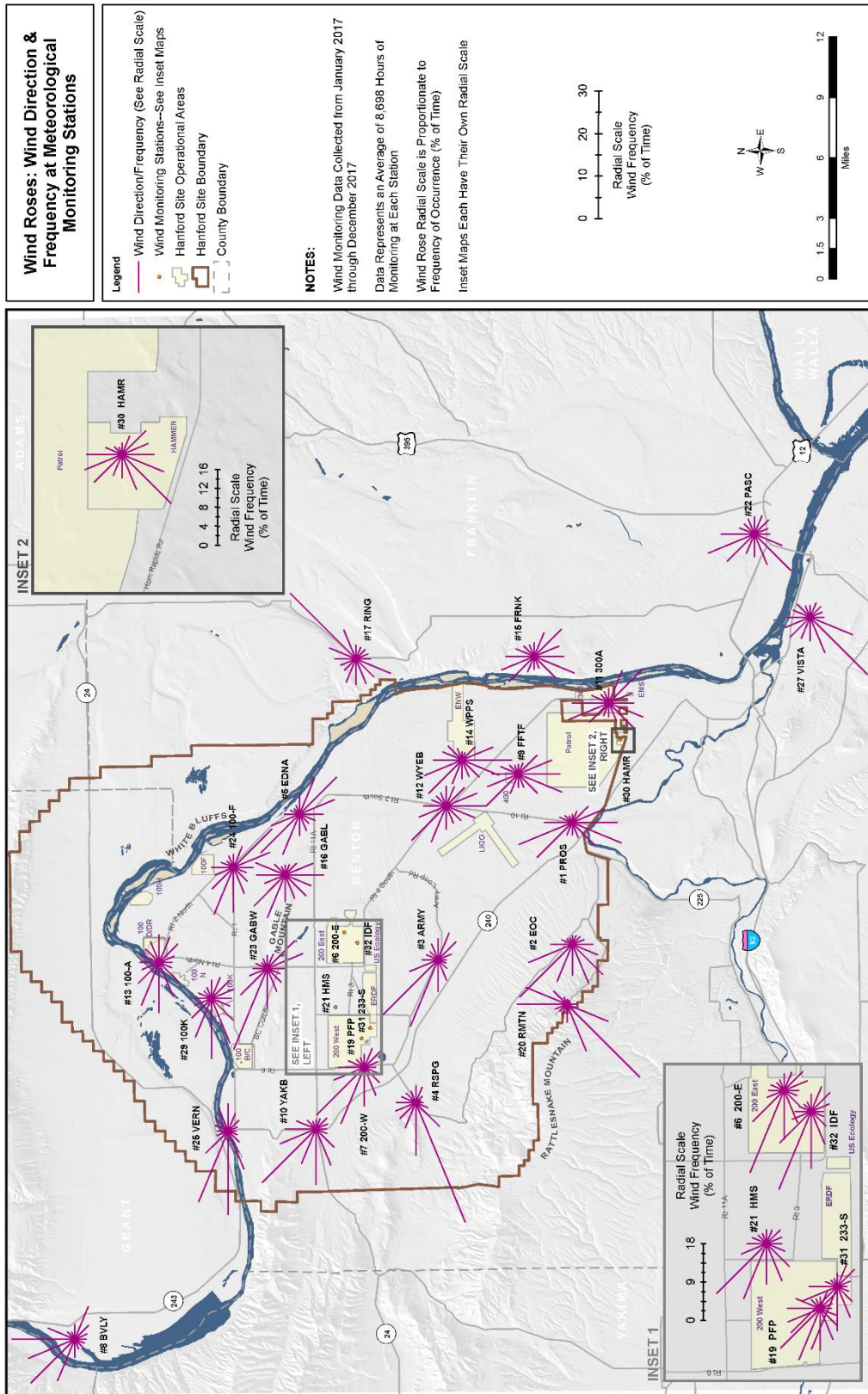


Figure 1-6. Meteorological Monitoring Network Wind Roses from 2017
NOTE: Measured at a height of 30 ft (9 m).

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.

1.6.1 Historical Climatological Information

Table 1-1 shows the climatological information for the Hanford Meteorological Station from 1945 through 2017.

Table 1-1. Hanford Meteorological Station Climatological Information for 1945 through 2017.

	Normal annual	Highest monthly average	Lowest monthly average	Record highest monthly average	Record lowest monthly average	Highest daily	Lowest daily
Temperature °F (°C)	53.9 (12.2)	77.1 (25.1)	31.1 (-0.5)	82.8 (28.2)	12.1 (-11.1)	113 (45)	-23 (-31)
Rel Humidity %	55.3	77.2	36.5	90.5	21.9	100	6
Precipitation in. (cm)	7.08 (17.98)	-	-	12.31 (31.23) ^a	2.99 (7.59) ^a	1.91 (4.9)	-
Snowfall in. (cm)	-	-	-	56.1 (142.5) ^b	0.3 (0.8) ^b	12.4 (31.5)	-
Wind Speed mph (m/s)	7.6 (3.4)	9.0 (4.0)	5.9 (2.6)	11.1 (5.0)	2.9 (1.3)	33.7 (15.1)	0.3 (0.1)
Pressure in./Hg (mb)	29.213	29.329	29.129	29.638	28.999	30.23 (1053.8)	28.10 (977.3)

- Not reported

^a Precipitation records are for a year

^b Snowfall records are for a season

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 [PNNL-15160, Hanford Site Climatological Summary 2004 with Historical Data](#).

1.6.2 Meteorological Monitoring

The average temperature for 2017 was 53.2 °F (11.8 °C), which was 0.7 °F (0.4 °C) below normal. During 2017, 7 months were warmer than normal, 5 months were cooler than normal. April had the greatest positive departure at 3.6 °F (2 °C) above normal and January had the largest negative departure at 11.8 °F (6.5 °C) below normal.

Precipitation totaled 8.60 in. (21.84 cm), which is 120% of normal precipitation (7.14 in. [18.14 cm]). Greatest monthly total of precipitation was 1.78 in. (4.52 cm) in February, and lowest monthly total was

a trace in July. February 15 and 16 had the greatest 24-hour precipitation at 0.55 in. (1.4 cm). Snowfall for 2017 totaled 30 in. (76.2 cm), which was 196% of normal (15.3 in. ([38.6 cm])).

Average wind speed was 7.8 mph (3.5 m/s), which was 0.2 mph (0.09 m/s) above normal. Occurring on April 7, the peak gust for the year was 61 mph (27.7 m/s). Peak gusts of 55 mph (24.6 m/s) and 50 mph (22.3 m/s) were recorded in March and November, respectively.

The growing season was 181 days in 2017. This made 2017's growing season just below the normal of 184 days. The last frost in spring was April 15, and the first frost in fall was October 14. The longest growing season was 2016 at 235 days. The shortest growing season was 1974 at 142 days.

Monthly and annual climatological data collected at the Hanford Meteorology Station is provided in Table 1-2. Real-time and historical data from the Hanford Meteorology Station are available at <http://www.hanford.gov/hms>, which includes hourly weather observations, 15-minute data, monthly climatological summaries, and historical data.

1.7 Stakeholder Involvement

JR Draper

DOE encourages information exchange and public involvement in discussions and decision making regarding Hanford Site cleanup and remediation actions. Participants help guide cleanup decisions and post-cleanup outcomes, these participants include the public; Indian 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.

1.7.1 Role of Native American Tribes

K Lutz

The role of Indian Tribes at the Hanford Site is guided by DOE O 144.1, [Department of Energy American Indian Tribal Government Interactions and Policy](#), which communicates departmental, programmatic, and field responsibilities for interacting with American Indian governments. DOE O 144.1 incorporates policy and consultation guidance in working with Indian Tribes. DOE will consult with any American Indian or Alaska Native Tribal governments with regard to any property to which that Tribe attaches religious or cultural importance and that might be affected by a DOE action. The policy outlines the trust relationship that DOE has with Indian 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 Framework to Provide Guidance for Implementation of DOE's American Indian and Alaska Native Tribal Government Policy," provides additional guidance on how Tribal consultation is to be conducted.

Table 1-2. Meteorology Station^a Monthly and Annual Climatological Data.

Month	Temperature (°F)								Precipitation (in.)				Relative Humidity (%)		15-m Wind ^b				
	Averages				Extremes				Total	Departure ^c	Snowfall		Average	Departure ^c	Average Speed (mph)	Departure ^c	Peak Gusts		
	Daily Maximum	Daily Minimum	Monthly	Departure ^c	Highest	Date	Lowest	Date			Total	Departure ^c					Speed (mph)	Direction	Date
Jan	40.2	29.3	34.7	+1.3	57	22	11	2	1.47	+0.53	3.5	-1.1	86.4	+6.6	5.6	-0.7	33	WSW	29
Feb	53.1	33.6	43.4	+5.2	66	27	24	3 ^d	0.27	-0.43	0.2	-2.1	71.2	+0.5	7.1	+0.2	53	WSW	28
Mar	59.5	36.4	48.0	+1.5	75	31	28	18	1.01	+0.44	0	-0.4	57.6	+0.4	9.3	+1.4	55	W	1
Apr	75.2	46.7	61.0	+7.5	89	20	37	6	0.34	-0.21	0	0	42.4	-5.9	8.9	+0.4	43	WSW	4
May	79.3	50.9	65.1	+3.0	91	3	44	28	0.20	-0.31	0	0	40.7	-2.5	9.5	+0.7	46	NW	26
Jun	86.8	56.8	71.8	+2.2	106	6	42	19 ^d	0.38	-0.13	0	0	33.1	-6.5	9.6	+0.6	43	NW	29
Jul	90.4	63.1	76.7	-0.4	106	29	53	5	0.27	+0.09	0	0	34.2	+0.1	10.3	+1.7	43	NW	4
Aug	92.6	61.3	77.0	+1.2	101	14	51	31	T	-0.18	0	0	28.5	-7.2	8.0	+0.1	39	NW	5
Sep	80.1	51.2	65.7	-0.7	94	10	42	14	0.08	-0.23	0	0	40.1	-2.8	8.0	+0.7	40	NNW	8
Oct	63.1	45.3	54.2	+1.1	77	8	33	12	2.59	+2.10	0	0	67.1	+11.0	8.2	+1.5	50	SW	14
Nov	55.7	38.9	47.3	-6.8	69	12	28	17	0.57	-0.38	0	-2.0	76.0	-2.1	7.3	+0.6	51	S	24
Dec	34.8	19.9	27.3	-3.8	56	3	-4	17	0.47	-0.73	4.1	+1.1	76.4	-4.8	6.4	+0.5	36	W	27
Year ^e	67.6	44.5	56.0	+2.1	106	Jul 29 ^d	-4	Dec 17	7.65	+0.57	7.8	-7.5	54.5	-0.8	8.2	+0.6	55	W	Mar 1

Note: Refer to Appendix A, Table A.2, for unit conversion information.

^a 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)

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

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

^d Latest of multiple occurrences

^e Yearly averages, extremes, and totals

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 Indian Tribes on certain issues include the [*American Indian Religious Freedom Act of 1978*](#), the NEPA, [*Archaeological Resources Protection Act of 1979*](#), [*National Historic Preservation Act of 1966*](#) (NHPA), and the *Native American Graves Protection and Repatriation Act of 1990*.

As Hanford Site cleanup progresses, Indian 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 (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 Indian 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, who 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 Yakama Nation, and supports Tribal involvement in decisions made at Hanford. Funding enables Indian 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>.

1.7.1.1 2017 Activities. DOE-RL continued to interact with the Tribes regarding Tribal access and use of the Hanford Site. In August 2017, the Secretary of Energy visited the Hanford Site and met with the Tribes to hear firsthand the rich cultural history and importance of the Columbia Basin and Columbia River to the Tribes. As an outcome of the discussion, the Secretary requested DOE-RL lead a Hanford Tribal Leaders Dialogue to discuss a more holistic approach to Tribal involvement in the DOE's Hanford decision making and future vision for Long-Term Stewardship at Hanford.

As part of mitigations agreed upon with the Nez Perce, CTUIR, and Wanapum for the transfer of land out of federal control, DOE and the Tribes finalized Tribal revegetation and/or rehabilitation projects to lands within documented Traditional Cultural Properties. The projects are in the planning process and will be conducted in the Preservation Area on lands managed by PNSO. The projects will span 5 years and can include plant revegetation, cultural site rehabilitation, weed suppression, and research and publication. DOE coordinated Tribal participation in Project Management Essentials training to assist with these projects.

The DOE-RL continued participation in the USFWS's Working Group. This group was formed to address motorized public access to the summit of Rattlesnake Mountain – another Traditional Cultural Property identified by the Yakama Nation.

The Tribal Program also conducted several annual events, such as Tribal training for DOE and Contractor managers; HAMMER Tribal Subcommittee participation; and participation in the bi-annual State and

Tribal Government Working Group, the annual Environmental Management Tribal Leader Dialogue, and the Secretary of Energy's Tribal Summit.

1.7.2 Cultural and Historic Resource Consultations

K Lutz

The NHPA requires federal agencies to consult with Indian Tribes, the Advisory Council on Historic Preservation, State Historic Preservation Officers, local government representatives, and the interested public on cultural and historic resource matters. The NHPA implementing regulations (36 CFR 800) require that DOE consider the effect of its actions on significant cultural and historic resources in consultation with consulting parties. DOE-RL solicits and gathers input from Indian Tribes, interested parties, and the Washington State Historic Preservation Officer to identify and evaluate cultural and historic resources within its areas of potential effect. DOE-RL assesses the impacts of its activities on significant resources and seeks concurrence with the Washington State Historic Preservation Officer.

DOE-RL's Cultural and Historic Resource Program consults with the Washington State Historic Preservation Officer, the Yakama Nation, the CTUIR, the Nez Perce Tribe, and the Wanapum through monthly and individual meetings and discussions, field walkdowns, and project comment resolution. Tribal cultural experts discuss project scope and design on a monthly basis with DOE-RL, the State Historic Preservation Officer, Tribal representatives, and other interested parties.

The Program also consults with other parties that express an interest in cultural and historic resources located on the Hanford Site, including groups such as the Benton County Historical Society, East Benton County Historical Museum, the Franklin County Historical Society and Museum, and the Reach Museum.

The DOE/RL-98-10, [Hanford Cultural Resources Management Plan](#), provides guidance on cultural and historic resources, cultural materials, and archaeological resources. The Plan also contains guidance on consultation in accordance with other statutes including, but not limited to, the *Native American Graves Protection and Repatriation Act* and the *Archaeological Resources Protection Act of 1979*.

[DOE P 141.1, Department of Energy Management of Cultural Resources](#), ensures that DOE-RL integrates cultural resources management into its mission and activities. Consultation with affected stakeholders is pivotal to maintaining the cultural and historical values associated with identified cultural resources for future generations and implementing all stewardship responsibilities.

1.7.2.1 2017 Activities. In 2017, the Cultural and Historic Resources Program focused on more than 150 proposed projects. DOE-RL hosted 10 monthly meetings with Tribal representatives. DOE-RL consulted on one Memorandum of Agreement (MOA) and completed the signature process during this year. New technologies were added to the Section 110 monitoring program in consultation with Tribes to document cultural resources during routine monitoring activities.

1.7.3 Hanford Natural Resource Trustee Council

TC Post

The *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) 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
- Yakama Nation.

Established in 1996 via an MOA, 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. A revised MOA was approved by the Trustees in FY 2016 (DOE-RL 2016). The MOA supersedes the 1996 Hanford Site Trustee MOA.

1.7.3.1 2017 Activities. Hanford NRDA work in fiscal year FY 2017 was focused on four primary areas of injury study: Aquatic Ecological Services, Terrestrial Ecological Services, Groundwater Ecological Services, and Tribal Loss Services. Trustees are currently overseeing 11 injury/restoration studies of which 7 will be completed in FY 2018.

The studies are based on the draft *Hanford Natural Resource Damage Assessment Injury Assessment Plan* (HNRT 2012) approved by the Council in 2013. The Council's goal is to complete the injury assessment and prepare a Restoration Plan by 2024. Implementation of the Injury Assessment Plan 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 continued to meet on a monthly basis to plan, organize, implement, and direct Hanford NRDA activities.

Project Teams met on a monthly basis to further oversee and implement the critical elements of each study. The Aquatic Project Team oversaw an Aquatic Data Compilation effort that collected and centralized all historical aquatic data. The data will be analyzed and used to quantify lost aquatic ecological services. The Aquatic Project Team also oversaw a Hanford Reach Habitat Assessment and Chinook Salmon Population Modeling of the effects of Hanford contaminants on early life stages.

Trustees completed a Terrestrial Habitat Disturbance Inventory across the Hanford Site and an Inventory of Institutional Controls related to remediated waste sites. A Terrestrial Habitat Recovery Analysis was completed that included a two-day workshop with an expert panel on shrub-steppe habitat restoration and recovery. Trustees also completed a Hanford Natural Resource Damage Assessment Data Quality Objectives Report to support terrestrial non-process area surface soil sampling. A Groundwater Loss Services study was completed by Trustees and three Tribal Loss Services studies are ongoing.

Information about the Council, including its objectives, history, and projects, is available online at <http://www.hanford.gov/page.cfm/hnrtc>.

1.7.4 Public Involvement in Hanford Site Decisions

RD Buel

DOE-RL and DOE-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 2017) 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 June 2017. During calendar year 2017, the Hanford Site worked to the June 2017 Plan (TPA 2017).

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:

- 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 electronic mailing list, visit the Listserv website (<http://listserv.ecology.wa.gov/scripts/wa-ECOLOGY.exe?SUBED1=HANFORD-INFO&A=1>) to subscribe or send an email to Hanford@ecy.wa.gov.
- Hanford Site Public Involvement Activities. Available at <http://www.hanford.gov/pageAction.cfm/calendar>, 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 Public Involvement Opportunities page on the Hanford website

(<https://www.hanford.gov/page.cfm/Outreach/PublicCommentOpportunities>), a public involvement calendar is available that frequently provides upcoming key public activities, including Hanford Advisory Board (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 from the public (including workers), about the Hanford Site cleanup public involvement opportunities. What began as a challenging, hand-written response interpretation and information gathering at biennial meetings has become an annual electronic survey. Among other lessons learned, the TPA agencies have used the feedback to improve printed communications materials and the structuring of public meetings. 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, Washington); on the TPA Administrative Record Public Information Repository website (<http://pdw.hanford.gov/arpir/>); 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 federal agencies; Tribal governments; and citizen groups.

Hanford Site cleanup documents are also available to the public through the TPA Administrative Record Public Information Repository website (<http://pdw.hanford.gov/arpir/>). 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 et al. 2011a, CERCLA, [*Resource Conservation and Recovery Act of 1976*](#) (RCRA), and NEPA; HAB meetings; Hanford 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:

DOE-RL	(509) 376-7501
DOE-ORP	(509) 376-9292
Ecology	(509) 372-7950
EPA	(509) 376-4919

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

1.7.5 State of Oregon

RD Buel

DOE recognizes Oregon's unique role and interests at the Hanford Site and its concerns with protecting Columbia River resources. In 2017, DOE-RL and DOE-ORP updated a 2004 Memorandum of Understanding (DOE-RL and DOE-ORP 2017) with the State of Oregon to consult and, when 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.

1.7.6 Hanford Advisory Board

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 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 https://www.hanford.gov/files.cfm/Membership_List_080918.pdf

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 Advice and Responses website at <http://www.hanford.gov/?page=453>. Additional information about the HAB, including its charter (operating ground rules), is available at <https://www.hanford.gov/page.cfm/hab>.

In 2017, the HAB provided DOE-RL with two pieces of advice regarding the HAB annual budget and the Hanford State-of-the-Site meetings. The TPA Agencies' responses to these advices may be found at [the response to budget advice](#) and [the response to State of the Site advice](#) web pages.

1.8 Hanford Site Regulatory Oversight

JR Draper

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. The EPA and Ecology are the two main agencies who regulate Hanford Site cleanup as part of the TPA. In addition, the Defense Nuclear Facilities Safety Board (DNFSB) provides oversight of DOE work.

1.8.1 Environmental Regulations

Before 1986 environmental laws only regulated private industry and state and local governments. Ecology and the EPA had to decide how to apply environmental regulations to a federal agency (DOE) at Hanford. Instead of lengthy litigation, these three agencies agreed to manage cleanup under the Tri-

Party Agreement. Signed in 1989, the original agreement had a schedule to clean up the Hanford Site over a 30-year period. The TPA defines roles and responsibilities between Ecology and EPA for regulating hazardous waste sites.

EPA's purpose is to ensure that:

- All Americans are protected from significant risks to human health and the environment where they live, learn, and work.
- National efforts to reduce environmental risk are based on the best available scientific information.
- Federal laws protecting human health and the environment are enforced fairly and effectively.
- Environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade. These factors are similarly considered in establishing environmental policy.
- All parts of society (e.g., communities; individuals; businesses; and state, local, and Tribal governments) have access to accurate information sufficient to effectively participate in managing human health and environmental risks.
- Environmental protection contributes to making our communities and ecosystems diverse, sustainable, and economically productive.
- The United States plays a leadership role in working with other nations to protect the global environment.

When Congress writes an environmental law, EPA implements it by writing regulations. Often, EPA sets national standards that states and Tribes enforce through their own regulations. If they fail to meet the national standards, EPA can help. EPA also enforces regulations and helps companies understand the requirements.

Ecology's Nuclear Waste Program focuses on keeping people and the environment safe from the dangers of mixed radioactive and chemically hazardous waste by:

- Enforcing state environmental regulations and cleanup at the Hanford Site and at other facilities managing nuclear waste statewide
- Promoting public involvement and community outreach and education in order to enhance nuclear waste management, compliance, and cleanup of the Hanford Site
- Ensuring appropriate oversight for the safe management and disposal of radioactive hazardous wastes at the Richland commercial LLRW disposal site.

The designation of lead regulatory agency and regulatory process for each operable unit, TSD group/unit or milestone at Hanford is determined through a change process. EPA and Ecology have joint authority to determine the choice of lead regulatory agency and regulatory process in consultation with DOE.

The WDOH's Hanford Environmental Radiation Oversight Program provides oversight of DOE's radiation monitoring programs. DOE's environmental radiation monitoring programs determine the impact of Hanford releases on the environment and the public. The WDOH program independently verifies the quality of DOE's program. The objectives of the oversight program are to:

- Independently verify the quality of DOE's monitoring programs at the Hanford Site by conducting sampling at locations having the potential to release radionuclides to the environment or areas where releases may have an impact.
- Use data from DOE and WDOH to assess the potential impact on people by comparing radionuclide concentrations in samples with background samples. Note that WDOH's monitoring program is intended to be oversight and not a program that finds and reports the highest levels of environmental contaminants.
- Address public concerns about environmental radiation at the Hanford Site.

1.8.2 Hanford Federal Facility Agreement and Consent Order

SW Davis, SL Brasher

The TPA is an agreement (Ecology et al. 2011a) among the TPA agencies to achieve compliance on the Hanford Site with the CERCLA remedial action provisions and RCRA TSD unit and corrective action regulations. The TPA is an interagency agreement under CERCLA, Section 120, a corrective action order under RCRA, and a consent order under the [RCW 70.105, "Hazardous Waste Management,"](#) that :

- Defines RCRA and CERCLA cleanup commitments
- Establishes responsibilities
- Provides a basis for budgeting
- Reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones.

Attachment 2 is the Action Plan of the Tri-Party Agreement, which describes how to implement the cleanup and permitting efforts; this includes milestones (in appendix D) for initiating and completing specific work and procedures the TPA agencies will follow (Ecology et al. 2011b).

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 (Ecology et al. 2011a). As new change control forms are approved through the TPA change control process, they are incorporated into the TPA. Electronic copies of Revision 8 of the TPA are publicly available online and can be viewed at <https://www.hanford.gov/page.cfm/TriParty/TheAgreement>. For additional TPA information or questions, call the Washington State Department of Ecology, Nuclear Waste Program office at (509) 372-7950 or e-mail to Hanford@ecy.wa.gov.

1.8.2.1 TPA Milestone Status. The TPA commits DOE to comply with the remedial action provisions of CERCLA, as well as with RCRA TSD unit regulations and corrective action provisions, including Washington State’s implementing regulations ([WAC 173-303, “Dangerous Waste Regulations”](#)).

From 1989 through December 31, 2017, a total of 1,314 TPA milestones were completed and 339 target dates were met. During 2017, 34 specific cleanup milestones were scheduled for completion; of those, 10 milestones were deleted, 22 milestones were completed on time, 1 milestone was missed, and 0 were in negotiation. In addition, one target date was met, zero target dates were deleted, and zero target dates were in negotiation.

1.8.2.2 TPA-Approved Modifications. During 2017, 35 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/>.

1.8.3 Defense Nuclear Facility Safety Board

JR Draper

Congress created the DNFSB as an independent agency within the Executive Branch to identify the nature and consequences of potential threats to public health and safety at DOE’s defense nuclear facilities, to elevate such issues to the highest levels of authority, and to inform the public. During 2017, the DNFSB oversaw projects pertaining to each contractor at the Hanford Site (e.g., Plutonium Finishing Plant, T-Plant, WTP, 242-A Evaporator, and Tank Farms). Reports produced by the DNFSB reporting on Hanford Site projects can be viewed at <https://www.dnfsb.gov/documents>.

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2017 Highlight

Resource Conservation and Recovery Act

The U.S. Department of Energy (DOE) and its contractors continue to manage dangerous waste in accordance with the *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste* (Ecology 1994). The DOE and Washington State Department of Ecology (Ecology) are working together to develop a renewal permit to replace the existing permit. Development and issuance of the renewal permit is a large undertaking and will take several years to complete. Completion of this effort is targeted for the latter part of 2019.

Air Quality and Protection

The Hanford Site continued to comply with the Hanford Site Air Operating Permit that contains requirements for 337 emission sources. No Notices of Violation were issued to the Hanford Site. An application for renewal of the permit was submitted to Ecology and deemed to be complete; thereby, ensuring the current permit will continue until a renewed permit is issued.

Radiation Protection of the Public and the Environment

Potential sources of radionuclide release from the Hanford Site include airborne emissions, groundwater seeping into the Columbia River, and fugitive emissions from soils and facilities. The annual dose to a maximally exposed member of the public continued to be well below the DOE public dose limit of 100 mrem/yr. The dose to biota of the Columbia River and other offsite locations was also well below the DOE standards. Section 4.0, *Radiological Protection and Doses*, explains the determination of public and biota dose in detail.

Pollution Prevention and Waste Minimization

The Hanford Site diverted 57% (1,224 metric tons) of nonhazardous solid waste for recycling and diverted 75% (2909 metric tons) of construction and demolition debris.

Greenhouse Gas Reduction

The Hanford Site continued to reduce greenhouse gas emissions. The Site has reduced Scope 1 and Scope 2 emissions by 23% and Scope 3 emissions by 31.2% since the 2008 baseline.

External Environmental Audits and Inspections

U.S. Environmental Protection Agency, the Washington State Department of Ecology, and the Washington State Department of Health representatives conducted audits, inspections, and site visits of various Hanford Site environmental programs to ensure regulatory compliance with state and federal regulations, the Hanford Federal Facility Agreement and Consent Order, and associated permits and licenses.

2.0 Compliance Summary

JR Draper

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 the U.S. Department of Energy (DOE) orders, notices, directives, policies, and guidance (Section 2.9). These measures include specific requirements, actions, plans, and schedules identified in the [Hanford Federal Facility Agreement and Consent Order](#) (Tri-Party Agreement [TPA]) (Ecology et al. 1989a) and other compliance or consent agreements. The U.S. Department of Energy, Richland Operations Office (DOE-RL) and Office of River Protection (DOE-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, Chg 1, Environmental, Safety and Health Reporting](#). The Order is intended to ensure that the DOE, including the National Nuclear Security Administration, receives timely, accurate information about events that have affected or could adversely affect the health, safety, and security of the public or workers, the environment, the operations of DOE facilities, or the credibility of DOE.

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 U.S. Environmental Protection Agency (EPA) or Washington State Department of Ecology (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

ME Mills

Enacted by Congress on October 6, 1992, the [Federal Facility Compliance Act of 1992](#) amends Section 6001 of the [Resource Conservation and Recovery Act of 1976](#) (RCRA) to specify that the U.S. waives sovereign immunity from civil and administrative fines and penalties for RCRA violations. In addition, 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 RCRA 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 Reports pursuant to TPA Milestone M-026-01.

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](#) amended 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 treatment, storage, and disposal (TSD). The Hanford Site dangerous waste activities are subject to applicable provisions of [WAC 173-303, "Dangerous Waste Regulations,"](#) including provisions in the WAC 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 the following seven permittees:

- DOE-RL and DOE-ORP as the owners/operators
- Five of DOE's contractors, as co-operators
 - Bechtel National, Inc.
 - CH2M Plateau Remediation Company (CHPRC)
 - Mission Support Alliance, LLC (MSA); the permit identifies MSA as a permittee but not a co-operator
 - Pacific Northwest National Laboratory
 - Washington River Protection Solutions, LLC (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. Because the DOE submitted a timely application for a renewal permit, and Ecology subsequently determined the application was complete, the DOE is allowed to operate under the expired permit per WAC 173-303-806(7). The 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](#) (Hanford Facility Dangerous Waste Permit) (Ecology 1994).

In May 2012, Ecology issued a draft renewal permit ([Ecology 2012](#)). Ecology received more than 4,000 comments on the draft renewal 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 the 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. The process will 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.

Ecology has completed activities associated with the first bullet above. Activities associated with the second bullet are underway.

During 2017, modifications were made to the expired permit. The changes affected requirements for the following TSD units pursuant to WAC 173-303-830, "Permit Changes":

- Liquid Effluent Retention Facility and 200 Areas Effluent Treatment Facility (Operating Unit Group 3)
- 242-A Evaporator (Operating Unit Group 4)
- 325 Hazardous Waste Treatment Unit (Operating Unit Group 5)
- Hanford Tank Waste Treatment and Immobilization Plant (WTP) (Operating Unit 10)
- 1325-N Liquid Waste Disposal Facility (Closure Unit Group 1)
- 1301-Liquid Waste Disposal Facility (Closure Unit Group 2)
- 207-A South Retention Basins (Closure Unit Group 5)
- 225B Waste Encapsulation and Storage Facility (Closure Unit Group 6)
- 300 Area Process Trenches (Post-Closure Unit Group 1)
- 183-H Solar Evaporation Basins (Post-Closure Unit Group 2).

2.1.2.2 Regulatory Agency Inspections

SA Szendre

DOE utilizes two internal tracking databases to track regulatory agency inspection activity and agency enforcement actions. The Regulatory Agency Inspection Database includes documentation for regulatory agency inspections of DOE facilities on the Hanford Site managed by the DOE-RL, DOE-ORP, and Pacific Northwest Site Office (PNSO). 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 (Section 2.9).

During calendar year (CY) 2017, 79 regulatory agency inspections were conducted at DOE facilities on the Hanford Site: Ecology conducted 45, WDOH conducted 31, EPA (Region 10) conducted 1, the City of Richland conducted 2, and DOE conducted 0. Some of the agency inspections were conducted jointly between multiple agencies.

Ecology inspections were conducted by the Nuclear Waste Program Office located in Richland, Washington. EPA Region 10 inspections focused on the Plutonium Uranium Extraction Facility (PUREX) Tunnel 1 collapse and the demolition of the Plutonium Finishing Plant, and conducted oversight of Ecology and WDOH inspections under EPA-delegated authority. WDOH inspections were performed by the Office of Radiation Protection, Richland, Washington. WDOH also had a high presence during the PUREX Tunnel 1 collapse and the Plutonium Finishing Plant Demolition Project. The City of Richland inspection focused on the 300 Area of the Hanford Site to evaluate compliance with Industrial Wastewater Discharge Permit (CR-IU010) requirements, including the monitoring of wastewater discharges to the publicly-owned treatment works. The DOE-RL, DOE-ORP, and PNSO facility inspections are performed in accordance with the terms and conditions of the Air Operating Permit, Radioactive Air Emissions License, Wastewater Discharge Permits, and RCRA permit. Inspections 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.

RCRA Inspections. The Ecology inspections focused on TSD unit compliance with the Hanford Facility Dangerous Waste Permit (Ecology 2012) and WAC 173-303, *Washington State Dangerous Waste Regulations*. The TSD units and other facilities inspected during CY 2017 included the following:

- 200 Areas Effluent Treatment Facility
- Waste Encapsulation Storage Facility
- 222-S Laboratory
- 400 Area Waste Management Unit
- 242-A Evaporator
- 325 Building
- B-Plant
- Liquid Effluent Retention Facility
- Hexone Storage and Treatment Facility
- Central Waste Complex
- Low-level Burial Grounds Trenches 31 and 34
- Plutonium Finishing Plant
- PUREX/PUREX Storage Tunnel
- Double-shell tank and single-shell-tank tank farms
- T-Plant
- Waste Receiving and Processing Facility
- 90-day accumulation areas
- Satellite accumulation areas
- Universal waste management operations.
- Nonradioactive Dangerous Waste Landfill
- Groundwater Monitoring Network Wells
- Waste Treatment Facility
- Low-level Burial Grounds.

Section II.O of the RCRA permit addresses general inspection requirements required in accordance with WAC 173-303-320. General inspections are conducted in addition to the TSD unit inspections specified in Parts III, V, and VI of the RCRA permit. The RCRA permit requires general inspections of the 100, 200-East, 200-West, 300, 400 Areas as well as the Columbia River shoreline. Inspections are performed annually in these areas by the Hanford contractors, with oversight from DOE, to identify and correct potential malfunctions, deterioration, operator errors, and discharges that 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.

Clean Air Act Inspections

SA Szendre and CJ Perkins

In 2017, the WDOH inspections focused on compliance of point and non-point emission units with the Radioactive Air Emissions License (FF-01). Ecology inspections included inspections of discharge points

(e.g., emergency engines/generators and passive vents and stacks) and packaged boiler systems regulated under the Hanford Site Air Operating Permit.

During CY 2017 two major events occurred that heightened the level of agency interest and presence on the Hanford Site. In June, the PUREX Tunnel 1 partially collapsed causing WDOH and Ecology to conduct multiple site inspections and fact findings visits. The Tunnel 1 was filled with grout to isolate any contamination from being released and to safeguard the remaining portions of the tunnel.

The other notable event occurred in November and December. Radioactive contamination was found outside the radiological controlled zone on mobile office trailers and vehicles near the demolition site of the Plutonium Finishing Plant (PFP) in the 200-West Area. EPA and Ecology sent a letter requesting DOE stop work on the demolition until such time investigations could be completed and safeguards put into place before restarting the demolition. As of December 31, 2017, work on the demolition of the remaining portions of the PFP was still halted.

2.1.2.3 RCRA Groundwater Monitoring

MJ Hartman

The Soil and Groundwater Remediation Project monitors 25 RCRA units on the Hanford Site. Section 8.0 includes a summary of groundwater monitoring activities for the RCRA units during 2017.

[DOE/RL-2017-65, Hanford Site RCRA Groundwater Monitoring Report for 2017](#), includes detailed groundwater monitoring information.

2.1.3 Comprehensive Environmental Response, Compensation, and Liability Act of 1980

GT Berlin

In 1980, Congress passed the [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (CERCLA) to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. Because the operation of nuclear production and disposal facilities at the Hanford Site has 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 review methods, technical assessments, and protectiveness statements. Recommendations to address identified issues are also provided. The results of the four 5-year reviews conducted since 2000 are documented in the [USDOE Hanford Site First Five-Year Review Report](#) (EPA 2001a); [DOE/RL-2006-20, Second CERCLA Five-Year Review Report for the Hanford Site](#); [DOE/RL-2011-56, Hanford Site Third CERCLA Five-Year Review Report](#); and [DOE/RL-2016-01, Hanford Site Fourth CERCLA Five-Year Review Report](#).

The Hanford Site Fourth CERCLA Five-Year Review Report (DOE/RL-2016-01), addressing 2011 through 2015, was completed by DOE-RL in 2017 and received EPA concurrence (EPA 2017). This report aligned with EPA's latest guidance on 5-year review reports, as well as recent training provided to multi-federal agencies as they strove for more consistent reports and the use of substantive tables and figures to more concisely present information that supports the protectiveness statements.

This latest CERCLA 5-year review report (DOE/RL-2016-01) evaluates the protectiveness of 30 operable units with remedies that have been documented in interim or final Records of Decision (RODs). Approximately 16 of the Hanford Site's operable units do not have remedies documented in interim or final RODs at this time; however, they will be addressed in future 5-year review reports as additional RODs are issued. A breakdown of the source and groundwater operable units that are in scope and out of scope for Hanford's fourth CERCLA 5-year review report is provided below.

- In scope (operable units with interim or final RODs):
 - Source operable units: 100-BC-1, 100-BC-2, 100-FR-1, 100-FR-2, 100-IU-2, 100-IU-6, 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-NR-1, 300-FF-1, 300-FF-2, 200-CU-1, 200-CU-3, 200-DF-1, 200-CW-5, 200-PW-1, 200-PW-3, 200-PW-6, 1100-EM-1.
 - Groundwater operable units: 100-FR-3, 100-HR-3, 100-KR-4, 100-NR-2, 300-FF-5, 200-UP-1, 200-ZP-1.
- Out of scope (operable units without RODs):
 - Source operable units: 100-OL-1, 200-BC-1, 200-CB-1, 200-CP-1, 200-CR-1, 200-CW-1, 200-DV-1, 200-EA-1, 200-IS-1, 200-OA-1, 200-SW-1, 200-SW-2, and 200-WA-1.
 - Groundwater: 100-BC-5, 200-BP-5, and 200-PO-1.

Hanford's next CERCLA 5-year review report is due by May 4, 2022.

2.1.3.1 Superfund Amendments and Reauthorization Act of 1986. The [Superfund Amendments and Reauthorization Act of 1986](#) (SARA) amended CERCLA on October 17, 1986. SARA reflected EPA's experience in administering the complex Superfund program during its first 6 years and made the following important changes and additions to the program:

- 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 tools
- 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 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.

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 onsite 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 2017.

Table 2-1. Emergency Planning and Community Right-to-Know Act Requirements Summary. (2 Pages)

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 OSHA hazardous chemical in quantity greater than or equal to 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	Annually by March 1	Local Emergency Planning Committee; State Emergency

Table 2-1. Emergency Planning and Community Right-to-Know Act Requirements Summary. (2 Pages)

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
		substance in quantity equal to or greater than threshold planning quantity or 500 lbs (230 kg), whichever is less.		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
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act CFR = Code of Federal Regulation CY = calendar year OSHA = Occupational Safety and Health Administration				

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 2017 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory (DOE/RL-2018-07) 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 50 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 offsite 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 2017.

Table 2-3. Average Quantity of the 10 Hazardous Chemicals Stored in Greatest Quantities. (2 Pages)

CAS#	Chemical	TPQ	Average Amount (lb/kg)
7647-14-5	Sodium Chloride	10,000	6,368,361/4,762,939
7440-23-5	Sodium	10,000	4,624,378/3,624,378
65997-15-1	Portland Cement	10,000	1,169,903/683,723

Table 2-3. Average Quantity of the 10 Hazardous Chemicals Stored in Greatest Quantities. (2 Pages)

CAS#	Chemical	TPQ	Average Amount (lb/kg)
00-00-0	Diesel fuel (Grades 1 and/or 2)	10,000	1,139,002/737,896
8012-95-1	Mineral Oil	10,000	822,228/822,228
68131-74-8	Fly Ash (Class F)	10,000	430,045/430,045
7664-93-9	Sulfuric Acid	500	350,391/325,758
00-00-0	Petroleum Distillates(Uspecified/Trade Secret)	10,000	339,156 /212,366
8052-42-4	Asphalt (Petroleum)	10,000	336, 579/299,519
7782-63-0	Iron(II) Sulfate hetahydrate	10,000	334,102/334,102

The 2017 Hanford Site Toxic Chemical Release Inventory report (DOE/RL-2018-31) was submitted to EPA and Ecology before the annual July 1 deadline. During CY 2017, 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 sitewide
Xylene	1330-20-7	Gasoline used for stationary equipment
Toluene	108-88-3	Gasoline used for stationary equipment

2.1.5 Reportable Releases

ME Mills

Federal regulations establish reporting requirements for certain environmental releases that must be reported to the National Response Center. The National Response Center is the central point of contact for reporting hazardous substance 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 none of these events required notification to Ecology. These relatively minor spill events primarily involved petroleum products from leaking equipment and vehicles (e.g., hydraulic fluid, diesel fuel, and motor oil). These spills have all been logged per CRD 436.1. All of these spilled products were cleaned up and all resulting materials (e.g., absorbents and impacted soils) were processed for disposal 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 regulations promulgated under the authority granted to EPA by [Toxic Substances Control Act](#) (TSCA). TSCA primarily involves regulation of polychlorinated biphenyls (PCBs). TSCA also regulates other constituents (e.g., asbestos, lead-based paint, and radon). The applicability of TSCA to the management of these constituents at the Hanford Site is discussed below:

- Lead-based Paint
 - The TSCA regulations for lead-based paint are applicable to residential and child-occupied facilities and do not apply to Hanford activities.
- Radon
 - The radon regulations under TSCA pertain to schools and public or assisted-housing and do not apply to Hanford activities.
- Asbestos
 - Asbestos at the Hanford Site is primarily regulated by the *Clean Air Act* and Occupational Safety and Health Administration (OSHA).
 - However, TSCA accreditation and training requirements provided in 40 CFR 763, Appendix C are applicable and the Hanford Site must comply with minimum training standards for personnel engaged in asbestos abatement activities.
- PCBs – federal regulations for PCB use, storage, and disposal are provided in [40 CFR 761](#), [“Polychlorinated Biphenyls \(PCBs\) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions.”](#) 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.
 - In service electrical equipment that might contain PCBs is maintained in accordance with 40 CFR 761.

- Signed on August 31, 2000, [*The Hanford PCB Framework Agreement 8/31/00: Framework Agreement for Management of Polychlorinated Biphenyls \(PCBs\) 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.
- DOE-RL submitted the DOE/RL-2017-27, [*2016 Polychlorinated Biphenyl Annual Report*](#), and DOE/RL-2017-28, [*2016 Polychlorinated Biphenyl Annual Document Log*](#) to EPA on June 29, 2017, 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 (RBDA) continued in 2017 including, but not limited to, single-shell tank waste retrieval activities in accordance with EPA Phase I and II RBDAs for the use of double-shell tank 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 Areas Liquid Waste Processing Facilities.
- The EPA’s 2005 RBDA letter (EPA 2005) 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 2017, DOE is developing plans to place additional K-Basin 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

JW Cammann

The [*National Environmental Policy Act of 1969*](#) (NEPA) requires federal agencies to assess the environmental consequences of proposed actions prior to making decisions that may have environmental effects. The Council on Environmental Quality regulations that implement NEPA (40 CFR 1500-1508) and DOE’s NEPA implementing procedures (10 CFR 1021) ensure compliance with the letter and spirit of NEPA.

Proposed actions are evaluated in accordance with Council on Environmental Quality regulations and DOE NEPA implementing procedures to determine whether an Environmental Impact Statement (EIS) or Environmental Assessment (EA) is required; or the proposed action is categorically excluded (CX) from preparation of an EIS or EA.

This section provides the status of NEPA documentation (EISs, EAs, and CXs) completed or underway at the Hanford Site during CY 2017. NEPA documentation completed in early CY 2018 is also mentioned,

where applicable, to provide the current status. Hanford Site NEPA documentation is available online at <https://www.hanford.gov/page.cfm/Documents>.

2.1.7.1 Hanford Site Environmental Impact Statements. There were no Environmental Impact Statements completed or underway at the Hanford Site during CY 2017.

2.1.7.2 Hanford Site Environmental Assessments. Hanford Site EAs that were completed or underway in CY 2017 are described in this section.

Environmental Assessment for Rebuild of the North Loop 230-kV Electrical Transmission Line (DOE/EA-2033). DOE prepared an EA for the rebuild of approximately 28 mi (45 km) of the North Loop transmission line in the northern part of the Hanford Site. The proposed project would reconfigure switching station and substation components, install equipment and conductors, build and recondition access roads, and remove structures and other ancillary activities. DOE made a determination to prepare an EA for the rebuild of the transmission line on February 1, 2016.

During CY 2017, work continued on the EA and Finding of No Significant Impact (FONSI). The FONSI was signed on May 7, 2018. A *National Historic Preservation Act* (NHPA) Section 106 cultural resources Memorandum of Agreement was prepared during CY 2017 and signed by the Washington State Historic Preservation Officer on May 14, 2018.

Environmental Assessment for Benton-Othello 115-kV Transmission Line Rebuild Project (DOE/EA-2038). An EA is under preparation to assess environmental effects of Avista Utilities' (Avista) proposal to rebuild 12.6 mi (20.27 km) of the Benton-Othello Switching Station electrical transmission line on the Hanford Site. The upgrade on the Hanford Site would begin approximately 0.5 mi (0.8 km) south of State Route 24.

DOE made a determination to prepare an EA for the rebuild of the transmission line on April 6, 2016. A Public Scoping Notice to prepare an EA was issued on January 3, 2017. Avista, in coordination with DOE and other agencies with jurisdiction, has been conducting cultural, ecological, and wetland field studies and a floodplain evaluation. Work continued on the EA during CY 2017.

Environmental Assessment Energy Northwest WNP-1/4 Lease Renewal (DOE/EA-2044). In 1975, the Washington Public Power Supply System (now known as Energy Northwest) obtained a lease from the U.S. Government for Washington Nuclear Power Plant Projects Number 1 and Number 4 (WNP-1/4), which included options for renewing the lease. DOE's proposed action was renewal of an existing lease and the EA analyzed activities authorized by the proposed lease amendment.

Activities that were authorized included subleasing office and warehouse space, and transitioning from groundwater wells to surface water to supply Energy Northwest's Industrial Development Complex with potable water. The existing water distribution system would be used.

DOE made a determination to prepare an EA on June 15, 2016. The FONSI was signed on January 6, 2017.

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 the environment and for which neither an EA nor an EIS is required (10 CFR 1021).

The DOE NEPA Compliance Officer (NCO) approved a total of 51 categorical exclusions during CY 2017. Of these, 40 were annual categorical exclusions to cover routine and recurring work activities planned to be performed during fiscal year (FY) 2018 at the Hanford Site (Mission Support Alliance – 25, CH2M Plateau Remediation Company – 8, and Pacific Northwest National Laboratory – 7). A total of 11 Activity-Specific CXs were approved by the NCO (Mission Support Alliance – 9, Washington River Protection Solutions – 1, and CH2M Plateau Remediation Company – 1). Annual and activity-specific categorical exclusions approved by the DOE NCO may be viewed at

<http://www.hanford.gov/page.cfm/CategoricalExclusions>.

2.1.8 Institutional Controls Plan

R Ranade

The MSA Long-Term Stewardship (LTS) program is responsible for managing institutional controls (IC) along the River Corridor with the exception of a portion of the 100-K Area. CHPRC is responsible for the ICs associated with groundwater. 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. The selected remedies chosen may include ICs through implementation of the remedy and then afterwards. The CERCLA decision documents identify the specific requirements for these 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. ICs such as drilling and excavation restrictions for waste sites with contamination below 15 ft (4.6 m), monitoring and controlling access to the area, and warning signs also may be employed after remediation is completed.

As required by DOE/RL-2001-41, ICs are assessed annually as required by the CERCLA and/or RCRA decision document. Hanford Site 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 Administrative Record Public Information Repository website (<http://pdw.hanford.gov/arpir/>). The Hanford Site CERCLA 5-year review also includes a rollup of the issues/actions noted during of the annual assessments.

The MSA LTS organization is responsible for managing ICs related to Hanford Site access control and the wastes sites in the River Corridor area. The IC assessments conducted in FY 2017 found the following:

- Most of the warning signs along the Hanford Site boundary and at the entrance of the River Corridor areas where cocooned reactor buildings are located were in place and visible. Some fire and wind-

related damage was observed. MSA LTS has initiated a project to replace the missing and damaged signs.

- The fence along State Route 240 was found to have broken wire strands in some places. The broken wire strands were replaced. Other fencing was intact.
 - 1.
- MSA has an ongoing project to replace “No Trespassing” signs that were missing, damaged, and/or could not be seen from the Columbia River.
- The Excavation Permits and Site Evaluation Processes were used successfully to ensure compliance with ICs, which require the restriction of drilling or excavating into the deep zone (below 15 ft [4.6 m]).
- Eight reportable trespassing incidents occurred from October 2016 to September 2017 and were reported to the Benton County Sheriff’s office.

Operable units in the Central Plateau of the Hanford Site also have a number of ICs in both interim and final ROD documents. In CY 2017, an assessment of ICs at 200-UP-1 Operable Unit, 221-U Facility, and 200-ZP-1 Operable Unit identified no deficiencies.

2.1.9 Federal Insecticide, Fungicide, and Rodenticide Act

JM Rodriguez

EPA administers the *Federal Insecticide, Fungicide, and Rodenticide Act*. The Washington State Department of Agriculture administers standards to regulate implementation of the Act in the state, including [RCW 15.58, “Washington Pesticide Control Act,”](#) [RCW 17.21, “Washington Pesticide Application Act,”](#) 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

TA Ikenberry

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) 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 458.1, *Radiation Protection of the Public and Environment*](#) and [DOE O 435.1, Chg. 1, *Radioactive Waste Management*](#). 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 to provide radiological protection of the public and the environment. DOE O 458.1 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 and the International Commission on Radiological Protection); 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, DOE O 458.1 adopted applicable standards issued by the National Council on Radiation Protection and Measurements and International Commission on Radiological Protection, incorporated regulatory requirements applicable to DOE operations, and consolidated and upgraded DOE guidance for property with residual radioactive material.

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. DOE O 458.1 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
- Manage real and personal property to control residual radioactivity
- Ensure potential exposures to the public are as far below established limits as low as reasonably achievable (ALARA)
- 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.

Table 2-5 provides the standards (dose limits) for radiation protection of the public and the environment from routine DOE operations. While the public dose limit of 100 mrem/yr (1 millisievert [mSv]/yr) is the

primary dose standard, other regulations impose additional constraints on the dose that may be received through specific exposure pathways. The air and water pathways are of interest and are also regulated by the EPA and State of Washington; they are discussed in more detail in Sections 2.3 and 2.4. DOE O 458.1 provides dose limits for protection of aquatic and terrestrial plants and animals in the vicinity of radiological activities on the Hanford Site. In addition, dose constraints are provided for the dose that could be received by a member of the public from certain other activities, including radioactive waste management, storage, and disposal, as well as unrestricted release to the public or clearance of real and personal property.

These radiation standards are dose limits but not DOE's expectation for dose to the public and the environment. DOE O 458.1 requires the application of the ALARA process to all routine radiological activities to further reduce (optimize) radionuclide releases and resulting doses to the extent possible.

**Table 2-5. Radiation Protection Standards for the Public and the Environment
from All Routine DOE Operations.^a (2 Pages)**

All Pathways (DOE O 458.1)		
Exposure of members of the public will not cause a total effective dose exceeding 100 mrem (1 mSv) in a year	Total Effective Dose^c	
	mrem/year	mSv/year
Routine public dose	100	1
Temporary public dose ^b , under special circumstances with specific authorization and justification	500	5
Air Pathway Dose Constraints (40 CFR 61 Subpart H, WAC 173-480, WAC 246-247)		
See Section 2.3		
Emissions of radionuclides shall not cause any member of the public to receive an effective dose equivalent of 10 mrem/yr	Effective Dose Equivalent	
	mrem/year	mSv/year
	10	0.1
Water Pathway Dose Constraints (40 CFR 141, WAC 246-290)		
See Section 2.4		
The annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/yr, based on average annual concentrations	Dose Equivalent	
	mrem/year	mSv/year
	4	0.04
Protection of Biota. (DOE O 458.1, DOE-STD-1153-2002)		
Radiological activities must be conducted to protect populations of aquatic animals, terrestrial plants, and terrestrial animals	Absorbed Dose	
	rad/day	mGy/day
Aquatic animal	1	10
Riparian animal	0.1	1
Terrestrial plant	1	10
Terrestrial animal	0.1	1
Radioactive Waste Dose Constraint (DOE O 458.1)		
Exposure from radioactive waste management, storage, and disposal activities shall be ALARA and meet the dose constraint.	Total Effective Dose	
	mrem/year	mSv/year
Public dose constraint	25	0.25
Release and Clearance of Property (DOE O 458.1)		
Exposure from release of real (land and buildings) and personal property shall be controlled to be ALARA and meet dose constraints.	Total Effective Dose	
	mrem/year	mSv/year
Public dose constraint from real property	25	0.25
Public dose constraint from personal property	1	0.01

Table 2-5. Radiation Protection Standards for the Public and the Environment from All Routine DOE Operations.^a (2 Pages)

NOTE: 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.

^a Routine DOE operations imply normal, planned activities and do not include actual or potential accidental or unplanned releases.

^b DOE-RL may request specific authorization from DOE-HQ for a temporary public dose limit greater than 100 mrem/yr (1 mSv/yr). It may be no more than 500 mrem (5 mSv)/yr and cannot exceed an average of 100 mrem/yr (1 mSv/yr) over 5 contiguous years. The request must document the justification, alternative considered, and the application of the ALARA process.

^c Dose units are those in the cited regulation, order or standard. DOE uses the most up-to-date dosimetry system of any United States agency.

ALARA = as low as reasonably achievable

CFR = *Code of Federal Regulations*

DOE-HQ = U.S. Department of Energy, Headquarters

mrem = millirem

mSv = millisievert

mGy = milligray

WAC = *Washington Administrative Code*

NOTE: International dose units shown in italics are not provided in the order or rules but are provided for information.

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 high-level waste, transuranic waste, and low-level waste, including the radioactive component of mixed waste (high-level waste, transuranic waste, and low-level waste containing chemically hazardous constituents) in a safe manner that is protective of the worker, public health, and the environment. DOE O 435.1 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](#). For facilities undergoing CERCLA removal actions or CERCLA remedial actions, DOE O 435.1 may not be an Applicable or Relevant and Appropriate Requirement as defined in Section 121(d) of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.

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 Clean Air Act

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](#)

provides the framework for a significant portion of current federal air quality regulations. The Washington *Clean Air Act*, 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 the requirements in [WAC 173-480, “Ambient Air Quality Standards and Emission Limits for Radionuclides”](#); and [WAC 246-247, “Radiation Protection – Air Emissions.”](#) Applicable federal requirements in 40 CFR 61, “National Emission Standards for Hazardous Air Pollutants,” Subpart A, and [40 CFR 61, Subpart H, “National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities,”](#) are adopted by reference in [WAC 246-247.](#)

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, “National Emission Standards for Hazardous Air Pollutants”; [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, “Ambient Air Quality Standards and Emission Limits for Radionuclides”](#); 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. Ecology also 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 regulates outdoor burning activities at the Hanford Site in accordance with state requirements in [WAC 173-425, “Outdoor Burning.”](#)

2.3.2 Air Permits Required by Regulations

RA Kaldor, SA Szendre

Hanford Site contractors evaluate each proposed new or modified emission unit using the new source review requirements of radioactive air emissions ([WAC 246-247](#)) 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 DOE-RL Hanford Site, License FF-01 issued by the WDOH. 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 offsite individual remains well below the 10 mrem (100 microsievert [μSv])/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-2018-05, Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2017](#)).

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 2017, regulatory agencies conducted 41 *Clean Air Act* inspections on the Hanford Site. There were no compliance actions involving airborne radioactive materials.

2.4 Water Quality Permits, 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*, 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 2017: ST0004500, ST0004502, ST0004511, and ST0045514. Ecology's wastewater discharge permits page is located at <https://fortress.wa.gov/ecy/nwp/permitting/WWD/index.html>. WDOH issues annual permits to DOE to operate Hanford Site onsite sewage systems, which include some holding-tank sewage systems. Most onsite sewage systems (septic systems) operate under permits issued by the WDOH.

Two Ecology general permits for sand and gravel were in effect (and issued to Bechtel National Inc.) during 2017: WAG-50-5180 and WAG-50-5181.

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. The current Permit was renewed in 2018 and will expire March 6, 2023.

2.4.4 Safe Drinking Water Act of 1974

BR Stenson

The [Safe Drinking Water Act of 1974](#) (SDWA) 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. 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. 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 address chronic threats from disinfectant residuals and disinfection byproducts. Disinfection byproducts are sometimes formed when an oxidizing agent like chlorine is added to water during the water treatment process to kill or inactivate harmful organisms that may cause various diseases. Chlorine is a very active substance and reacts with naturally occurring substances, like organic material and bacteria, to form compounds known as 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 2017, all but one of the 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 2017 for microbiological, chemical, physical, and radiological constituents. There were no microbiological detections during the 2017 monitoring cycle, and seven of the eight water systems had chemical concentrations in drinking water that 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 2017 radiological monitoring are summarized in Section 7.1.3.

The 300 Area water system experienced an maximum contaminant level exceedance for disinfection byproducts monitoring in the third and fourth quarters of 2017. The exceedance was slightly above the 80 µg/L locational running annual average maximum. The contributing factors towards the exceedance were likely a combination of low water usage in the water system, potable water temperatures, and a system design that favors former large industrial uses that are no longer present. Transition of the 300 Area operations and responsibilities from MSA to Pacific Northwest National Laboratory (PNNL) occurred on October 1, 2017. MSA assisted the Water Purveyor, PNNL, with the exceedance response, operational updates, and public notifications. MSA Water & Sewer Utilities continued to operate the water system under an inter-contractor work order agreement with PNNL for the remainder of CY 2017.

Table 2-6. Selected Drinking Water Standards. (2 Pages)

Constituent	DWS ^a		Agency ^b
Antimony	6 µg/L	0.006 ppm	EPA, WDOH
Arsenic	10 µg/L	0.01 ppm	EPA, WDOH
Asbestos	7 million fibers/L	7 million fibers/L	WDOH
Barium	2,000 µg/L	2 ppm	EPA, WDOH
Beryllium	0.4 mg/L	0.004 ppm	WDOH
Bromate	10 µg/L	0.010 ppm	EPA, WDOH
Cadmium	5 µg/L	0.005 ppm	EPA
Carbon tetrachloride	5 µg/L	0.005 ppm	EPA, WDOH
Trihalomethanes ^c	80 µg/L	0.08 ppm	EPA
Chromium	100 µg/L	0.1 ppm	EPA, WDOH
Chlorite	1000 µg/L	1.0 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
Haloacetic Acids	60 µg/L	0.060 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
Nickle	0.1 mg/L	0.1 ppm	
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 ^d	11.1 Bq/L	EPA
Beta particle and photon activity	4 mrem/yr ^e	40 µSv/yr	EPA, WDOH
Carbon-14	2,000 pCi/L ^d	74.1 Bq/L	EPA
Cesium-137	200 pCi/L ^d	7.4 Bq/L	EPA
Cobalt-60	100 pCi/L ^d	3.7 Bq/L	EPA
Iodine-129	1 pCi/L ^d	0.037 Bq/L	EPA
Ruthenium-106	30 pCi/L ^d	1.11 Bq/L	EPA
Strontium-90	8 pCi/L ^d	0.296 Bq/L	EPA, WDOH
Technetium-99	900 pCi/L ^d	33.3 Bq/L	EPA
Total alpha (excluding uranium)	15 pCi/L ^d	0.56 Bq/L	EPA, WDOH
Tritium	20,000 pCi/L ^d	740 Bq/L	EPA, WDOH
Uranium	30 µg/L	0.03 ppm	EPA, WDOH

^a Maximum contaminant level for drinking water supplies.

Table 2-6. Selected Drinking Water Standards. (2 Pages)

Constituent	DWS ^a	Agency ^b
^b WDOH at WAC 246-290; EPA at 40 CFR 141, "National Primary Drinking Water Regulations;" 40 CFR 143, "National Secondary Drinking Water Regulations;" and <i>Drinking Water Regulations and Health Advisories</i> (EPA 1996).		
^c Standard is for total trihalomethanes.		
^d EPA DWSs for radionuclides were derived based on a 4-mrem/yr dose standard using maximum permissible concentrations in water specified in <i>National Bureau of Standards Handbook 69</i> (U.S. Department of Commerce 1963, as amended).		
^e 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 greater than 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 less than 50, 20,000, and 8 pCi/L, respectively.		
Bq	= Becquerel	
CFR	= <i>Code of Federal Regulations</i>	
DWS	= drinking water standards	
EPA	= U.S. Environmental Protection Agency	
L	= liter	
Mg	= milligrams	
MSv	=	
pCi	= picocuries	
ppm	= parts per million	
µg	= micrograms	
WAC	= <i>Washington Administrative Code</i>	
WDOH	= Washington State Department of Health	
yr	= year	

2.4.5 Surface Water Standards

The state of Washington has established surface water quality standards to protect public health and public enjoyment of the waters and for the propagation and protection of fish, shellfish, and wildlife. The standards apply to all surface water and water courses within the jurisdiction of the state of Washington. For the Hanford area, this primarily encompasses the Columbia River. The standards are contained within WAC 173-201A.

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

The [Hanford Site Biological Resources Management Plan](#) (BRMP; DOE/RL-96-32) requires 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](#), the [Migratory Bird Treaty Act of 1918](#) (MBTA), and the [Bald and Golden Eagle Protection Act](#), as well as [Executive Order 11988](#) and [Executive Order 11990](#), "[Protection of Wetlands](#)." 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 172 ecological compliance reviews requested during FY 2017. By comparison, 158 ecological compliance reviews were performed in 2016 including 143 reviews to support general Hanford Site activities and 15 reviews for River Corridor environmental restoration activities. The River Corridor project was completed in FY 2016.

2.5.1.1 Endangered Species Act of 1973. 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* as either threatened or endangered ([50 CFR 17, “Endangered and Threatened Wildlife and Plants,”](#) Subpart B) and occur onsite. Critical habitat for these species has been designated within the Hanford Reach. The bull trout (*Salvelinus confluentus*) is also listed under the *Endangered Species Act of 1973* and may occasionally occur in the Hanford Reach; critical habitat for bull trout was designated in the Hanford Reach in 2010 (USFWS 2010). The [Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout](#) (DOE/RL-2000-27) is in place for all three fish species. 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 Washington Department of Fish and Wildlife (WDFW) as endangered, threatened, or sensitive (see Section 11.2).

2.5.1.2 Migratory Bird Treaty Act. The MBTA prohibits taking or disturbing listed migratory birds or their feathers, eggs, or nests. Over 200 species of birds that regularly occur on the Hanford Site are protected under the MBTA. All Hanford Site projects with a potential to affect federal or state-listed species of concern complied with the requirements of the MBTA by using the ecological compliance review process as described in the BRMP (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 U.S. Fish and Wildlife Service (USFWS) 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. The *Bald and Golden Eagle Protection Act* 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. DOE/RL-94-150, [Bald Eagle Management Plan for the Hanford Site, South Central Washington](#), directs 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 and establishes guidelines for the protection of perches, roosts, and 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.

2.5.1.4 Executive Orders 11988 and 11990. Executive Order 11988 and Executive Order 11990 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*, 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](#), [Historic Sites Act of 1935](#), [National Historic Preservation Act of 1966](#), NEPA, [Archaeological and Historic Preservation Act of 1974](#), [American Indian Religious Freedom Act of 1978](#), [Archaeological Resources Protection Act of 1979](#), and [Native American Graves Protection and Repatriation Act](#).

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”](#); [Executive Order 13007, “Indian Sacred Sites”](#); [Executive Order 13175, “Consultation and Coordination with Indian Tribal Governments”](#); [Executive Order 13287, “Preserve America”](#); and [Presidential Proclamation 7319, “Establishment of the Hanford Reach National Monument”](#) (65 FR 37253). Refer to Section 11.3 for details regarding the Hanford Site Cultural and Historic Resources Programs.

2.6 Sustainability Statutes

The federal government is committed to avoiding the depletion of natural resources. Federal requirements and guidance have been initiated for agencies to follow. The following are additional statutes implemented at the Hanford Site.

2.6.1 Chemical Management Systems

ML Hermanson

Each Hanford Site contractor maintains a formal program to manage chemicals used by their respective contracts. These chemical management programs apply to the acquisition, use, storage, transportation, and final disposition of all chemicals used at Hanford. A central sitewide information system (The Safety Data Sheets-Material Safety Data Sheets [SDS-MSDS] Database), used by all Hanford Site contractors, maintains an inventory of chemical product SDS and MSDS. The SDS-MSDS Database is available to all Hanford Site employees with access to the Hanford Local Area Network. An information only copy of the SDS-MSDS Database has been made available outside the Hanford Local Area Network in a public

domain. This public domain copy makes the manufacturers SDS and MSDS documents available to public emergency responders, should the need arise, when any chemicals managed by a Hanford contractor are shipped offsite. The SDS-MSDS Database is also the information point of entry for the Hanford Site's Chemical Inventory Tracking System (CITS).

Each chemical product is entered into the CITS Database and is profiled identifying information such as the percentage of pure chemical constituents; Specific Gravity; flash point; physical state; National Fire Protection Association (NFPA) 704 classification; Occupational Safety and Health Administration [29 CFR 1910.1200, "Hazard Communication"](#); hazard class; and category. Codes are applied to each chemical constituent that identify reporting requirement categories.

Hanford Site contractors assign personnel to enter information into CITS to track the inventory of their company's chemicals from acquisition, use, storage, and transportation through final disposition. Using the CITS inventory quantity and location data combined with the chemical product profile information, data sets are generated to support company hazard communication and required reporting such as EPCRA Toxic Release Inventory, NFPA 1 Maximum Allowable Quantity limitations, and DOE Sustainable Environmental Stewardship goals.

2.6.2 Pollution Prevention Program

MM Rehberg

The [Pollution Prevention Act of 1990](#) 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 Sustainability Plan* (HNF-54800) was created to promote sustainability, ecological and cultural resource preservation, and the integration of sustainable practices into management functions and mission activities. DOE is responsible for the Hanford Site Sustainability Plan and provides the Site Sustainability Guidance to Hanford Site contractors to build a comprehensive approach to site sustainability. This plan provides goals and expectations for the implementation of energy conservation opportunities, water conservation initiatives, greenhouse gas emission reductions, waste minimization, and pollution prevention.

[DOE O 436.1, Departmental Sustainability](#), establishes pollution prevention and environmental stewardship requirements. In accordance with these requirements, pollution prevention and waste minimization activities are documented, tracked, and reported. Table 2-7 summarizes Hanford Site pollution prevention and waste minimization quantities recycled in FY 2017.

Note: Antifreeze (fleet) and used engine oil (fleet) quantities are included in antifreeze and used oil totals, respectively and are not included in the regulated solid wastes subtotal. Lead acid batteries (fleet) quantities are not included in lead acid batteries and are an addition to the regulated solid wastes subtotal.

Table 2-7. Recycle Quantities.

Material	FY 2017 Total (metric tons)
<i>Non-hazardous Solid Wastes</i>	
Cardboard	93.72
CI Shredded Paper	436.35
Furniture	142.06
Plastic Bottles	37.49
Tires	50.98
Wood Pallets	45.13
Activated Carbon	44.54
Ferrous Metal	207.81
Non-ferrous Metals	133.73
Electronics	29.60
Aluminum Cans	2.63
Subtotal	1224.04
<i>Regulated Solid Wastes</i>	
Aerosol Cans	0.25
Antifreeze	1.79
Antifreeze – Fleet	0.21
Ballasts	6.45
Batteries	5.31
Bulbs	5.64
Lamps - Mercury Containing	0.03
Lead Acid Batteries	37.87
Lead Acid Batteries (Fleet)	11.71
PCB Waste Oil <50ppm	0.00
Toner Cartridges	6.35
Urea	0.34
Used Engine Oils (Fleet)	20.83
Used Oil	47.91
Transformers	10.3
Subtotal	133.94
TOTAL	1357.99

2.6.2.1 Pollution Prevention and Waste Minimization Awards. The Hanford Site received one DOE, federal agency, state agency, or industry-sponsored award for pollution prevention and waste minimization accomplishments in CY 2017. The Green Electronics Council notified The Hanford Site that they received a three-star 2018 Electronic Product Environmental Assessment Tool (EPEAT) Purchasers Award for the combined application MSA submitted on behalf of MSA, CHPRC, and WRPS for CY 2017 (Figure 2-1). The goal of the EPEAT Purchaser Awards is to recognize excellence in the procurement of green and sustainable electronics among a wide range of organizations. The EPEAT-registered product categories are computers and displays, imaging equipment, televisions and mobile phones with rating tiers of gold, silver, and bronze. EPEAT Purchasers earn one star for each product category for which they have a written policy in place that requires the purchase of EPEAT-registered electronics registered in the EPEAT green-rating system. Collectively, the Hanford site reduced the use of primary materials by 580 metric tons, avoided the disposal of 4.7 metric tons of hazardous waste, eliminated 18.6 metric tons of solid waste, and avoided 3.4 metric tons of water pollutant emissions. These efforts saved 1,870 MWh of electricity, reduced 312 metric tons of greenhouse gas emissions, and generated \$192,800 in lifetime cost avoidance.



Figure 2-1. The 2018 EPEAT Purchaser Award presented by Green Electronics Council.

2.6.2.2 Accomplishments. The Hanford Site has recycled 57% of non-hazardous solid waste, excluding construction and demolition (C&D) debris. In 2017 1,357 metric tons of non-hazardous (i.e., plastic, aluminum, cardboard, paper, wood, and metal), universal waste (i.e. batteries and lamps) and other regulated (i.e. antifreeze and used oils) wastes were recycled through Hanford Site programs administered through the Mission Support Contract. Along with material recycling and diversion, the Hanford Site strives to reduce greenhouse gases Scopes 1, 2, and 3. There was a 23% reduction in Scope 1 and 2 greenhouse gas emissions for FY 2017 from the FY 2008 baseline; emissions in FY 2017 were 79,342 metric tons of carbon dioxide equivalent compared with 102,645 metric tons of carbon dioxide equivalent in FY 2008. There was a 31.2% reduction in Scope 3 greenhouse gas emissions for the Hanford Site in FY 2017 from the FY 2008 baseline; emissions in FY 2017 were 28,513 metric tons of carbon dioxide equivalent, whereas emissions in FY 2008 were 41,427 metric tons of carbon dioxide equivalent. Greenhouse gas emissions from employee commuting, business travel, offsite wastewater treatment, and contracted solid waste disposal are primarily dependent on work locations and the number of workers employed at the Hanford Site.

During FY 2017, contractors at the Hanford Site continued to divert C&D debris from landfill disposal. The Hanford Site diverted approximately 75% (2,909 metric tons) of C&D debris from the inert landfill. Hanford continues to make efforts to divert C&D materials suitable for reuse and recycle from landfills. The following are some ongoing Hanford Site projects and operations expected to increase the generation of C&D debris in FY 2018:

- Removing 11 mi (17.7 km) of electrical utility poles
- Upgrading electrical in future support to WTP
- Land clearing operations for construction
- Reducing Hanford Site footprint

- Reducing waterline pipe size and runs
- Maintaining site infrastructure and utilities.

2.6.3 DOE O 436.1, Departmental Sustainability

MM Rehberg

DOE O 436.1, *Departmental Sustainability*, requires developing a Site Sustainability Plan integrated with the Hanford Site operational plans. In addition, DOE O 436.1 requires 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.

In addition, DOE O 436.1 requires that an Environmental Management System (EMS) be established as the platform for managing environmental goals, as well as other impacts to the environment from Hanford Site operations, and establishing environmental objectives and targets. DOE O 436.1 also requires sites to maintain their EMS as being certified or conforming to the ISO 14001, *Environmental Management Systems*.

As the Hanford Site services and infrastructure contractor, MSA updated the sustainability plan (HNF-54800) for the Hanford Site in 2017 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 2017, as were plans for recycling, environmentally preferred procurement management and electronic asset stewardship (Section 3.0).

Environmental performance objectives are established to meet requirements provided by DOE O 436.1 and directed guidance for some Executive Orders. Executive Order 13834, *Efficient Federal Operations*, superseded Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*, and established a policy for federal agencies to meet statutory requirements in a manner that increases efficiency, optimizes performance, eliminates unnecessary use of resources, and protects the environment. It allows agencies to conduct legally, environmentally, economically, and fiscally sound environmental and energy-related activities in an integrated, efficient, continuously improving, and sustainable manner.

2.7 Occurrence Reporting and Processing of Operations Information

ME Mills

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](#)). From January 1, 2017, thru September 30, 2017, 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). On October 1, 2017, new Occurrence Reporting Criteria were established and implemented based on DOE O 232.2A, *Occurrence Reporting and Processing of Operations Information* and associated Supplemented Contract Requirements Document. The new Reporting Criteria provide a set of requirements that must be used to identify reportable occurrences. Report Levels provide a means to reflect the impact associated with a given occurrence in terms of health, safety, and security to personnel, the public, the environment, and the operational mission. The three report levels are: High (**H**), Low (**L**), and Informational (**I**). The following sections summarize occurrences that may have impacted the Hanford Site environment in 2017.

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.

2.7.4.1 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. From January 1, 2017, thru September 30, 2017, there were 26 documented occurrences of legacy contamination.

2.7.5 High-Level Report

Occurrences in this category meet any of the following conditions: Impact to worker or public safety and health; environmental harm; regulatory compliance; potential for mission interruption. There were no Hanford Site Environmental High-Level Report occurrences.

2.7.6 Low-Level Report

Occurrences in this category are those that do not meet High-Level Report occurrences but involve personnel injury, environmental releases, equipment damage, or hazardous circumstances; additional time is appropriate for written notifications. There were no Hanford Site Environmental Low-Level Report occurrences.

2.7.7 Informational Level Report

Occurrences in this category are those that do not meet High- or Low-Level Report occurrences and generally meet the following conditions:

- Determined to be a safety, environmental, or mission concern
- Provide potential learning opportunities for others.

Discovery of legacy contamination is an “Informational Level Report” occurrence. There were five documented occurrences of legacy contamination from October 1, 2017, to December 31, 2017. Section 2.7.4.1 provides further details into legacy contamination spread from environmental conditions.

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 2-8.

Table 2-8. Environmental Permits. (3 Pages)

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. A permit renewal application was submitted to Ecology in August 2017 and determined to be complete by Ecology in November 2017. As such, Renewal 2 will remain in effect until Renewal 3 is issued. 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. The current permit was effective October 20, 2017, and expires October 20, 2022. The FF-01 license is a compilation of all applicable radioactive air emission requirements and is incorporated into the Hanford Site Air Operating Permit as an Attachment, pursuant to WAC 246-247-060(7).
Drinking Water Permits

Table 2-8. Environmental Permits. (3 Pages)

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 DOE-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. This permit expires March 6, 2023.
HAN002 through HAN075 permit onsite 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 Areas Treated Effluent Disposal Facility. This permit expired June 30, 2017. ST0004502 required reapplication for permit renewal by June 30, 2016. The permit renewal application was verified as having been received by Washington State Department of Ecology on June 28, 2016. A letter was received from Ecology on May 24, 2017, in which they accepted the permit application as complete and extended the term of the current permit for up to 5 years while the new permit is being drafted.
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 stormwater discharges at the Hanford Site. This permit expires December 31, 2018.
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 Hanford 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 stormwater associated with Ready Mix Concrete operations. Bechtel National is the permit owner. This permit expires March 31, 2021.
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 Bechtel National, Inc. 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 expires March 31, 2021.
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.
Permit MB05788C-0, Federal Fish and Wildlife Permit, issued by the U.S. Fish and Wildlife Service to DOE-RL, authorizes the trimming and maintenance of a Bald Eagle nest located on a Bonneville Power Administration Tower. This permit expires December 31, 2017.
Review Reference Number 13260-2009-I-0121, Federal Fish and Wildlife Section 10.0 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 7.0 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.

Table 2-8. Environmental Permits. (3 Pages)

Permit 15-221a, Scientific Collection Permit issued by WDFW to MSA for May 2015 through May 2016 (extended through June 2016), authorizes food fish, shellfish, game fish, and wildlife collection for research purposes. This permit is renewed annually.		
Permit 16-250, Scientific Collection Permit issued by WDFW to MSA for June 2016 through June 2017, 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 Enforcement Actions

SA Szendre

Hanford Site operations are affected and, in many cases, regulated by numerous federal and state agencies enforcing legal requirements that address environmental compliance. For example, the DOE has sole authority to take action on matters under the AEA. In some cases, other federal agencies (e.g., the Council on Environmental Quality, EPA, and U. S. Fish and Wildlife Service) have authority to regulate activities pursuant to the NEPA, CERCLA, *Endangered Species Act*, and MBTA. The EPA has delegated authority to Ecology and WDOH to implement state laws and regulations in lieu of RCRA, the *Clean Air Act*, and the *Clean Water Act*. State laws and regulations requiring licenses or permits apply to activities at the Hanford Site. Examples of such permits are Hanford Site Radioactive Air Emissions License, the RCRA Permit, the Air Operating Permit, and several State Waste Discharge Permits.

In general, the laws, regulations, and other requirements applicable to Hanford Site operations include, but may not be limited to, those that address environmental quality; air quality and noise; water resources; hazardous waste and materials management; radioactive waste and materials management; ecological resources; cultural and paleontological resources; worker safety and health; radiological safety and radiation protection; transportation; emergency planning, pollution prevention, and conservation; and environmental justice. It is DOE's policy to carry out its mission in a regulatory compliant and sustainable manner to maximize energy and water efficiency; minimize chemical toxicity and harmful environmental releases; promote renewable and other clean energy development; and conserve natural, cultural, and ecological resources while sustaining assigned mission activities.

This section discusses the environmental noncompliances alleged by regulatory agencies at the Hanford Site during CY 2017.

2.9.1 Enforcement Actions by Regulatory Program Area

During CY 2017, there were 34 regulatory agency compliance actions filed against the DOE and its contractors for alleged violations of regulatory requirements or other enforceable agreements. All 34 compliance actions were issued by Ecology. Twenty-eight of the 34 compliance actions resulted from

regulatory agency inspections of DOE facilities on the Hanford Site (Section 2.1.2.2). The compliance actions also resulted in 33 concerns. DOE-RL was fined \$16,000 for failure to designate a white powder in the tour paths within the PUREX plant. On October 5, 2017, CHPRC informed Ecology they would appeal the \$16,000 fine to the Pollution Control Hearing Board.

Table 2-9 summarizes the alleged environmental noncompliances by program area. Table 2-10 summarizes the 34 alleged environmental noncompliances filed against the DOE and its contractors during CY 2017 including a description of the alleged noncompliances. Figure 2-2 shows alleged environmental noncompliance concerns, violations, and associated fines.

Table 2-9. Alleged Environmental Noncompliance Summary by Program Area, 2012–2017.

Program Area	2012	2013	2014	2015	2016	2017
CAA	0	4	2	3	1	0
CWA	0	0	0	1	0	1
RCRA	2	4	7	16	22	33
CERCLA	3	1	0	0	1	0
Others	2	1	1	7	3	0
Total Notices of Violation	7	10	10	27	27	34
CAA = <i>Clean Air Act</i>						
CERCLA = <i>Comprehensive Environmental Response, Compensation, and Liability Act</i>						
CWA = <i>Clean Water Act</i>						
RCRA = <i>Resource Conservation and Recovery Act</i>						

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2017. (4 Pages)

Agency	Document Number	Title	Alleged Noncompliance Description
Ecology	2018-06	ECOLOGY WARNING LETTER BASED ON 8/24/2017 DANGEROUS WASTE COMPLIANCE INSPECTION AT THE 216-B-3, 216-S-10, 216-B-63, 216-A-29, 216-A-36B, AND 216-A37-1 CRIBS AND DITCHES	Inadequate inspection recordkeeping, Operating Records, and Dangerous Waste Training Plan. There was one concern for Access Control (signage) at the 216-A-29 Ditch and 216-B-63 Trench.
Ecology	2018-05	ECOLOGY WARNING LETTER BASED ON 8/22/2017 INSPECTION OF THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL (NRDWL) AND THE LOW LEVEL BURIAL GROUNDS (LLBG) - GREEN ISLANDS	Inadequate recordkeeping, Dangerous Waste Training Plan, and Security (Access Control). There were two concerns for Access Control (signage) at NRDWL, and Interim Status questions for the LLBG - Green Islands.
Ecology	2018-04	ECOLOGY WARNING LETTER BASED ON 8/10/2017 DANGEROUS WASTE COMPLIANCE INSPECTION OF THE WASTE RECEIVING AND PROCESSING FACILITY (WRAP)	Inadequate recordkeeping, Dangerous Waste Training Plan, and Security (Access Control). Failure to mark or label containers of dangerous waste (propane bottles), improper designation of dangerous waste, inadequate Training Plan, and insufficient major risk labeling of containers of dangerous waste.

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2017. (4 Pages)

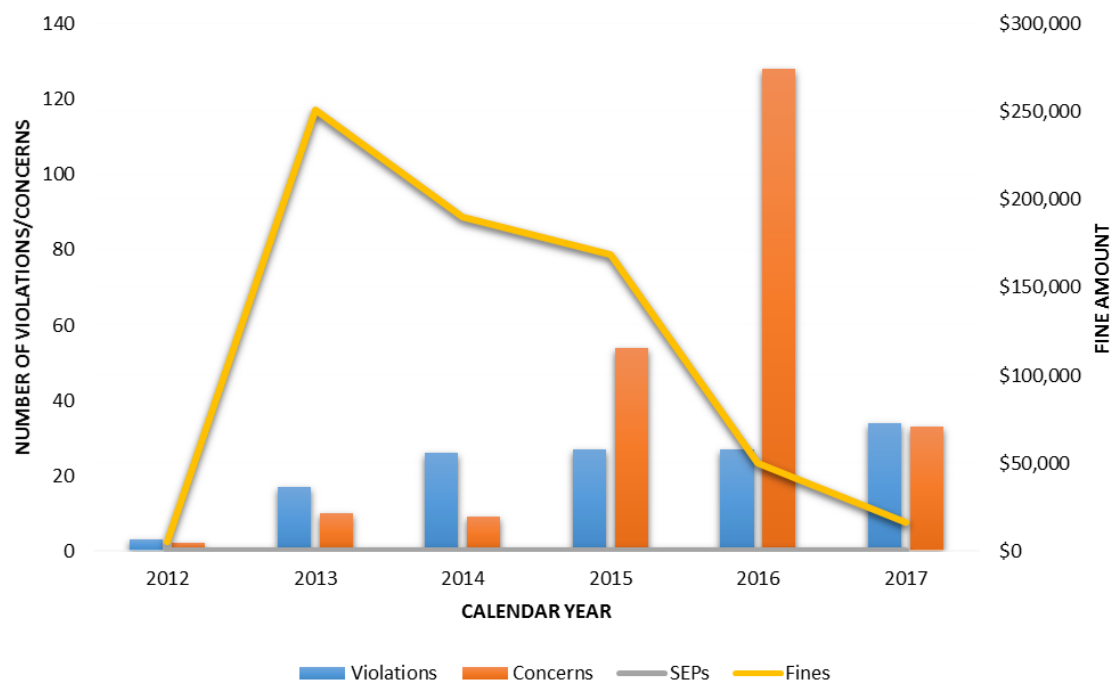
Agency	Document Number	Title	Alleged Noncompliance Description
Ecology	2018-03	ECOLOGY WARNING LETTER FOR ALLEGED DANGEROUS WASTE VIOLATIONS AT THE CENTRAL WASTE COMPLEX BASED ON 4/20/2017 INSPECTION	Dangerous waste containers not properly marked/labeled with major risks, inadequate Training Plan and personnel training, availability and retention of required records, and container integrity of container WH-76-630.
Ecology	2018-02	ECOLOGY WARNING EMAIL FOR LACK OF A WRITTEN CERTIFICATION THAT THE OPERATIONS AND MAINTENANCE MANUAL WAS REVIEWED BY 9/1/2017, PER STATE WASTE DISCHARGE PERMIT ST0045514.	Failure to meet ST0045514 Permit Condition S5.G.2 A, which requires the annual Operations and Maintenance Manual review confirmation letter be sent to Ecology by September 1, 2017.
Ecology	2018-01	ECOLOGY WARNING LETTER FOR NOT COMPLETING AND RETAINING WASTE MINIMIZATION CERTIFICATIONS FOR 2008-2014 FOR CHPRC UNITS AND 2016 FOR WRPS UNITS BASED ON INSPECTIONS OF MULTIPLE DANGEROUS WASTE MANAGEMENT UNITS	Failure to document a certification statement for the waste minimization plans for multiple waste management units during FY 2017.
Ecology	2017-13	ECOLOGY LETTER BASED ON DW COMPLIANCE INSPECTION ON 8/17/2017 AT 300 AREA PROCESS TRENCHES, 1301-N, 1325-N, 1324-N, 1324-NA, AND 183-H	During the inspection, 2014 Waste Minimization Plan Certification for 1301-N, 1325-N, 1324-N and NA, 183-H, and the 300 Area Process Trenches could not be located. On September 12, 2017, CHPRC submitted an update to their operating record, dated August 23, 2017, and September 12, 2017, that explained that the Annual Waste Minimization Certifications were missing for 2008 through 2014 for all of CHPRC Treatment, Storage, and Disposal Unit Groups, including 1301-N, 1325-N, 1324-N and NA, 183-H, and the 300 Area Process Trenches.
Ecology	2017-12	PUREX PLANT NOTICE OF PENALTY (DOCKET #15342) AND ADMINISTRATIVE ORDER (DOCKET #15343) FOR FAILURE TO DESIGNATE WHITE POWDER ALONG TOUR PATHS	Failure to designate white powder and submit to Ecology, for approval, a plan to recover and manage any solid waste that may be designated as dangerous waste in accordance with WAC 173-303
Ecology	2017-1125	NOTICE OF NON-COMPLIANCE WITH HANFORD RCRA PERMIT FOR OPERATING UNIT 10 WASTE TREATMENT AND IMMOBILIZATION PLANT (WTP)	Modification of Waste Treatment and Immobilization Plant Analytical Laboratory piping to support Direct Feed Low-Activity Waste configuration changes was initiated prior to the final approval of the Underground Waste Transfer Pipelines Class 2 modification (24590-BOF-PCN-ENV-15-001). DOE-ORP is working on

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2017. (4 Pages)

Agency	Document Number	Title	Alleged Noncompliance Description
			identifying and tracking corrective actions and will keep Ecology's staff apprised of those at the routine Dangerous Waste Permit meetings.
Ecology	2017-10	PUREX STORAGE TUNNELS 1 WASTE MANAGEMENT UNIT INTEGRITY ISSUES - PARTIAL ROOF COLLAPSE AT HEAD END OF TUNNEL 1 ADMINISTRATIVE ORDER DOCKET #14156	Determine the cause of breach in PUREX Storage Tunnel 1 and assess if there is an immediate risk of further failures in PUREX Storage Tunnels 1 and 2. By July 1, 2017, submit to the Ecology Nuclear Waste Program a structural integrity evaluation for both PUREX Storage Tunnels 1 and 2.
Ecology	2017-09	ECOLOGY WARNING LETTER BASED ON DANGEROUS WASTE COMPLIANCE INSPECTION AT SINGLE-SHELL TANK SYSTEM ON 7/28/2016 AND 8/24/2016	Inadequate inspection record keeping. Within 60 days upon receipt of the compliance report, submit 1 month of inspection records associated with the WRPS Monthly NFPA 801 Inspection, Monthly Emergency SCBA Inspection, and WRPS Monthly Fire Extinguisher Inspections that document the time of the inspections.
Ecology	2017-0822	ECOLOGY WARNING LETTER BASED ON 9/14/2017 DANGEROUS WASTE COMPLIANCE INSPECTION AT 222-S LABORATORY	Uniform Hazardous Waste Manifests did not document Generator's Site Address (if different than mailing address), in accordance with Appendix to Part 262 - Uniform Hazardous Waste Manifest and Instructions.
Ecology	2017-07	ECOLOGY WARNING LETTER BASED ON 3/8/2016 DANGEROUS WASTE COMPLIANCE INSPECTION AT DOUBLE SHELL TANK SYSTEM AND 204-AR WASTE UNLOADING	Double-Shell Tank annulus leak detection system alarm reporting, development of schedules for equipment inspection, incomplete inspection records, failure to perform tank system component integrity testing.
Ecology	2017-06	ECOLOGY WARNING LETTER BASED ON 8/30/2016 DANGEROUS WASTE COMPLIANCE INSPECTION OF THE LIQUID EFFLUENT RETENTION FACILITY/EFFLUENT TREATMENT FACILITY (LERF/ETF)	Improper shipping manifest address, failure to use printed names on inspection records, failure to provide all requested records, improper packaging of universal waste lamps..

Table 2-10. Summary of Alleged Environmental Noncompliances for CY 2017. (4 Pages)

Agency	Document Number	Title	Alleged Noncompliance Description
CHRPC		= CH2M HILL Plateau Remediation Company	
DOE-ORP		= U.S. Department of Energy, Office of River Protection	
Ecology		= Washington State Department of Ecology	
LLBG		= low-level burial ground	
NFPA		= National Fire Protection Association	
NRDWL		= Nonradioactive Dangerous Waste Landfill	
PUREX		= Plutonium Uranium Extraction Plant	
SCBA		= Self-Contained Breathing Apparatus	
WAC		= <i>Washington Administrative Code</i>	
WRPS		= Washington River Protection Solutions	

**Figure 2-2. Alleged Environmental Noncompliance Violations, Concerns, and Associated Fines Summary.**

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 Wastewater Permit Deviations

J Russell

During CY 2017, there were 82 non-compliances reported to regulatory agencies for wastewater permit deviations. Four of the events involved Large Onsite Sewage System permits, 5 involved State Waste Discharge Permits, and 73 involved the City of Richland Industrial Wastewater Discharge Permit. The City of Richland discharge permit non-compliances were a result of daily flow exceedances of the 300 Area sewer due to an increase in filter backwash frequency at the 331 Aquatics Laboratory and the installation of a new chiller unit at the 3709A fire station, which produced an increased amount of cooling water. In all cases, action was taken to repair and correct the non-compliant conditions and regulatory notifications were made in accordance with permit requirements. Table 2-11 shows the dates of non-compliance, applicable Permit Numbers, Regulatory Agencies, and Reasons for each deviation.

Table 2-11. CY 2017 Wastewater Permit Deviations. (2 Pages)

Date	Permit Number Deviated	Reported To	Reason(s)
March 9	ST0004500	Ecology	A routine surveillance of the State-Approved Land Disposal Site transfer line discovered a small leak from the air vacuum relief valve in manhole MH-ETF-12.
April 27	ST0004502	Ecology	The nitrate sample taken on January 10, 2017, exceeded the 48-hr hold time. This was reported in a 2017 discharge monitoring report.
June 20	HAN011	Health	10 gal (37.8 L) of sewage was released to the ground from the 2607-Z lift station.
August 31	ST0004502	Ecology	On August 26, a fire water line at the Plutonium Finishing Plant leaked a large volume of water across a potentially contaminated area into storm drains that route to the 200 Area TEDF. The TEDF sampler was operating at the time and results indicated no elevated radionuclide levels.
August 31	HAN049	Health	2 gal (7.57 L) of sewage was released to the ground at 2607-EM lift station.
September 14	ST0004500	Ecology	An unplanned release of potable water resulted from an overflow of the Waste Treatment Plant Water Treatment Building, Process Service Water Tank 3.
November 1	HAN049	Health	75 gal (283.9 L) of sewage was released to the ground from 2607-EP LOSS near Route 4 South and Route 3 200-East.
November 2	ST0045514	Ecology	The Operations and Maintenance manual annual review was completed on June 28, 2017, but was not included as a comment in a 2017 discharge monitoring report when submitted. No changes were necessary.
December 20	HAN043	Health	A leak was discovered, originating at the MO-588 restroom. Approximately 20 gal (75.7 L) of sewage was discovered on a

Table 2-11. CY 2017 Wastewater Permit Deviations. (2 Pages)

Date	Permit Number Deviated	Reported To	Reason(s)
			plastic liner under the trailer. MO-588 sewage discharges to the LOSS 6607-11. The leak was not a failure of the regulated LOSS and the system was not impacted by the leak. No sewage discharged to the ground. Piping repairs were completed on December 14, 2017, and the plastic liner was cleaned.
Various Dates May 2017 – August 2017	CR-IU010	City of Richland	City of Richland Industrial Wastewater Discharge Permit daily flow limits were exceeded 73 times. An increase in the flow limit was requested, was accepted, and implemented in the new 2018 discharge permit.
LOSS = Large Onsite Sewer System TEDF = Treated Effluent Disposal Facility			

2.10 References

- 10 CFR 820, "Procedural Rules for DOE Nuclear Activities." *Code of Federal Regulations*, as amended. Online at <http://energy.gov/ea/downloads/10-cfr-part-820-procedural-rules-doe-nuclear-activities>.
- 10 CFR 830, "Nuclear Safety Management." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title10/10cfr830_main_02.tpl.
- 10 CFR 835, "Occupational Radiation Protection." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?SID=40dc5b37cae52e891f095e943d5a3d69&mc=true&node=pt10.4.835&rgn=div5>.
- 10 CFR 1021, "National Environmental Policy Act Implementing Procedures." *Code of Federal Regulations*, as amended. Online at <https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=10:4.0.3.5.14>.
- 10 CFR 1022, "Compliance with Floodplain and Wetland Environmental Review Requirements." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?SID=f0182280d0e89b8f8b419ba359c4de96&mc=true&node=pt10.4.1022&rgn=div5>.
- 29 CFR 1910.1200. "Hazard Communication." *Code of Federal Regulations*, as amended. Online at https://www.ecfr.gov/cgi-bin/text-idx?SID=dce08c1f6da7a829b84ddeab99f5dd8e&mc=true&node=se29.6.1910_11200&rgn=div8.
- 36 CFR 60. "National Register of Historic Places." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=af4fa0b4fb36604e8682834d7d507c8c&rgn=div5&view=text&node=36:1.0.1.1.2.6&idno=36>.

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- 36 CFR 63. "Determinations of Eligibility for Inclusion in the National Register of Historic Places." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5;node=36%3A1.0.1.1.29>.
- 36 CFR 65. "National Historic Landmarks Program." *Code of Federal Regulations*, as amended. Online at <http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=36:1.0.1.1.31>.
- 36 CFR 79. "Curation of Federally-Owned and Administered Archaeological Collections." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title36/36cfr79_main_02.tpl.
- 36 CFR 800. "Protection of Historic Properties." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title36/36cfr800_main_02.tpl.
- 40 CFR 52. "Approval and Promulgation of Implementation Plans." *Code of Federal Regulations*, as amended. Online at https://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr52_main_02.tpl.
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2017 Highlight

The U.S. Department of Energy sets goals for carrying out its mission in an environmentally sustainable manner that supports a policy of national energy security and addresses global environmental challenges. The Hanford Site continues to make substantial progress in meeting the goals for the Site. Below are the highlights of the progress cumulative through 2017.

Pollution Prevention and Waste Minimization

The Hanford Site diverted 57% (1,224 metric tons) of nonhazardous solid waste for recycling and 75% (2,909 metric tons) of construction and demolition debris in fiscal year 2017.

Water Management

The Hanford Site continued to reduce potable water consumption intensity in fiscal year 2017 at 13.70 gal/ft².

Renewable Energy Intensity

The Hanford Site derived 17% of electricity from renewable energy sources.

Greenhouse Gas Reduction

The Hanford Site continued to reduce greenhouse gas emissions. The Site has reduced Scope 1 and Scope 2 emissions by 23% and Scope 3 emissions by 31.2% since 2008.

Transportation and Fleet Management

Acquisitions for 50% of Hanford light-duty vehicles were hybrid, electric, or use E85 (ethanol) fuel.

Environmental Management System Best Practices

Hanford implemented an electronic Environmental Activity Screening System for Mission Support Alliance-led projects that ensures inclusion of environmental personnel for the appropriate evaluations.

3.0 Environmental Management System

MM Rehberg

The U.S. Department of Energy (DOE) requires Hanford Site contractors to develop and operate under an Integrated Safety Management System (ISMS). In accordance with contract obligations, contractors maintain an Environmental Management System (EMS) that is consistent with ISO 14001, *Environmental Management Systems*, 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.

Performance related to EMS must be reported annually to DOE Headquarters (DOE-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 DOE, Richland Operations Office (DOE-RL) and Office of River Protection (DOE-ORP).

Table 3-1. DOE Contract Actions and Contractor Implementation.

Actions, Implementation	Richland Operations Office				Office of River Protection		
	HPMC	CHPRC	MSA	WCH	WAI	BNI	WRPS
Contractor Start Date	Oct 1, 2012	Oct 1, 2008	Aug 24, 2009	Aug 27, 2005	Nov 22, 2015	Dec 11, 2000	Oct 1, 2008
DOE Approval of Contractor ISMS	NA	Nov 2009	Jan 2011	Nov 2007	Oct 2016	Feb 2003	Sept 2009
Direction to Implement DOE EO 13423	Oct 2012	Oct 2008	Aug 2009	June 2009	Nov 2015	NA	Oct 2008
Direction to Implement DOE EO 13514	NA	June 2012	May 2011	Oct 2012	Nov 2015	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	NA	NA	Oct 2009
Direction to Cancel DOE O 450.1A	Oct 2012	July 2012	Dec 2012	Oct 2012	NA	NA	Sept 2014
Direction to Implement DOE O 436.1	Sept 2014	July 2012	July 2012	Oct 2012	Nov 2015	NA	Oct 2013
Contractor EMS Established	Oct 2012	Nov 2009	Dec 2009	Sept2009	Sept 2016	NA	Sept 2009
ISO 14001 Certification	NA	Jul 2012/ 2015	Sept 2011/ 2014/ 2017	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	March 2016	Jul 2015	Sept 2017	Sept 2015	Sept 2016	NA	Sept 2015
Contractor EMS Scorecard Rating	Green	Green	Green	NA	Green	Red	Green
EMS Scorecard for 2017	Green			Yellow	Yellow		
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 WAI=Wastren Advantage, Inc. WRPS=Washington River Protection Solutions, LLC							

Table 3-2. DOE Order and Executive Order Issuance.

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

As the services and infrastructure contractor for the Hanford Site, Mission Support Alliance (MSA) developed a sustainability plan (HNF-54800) for the Hanford Site in 2018 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, *Departmental Sustainability*](#). Environmental objectives were established and maintained in 2017, as were plans for recycling, environmentally preferred procurement management, and electronic asset stewardship. Sustainability plans from fiscal year (FY) 2001 through present are available on the MSA website.

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-EP-5054.pdf	Policy
MSA	http://msa.hanford.gov/files.cfm/ems.pdf	Policy, Aspects
WAI	http://wadv.wastrencloud.com/?page_id=601	Policy
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 tracks environmental performance measures for the Hanford Site. Performance measures address the goals of DOE O 436.1 and [Executive Order 13693, “Planning for Federal Sustainability in the Next Decade.”](#) The measures developed in response to these 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, 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 DOE-HQ.

3.1.1 Fleet Management

The acquisition target for alternative fuel vehicles was not met in 2017 (Figure 3-1). DOE required that a minimum of 75% of all non-mission critical light-duty vehicles purchased during FY 2017 be alternative fuel vehicles (DOE O 436.1).

3.1.2 Alternative Fuel Use

The alternative fuel use target was surpassed for FY 2017; however, the target for petroleum-based fuel use was missed (Figure 3-2). Mission and contract structure changes since 2005 continue to challenge target achievement. The requirement specifies that Hanford Site contractors' fleets operate alternative fuel vehicles exclusively on alternative fuels to the maximum extent possible. This will reduce the amount of petroleum-based fuels used annually by 20% by FY 2015 relative to an FY 2005 baseline and maintain that level thereafter. The requirement includes increasing the amount of alternative fuels used annually by 10% or 2% annually by FY 2015 relative to an FY 2005 baseline and maintain that level thereafter.

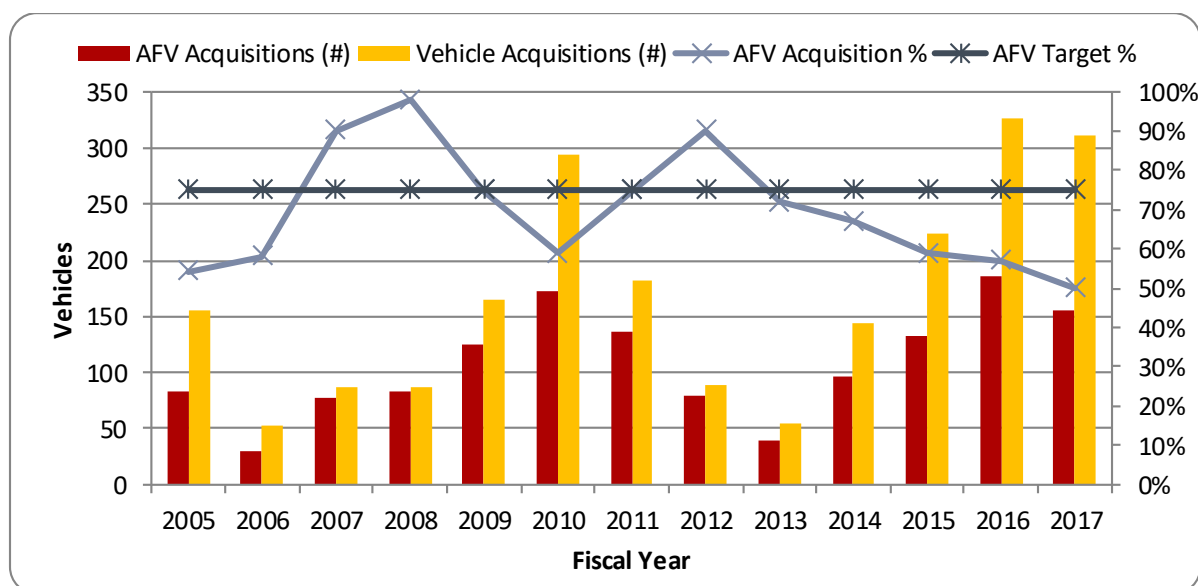


Figure 3-1. Fleet Management – Acquisitions FYs 2005–2017.

NOTE: AFV stands for alternative fuel vehicle

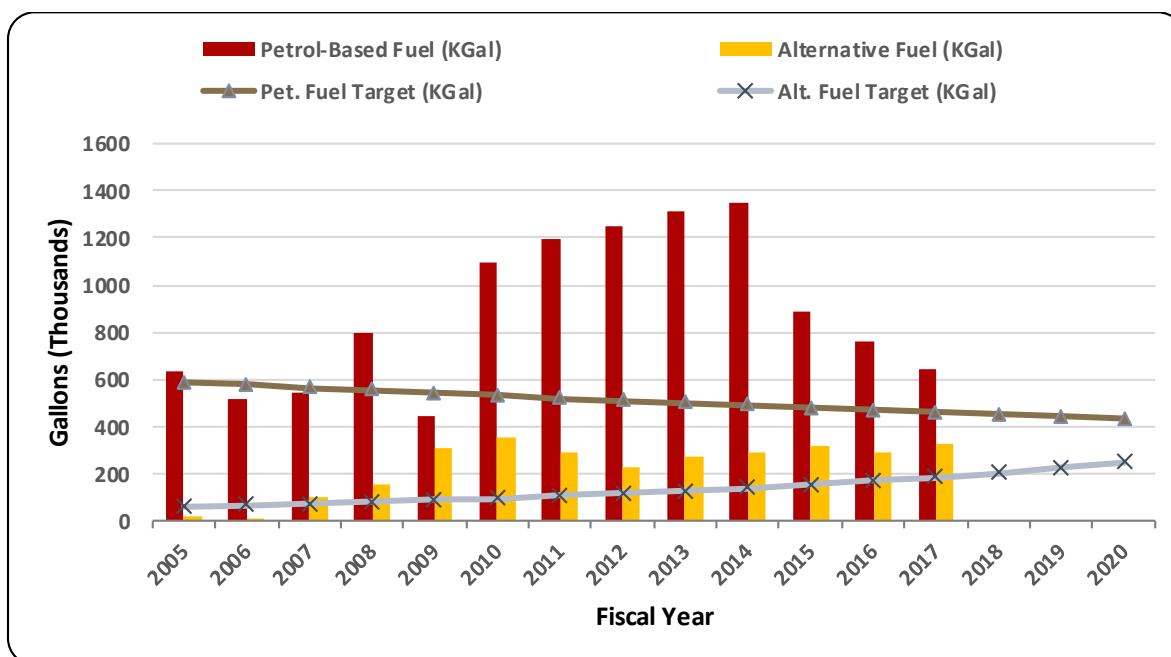


Figure 3-2. Vehicle Fuel Use – FYs 2005–2017.

3.1.3 Potable and Non-potable Water Use

The target objectives for potable and non-potable water were met in FY 2017 (Figure 3-3). As specified by Executive Order 13693, water use requirements stipulate the reduction of potable water consumption intensity by 2% annually through FY 2025 or 36% by the end of FY 2025, relative to a baseline of water consumption in FY 2007. There is a requirement to reduce non-potable water use by 2% annually through the end of FY 2025 or 30% by the end of FY 2025 relative to an FY 2010 baseline.

3.1.4 Electricity Use

As directed by Executive Order 13693, this metric has changed to track renewable electric energy as a percentage of the total electricity usage. Requirements call for renewable electric energy account for no less than 10% of the total electricity use in FY 2016 to 2017 and working towards 30% of total usage by FY 2025. The target objective for renewable electric energy was met in FY 2017 (Figure 3-4) representing 15% of total electricity usage. Renewable electric energy is defined in Executive Order 13693 as electricity produced or displaced by solar, wind, biomass, landfill gas, ocean, geothermal, geothermal heat pumps, micro-turbines, municipal solid waste, or new hydroelectric generation.

3.1.5 Facility Fuel Use

The target objectives for facility fuel use were met in FY 2017 (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.

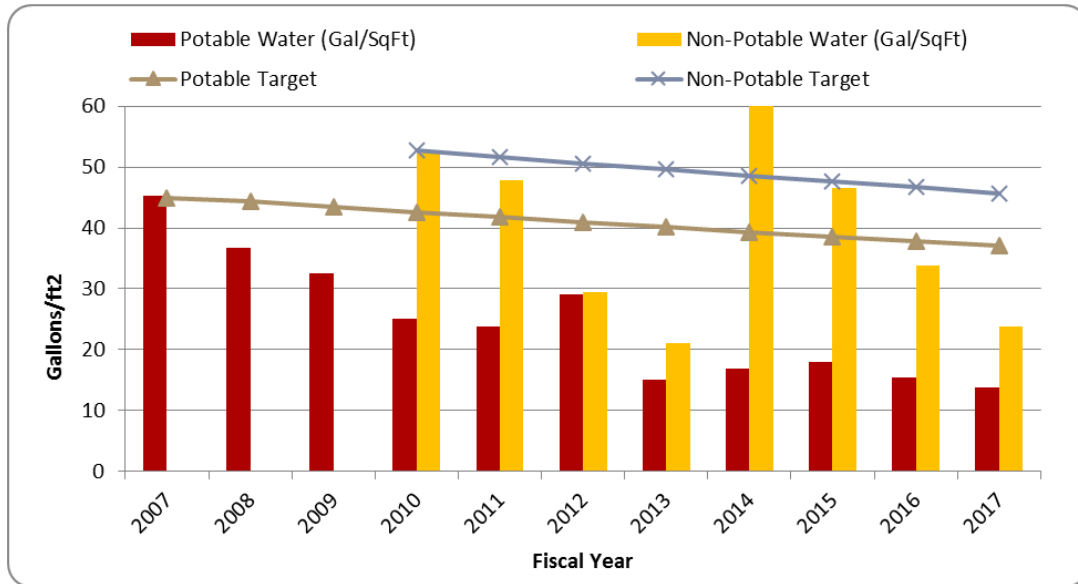


Figure 3-3. Water Use – FYs 2007–2017.

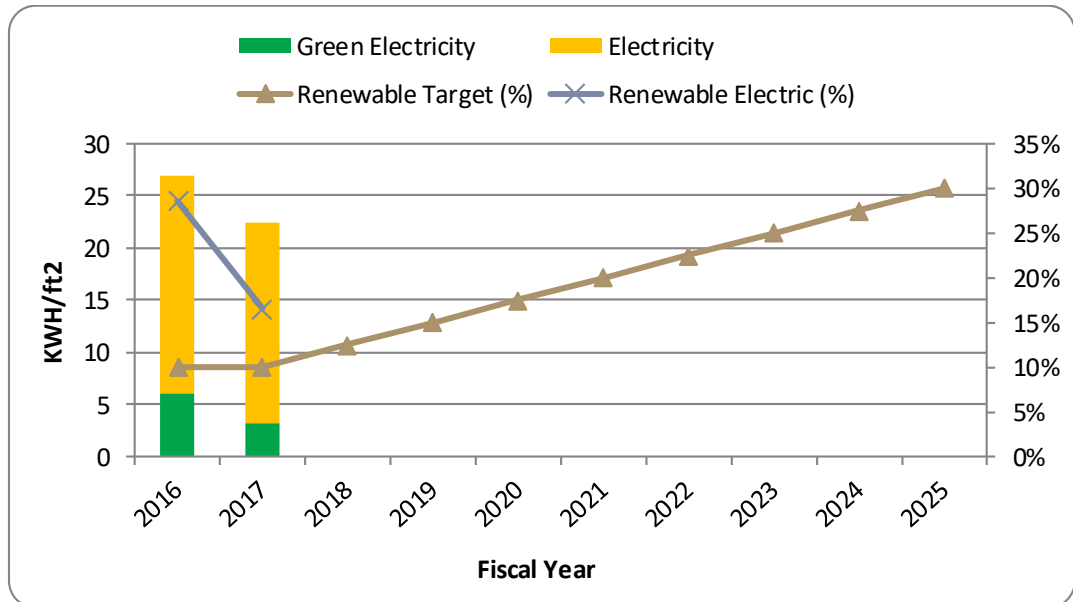


Figure 3-4. Electricity Use – FYs 2016 – 2017 with Target Objectives through 2025.

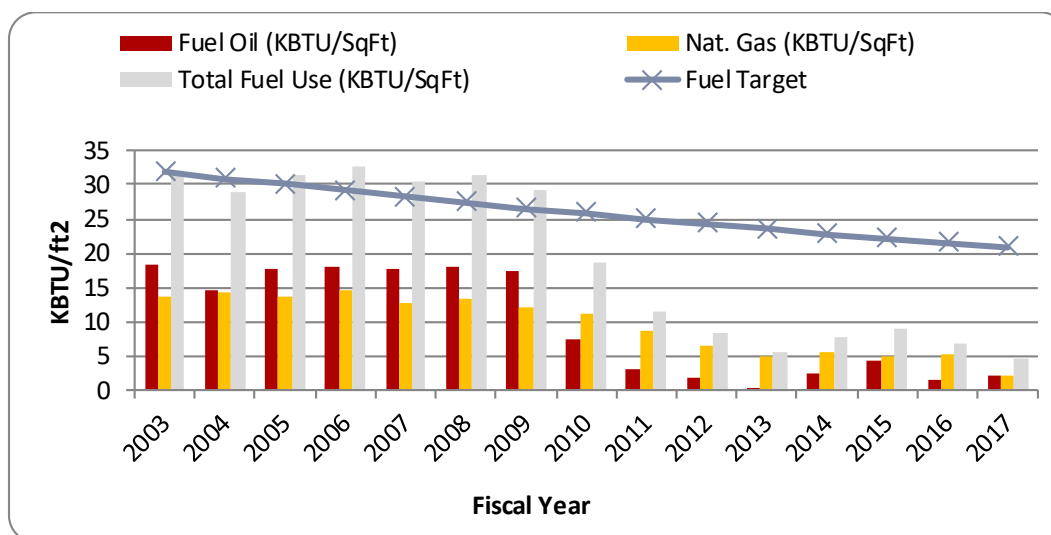


Figure 3-5. Facility Fuel Use – FYs 2003–2017.

NOTE: KBTU stands for one thousand British thermal units

3.1.6 Facility Energy Use

The target objective for facility energy use has been extended per Executive Order 13693. Requirements call for the reduction of energy use (a combination of electricity, fuel oil, and natural gas) by 25% by the end of FY 2025 or 2.5% annually relative to the FY 2015 baseline. The target objective was met in FY 2017 (Figure 3-6). Note: In Figure 3-6, FY 2015 and FY 2016 data was corrected for data inclusion consistency with Hanford Site contractors, Pacific Northwest National Laboratory, and Hanford Tank Waste Treatment and Immobilization Plant operations.

3.1.7 Electronic Product Environmental Assessment Tool

The target objectives for the Electronic Product Environmental Assessment Tool were exceeded in FY 2017, with 99% of the purchases meeting the requirements (Figure 3-7). The requirements in Executive Order 13693 specify 95% of procured electronic assets (i.e., notebooks, computers, tablets, monitors, and mobile phones) must comply with the standard in an effort to reduce or eliminate the environmental impacts of electronic assets by incorporating electronic stewardship practices.

3.1.8 Sanitary Waste Reduction.

The target objective for sanitary waste reduction requires the diversion of post-consumer materials suitable for reuse and recycling from landfills to a target of 50% annually by FY 2015 based on an FY 2009 baseline (Figure 3-8) and maintain that level thereafter. The sanitary waste objective was achieved in FY 2017. Note: In Figure 3-8, FY 2011 through FY 2016 sanitary waste disposal data was corrected and may reflect different recycling percentages than reports in previous fiscal years. Corrected fiscal year data still meets the sanitary waste objective of 50% reduction.

3.1.9 Regulated Waste Reduction.

Efforts toward regulated waste reduction on the Hanford Site include eliminating or minimizing regulated waste generation through source reduction, including segregation, substitution, and reuse. Regulated waste includes waste such as hazardous, universal, special, and state-regulated industrial not suitable for disposal in sanitary or construction and demolition landfills. Regulated waste from Hanford's

Environmental Restoration Disposal Facility is not included in Figure 3-9. Waste to this facility decreased in FY 2017 (Figure 3-10).

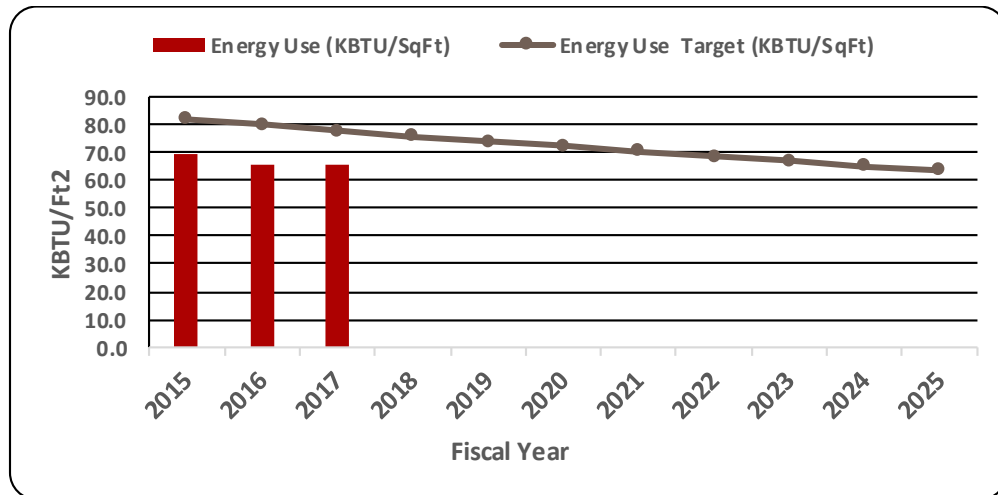


Figure 3-6. Facility Energy Use – FYs 2015-2017 with Target Objectives through 2025.

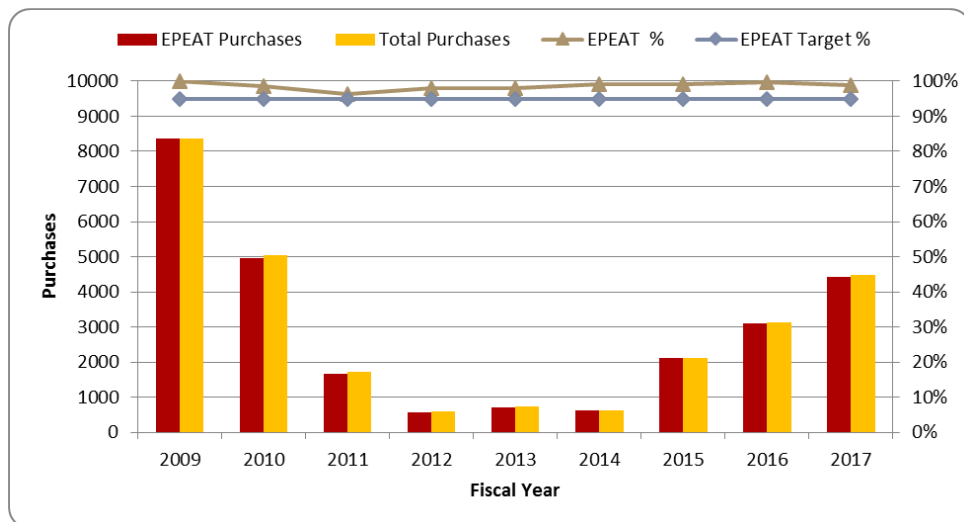


Figure 3-7. Electronic Product Environmental Assessment Tool Standards Compliance.

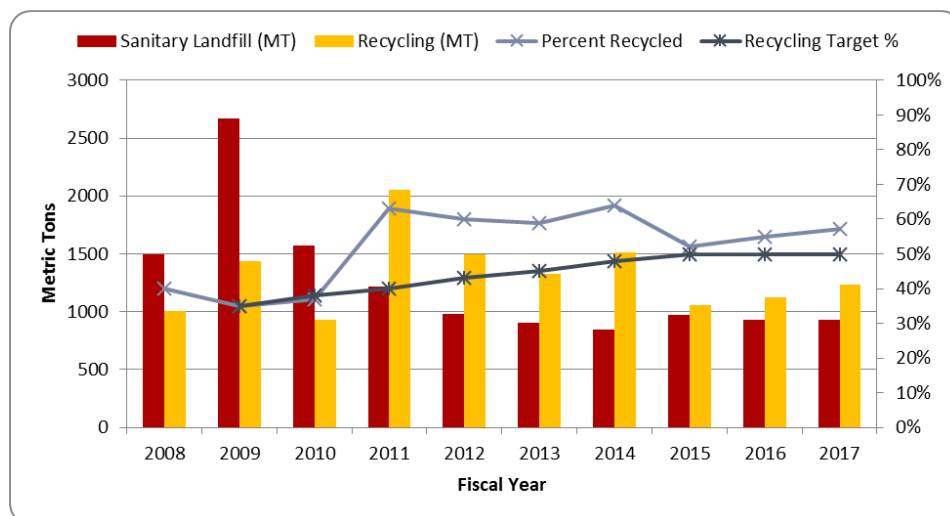


Figure 3-8. Sanitary Waste Reduction.

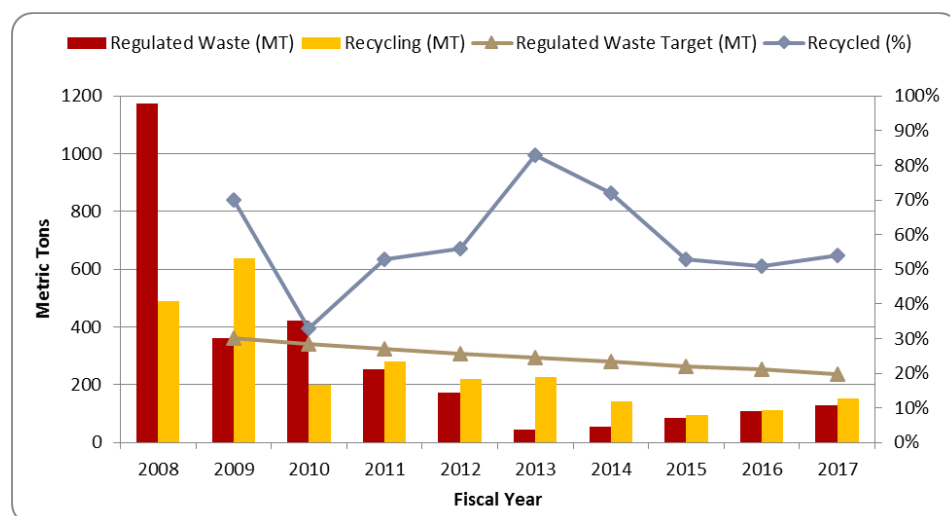


Figure 3-9. Regulated Waste Reduction.

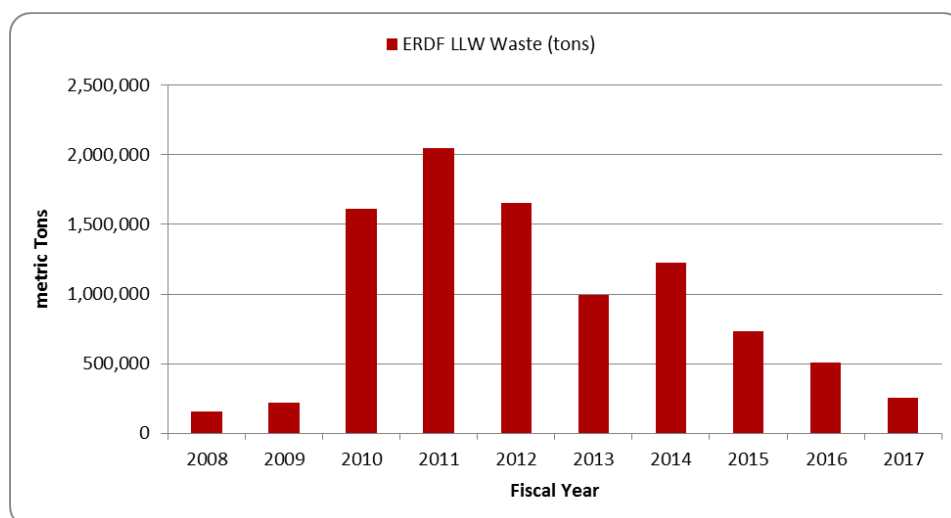


Figure 3-10. Onsite Waste Disposal—FYs 2008–2017 at the Environmental Restoration Disposal Facility.

3.2 Hanford Site Awards and Recognition

MM Rehberg

3.2.1 HPMC Occupational Medical Services

HPMC Occupational Medical Services 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

CH2M Plateau Remediation Company's (CHPRC) EMS as described in PRC-MP-EP-40182, *Environmental Management System Manual*, was reviewed for conformance with ISO 14001:20015 in May 2018. NSF-International Strategic Registrations, Ltd., an American National Standards Institute National Accreditation Board-accredited certification body for the international standard ISO 14001, conducted its full reassessment audit of the CHPRC EMS. Four auditors reviewed CHPRC documents, visited CHPRC Projects, interviewed CHPRC workers to discuss CHPRC implementation of the International Organization for Standardization (ISO) core elements, and met with CHPRC senior staff members to gauge management commitment. Eight "system strengths" were noted. One minor non-conformance and four opportunities for improvement were issued. The auditors concluded that CHPRC remains compliant with the ISO 14001 standard and recommended certification to the 2015 revision.

3.2.3 Mission Support Alliance, LLC

MSA completed a full reassessment recertification audit in August 2017 to maintain the ISO 14001:2015 registration. There were seven system strengths, no major non-conformances, two minor non-conformances, and four opportunities for improvement. The auditors concluded that MSA remains compliant with the ISO 14001 standard and recommended certification to the 2015 revision.

MSA's EMS coordinator also presented the 2017 Environmental Leadership Awards. The awards were established to recognize outstanding environmental performance by employees. The FY 2017 winners were two employees from MSA's Information Management team.

3.2.4 Washington River Protection Solutions, LLC

In 2017 and 2018 the Washington River Protection Solutions (WRPS) Quality Assurance Organization conducted an internal audit and several surveillances to review implementation of WRPS's EMS as described in TFC-PLN-123, *EMS Description*, and its conformance with ISO 14001. The Quality Assurance Organization performs annual independent assessments of the WRPS EMS and divides the elements of ISO evenly over a 3-year time period so that all the elements of ISO have been thoroughly assessed between the required External Independent Triennial Audits for Declaration of Conformance to the ISO 14001 standard. The last triennial conformation audit was held in July 2015. There were no non-conformances found in either the surveillances or the 2015 triennial external audit.

3.2.5 Wastren Advantage Inc. Hanford Laboratory

In FY 2017 the Wastren Advantage Inc. Hanford Laboratory (WAI) conducted three assessments to review implementation of the EMS as described in WHL-MP-1044, *Environmental Management System Description*, and its conformance with ISO 14001. One minor Finding and no Opportunities for Improvement were identified. WAI's last conformation audit was held in September 2016.

3.3 References

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2017 Highlight

External Monitoring

Overall, the average dose rate levels measured in the operational areas during 2017 were comparable to the previous years' levels. Individual thermoluminescent dosimeter results and detailed maps of monitoring locations are available upon request.

Dose to the Offsite Maximally Exposed Individual

The dose to the offsite maximally exposed individual was 0.22 mrem (2.2 μ Sv)/yr for air emissions releases and releases to Columbia River water, which is 0.22% of the 100 mrem/yr U.S. Department of Energy dose standard.

Recreationalist Dose

Wildlife sampling was conducted at the Hanford Site to estimate radionuclide tissue concentrations in fish and game animals that could potentially be food sources. A fish ingestion dose of up to 0.15 mrem (1.5 μ Sv)/yr was calculated based on tissue samples of walleye and whitefish. Site-related radionuclides were not detected at levels greater than analytical minimum detectable activities in muscle tissue samples of game animals (Canada goose and cottontail rabbit).

Radiation Dose to Aquatic and Terrestrial Biota

The biota dose assessment evaluated potential exposures from Columbia River sediment and water, soil, and at West Lake. Columbia River sediment and water samples, as well as terrestrial soil samples passed the Tier 1 screen. Tier 3 biota dose calculations for West Lake using site-specific bioaccumulation factors indicated no expected adverse ecological effects.

Clearance of Property with Potential for Residual Radioactivity

Over 30,000 individual items of personal property were cleared from the Hanford Site during 2017 and released for unrestricted use by members of the public. These items were considered to have potential for residual radioactivity; they were verified to be free of residual radioactivity and to meet the DOE O 458.1 requirements. The Hanford Site did not release any real property (i.e., land or buildings) in 2017.

4.0 Radiological Protection and Doses

This section provides information on the Hanford Site radiological program and doses, as well as cleanup activities as the U.S. Department of Energy (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 Appendices A and B.

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 to 25% at any location because of changes in soil moisture and snow cover (NCRP 1975).

The Harshaw^{TM1} thermoluminescent dosimeter (TLD) system is used to measure external radiation on the Hanford Site. This type of TLD measures very low dose rates only and is not suitable for use for personnel monitoring. 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 2017 at 125 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.

Table 4-1. Thermoluminescent Dosimeter Locations (2017).
(2 Pages)

Location	No. of Dosimeters
100-K Area	14
100 Areas	4
200-East Area and WTP	45
200-West Area	24

¹ Harshaw is a trademark of Thermo Fisher Scientific, Inc., Waltham, Massachusetts.

Table 4-1. Thermoluminescent Dosimeter Locations (2017).
(2 Pages)

Location	No. of Dosimeters
200-North Area	1
300 Area	14
400 Area	7
618-10 Burial Ground	4
CVDF	4
ERDF	3
IDF	1
Perimeter	3
Reference	1
Total	125
CVDF=Cold Vacuum Drying Facility (100-K Area) ERDF=Environmental Restoration Disposal Facility (200-Westest Area) IDF=Integrated Disposal Facility (200-Eastast Area) TEDF=300 Area Treated Effluent Disposal Facility WTP= Waste Treatment Plant	

The average dose rate levels measured in the operational areas during 2017 were comparable to the previous years' levels (Figure 4-1).

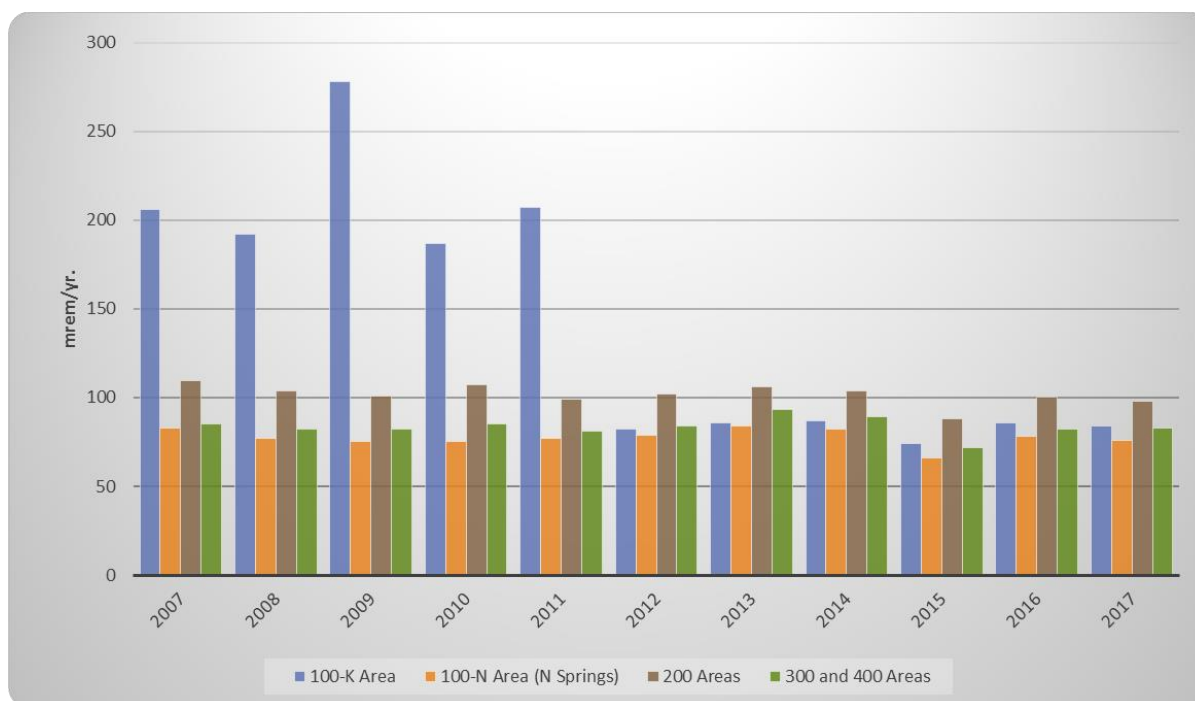


Figure 4-1. Average Thermoluminescent Dosimeter Results (mrem/year) in Selected Operational Areas.

4.1.1.1 100-K Area. As in years past, the 2017 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 the 100-K Area.

4.1.1.2 100 Areas. Dose rates measured along the Columbia River shoreline in the 100-N Area (N Springs) remained low during 2017. Three new locations along the River Corridor that were established during 2016 showed typical Hanford background dose rate levels during 2017.

4.1.1.3 200-East Area. Dose rate levels measured during 2017 near the “A” and “C” Tank Farms were higher than other 200-East Area locations.

200-East Area – Plutonium Uranium Extraction Facility (PUREX) Tunnel Monitoring. Immediately following the discovery of the collapsed PUREX tunnel in May, 12 nearby TLDs were collected and submitted to the laboratory for analysis. The data obtained showed no elevated dose rate levels at any of the 12 locations (Figure 4-2).

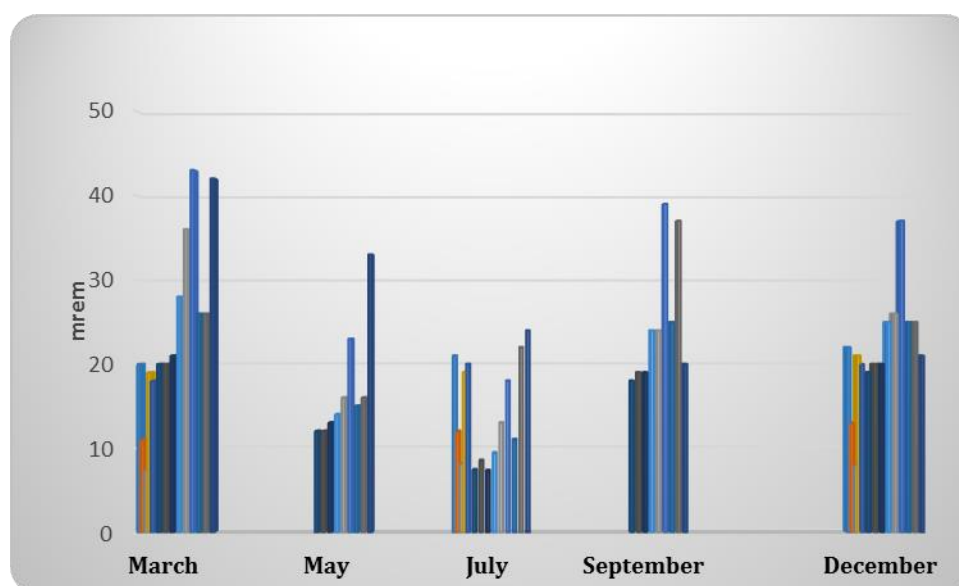


Figure 4-2. Thermoluminescent Dosimeter Results (mrem/hour) near PUREX.

200-East Area - Waste Treatment Plant (WTP) Baseline. During 2016, six new TLD monitoring locations were added in support of baseline monitoring for the WTP: three locations at onsite air sampling locations and three locations at offsite (perimeter) air sampling locations. Data obtained during 2017 showed dose rate levels at each location comparable to typical Hanford background levels.

200-West Area. Dose rate levels measured during 2017 near the “S” and “T” Tank Farms and at the Solid Waste Operations Complex were higher than other 200-West Area locations.

200-West Area – Plutonium Finishing Plant (PFP) Demolition. Demolition of the PFP facility continued during 2017. Three TLDs nearest the site showed dose rate levels at/near typical Hanford background

for most of the year. During the third quarter (June through September) there was a temporary increase (~ 20%) in dose rate levels at these three location (Figure 4-3).

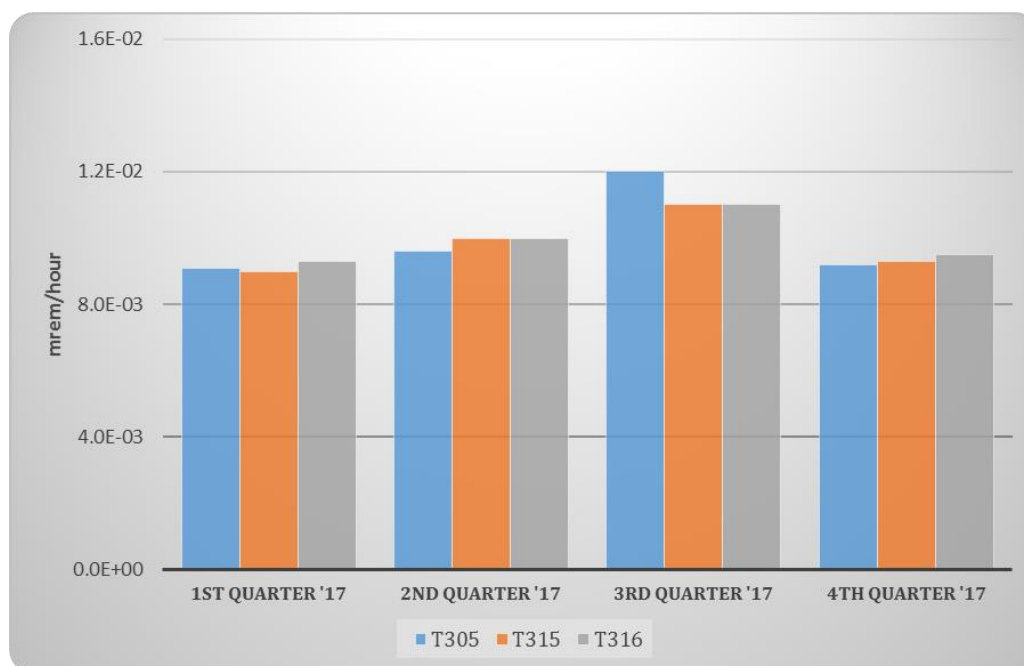


Figure 4-3. Thermoluminescent Dosimeter Results (mrem/hour) near the Plutonium Finishing Plant.

200-North. Dose rates measured in 2017 were low, and all four quarterly measurements were similar to each other and to recent years.

300 Area. Dose rate levels measured during 2017 at all locations in the 300 Area were at/near typical Hanford background levels.

400 Area. Dose rates measured in 2017 at all seven monitoring locations were low and similar to each other and to recent years.

Environmental Restoration Disposal Facility (ERDF). Dose rates measured in 2017 at all three monitoring locations were low and similar to each other and to recent years.

618-10 Burial Ground. Dose rates measured in 2017 at all four monitoring locations were low and similar to each other and to recent years. Remediation activities at this site were completed in late 2017 and TLD monitoring was concluded at that time.

Integrated Disposal Facility. Dose rates measured in 2017 were low and all four quarterly measurements were similar to each other and to recent years.

Perimeter Locations. Three locations (i.e., Ringold, west end of Fir Road, and Dogwood Met Tower) established in January 2016 showed low dose rate levels in 2017 that were similar to each other and to onsite levels.

Reference Locations. A location at the Yakima airport was added during September 2016 to provide a reference (aka background) dose rate level monitoring station. Results obtained during 2017 were approximately 10% less than typical Hanford background dose rate levels.

4.1.2 Waste Disposal Sites Radiological Surveys

JE Cranna and JW Wilde

Radiological surveys are performed at active and inactive waste disposal sites and the surrounding terrain to detect and characterize radioactive surface contamination. Radiation surveys with portable instruments monitor and detect contamination and provide a coarse screening for external radiation fields. The types of areas surveyed include 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 are used to accurately measure the extent of contamination along ERDF haul routes. Routine radiological survey locations include former waste disposal cribs and trenches, retention basin perimeters, ditch banks, solid waste disposal sites (e.g., burial grounds), unplanned release sites, tank farm perimeters, stabilized waste disposal sites, roads, and firebreaks in and around the Hanford Site operational areas. These sites are posted as underground radioactive material areas, contamination areas, and soil contamination areas.

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, AG Fleury, RT Rytí,

Potential radiological doses to the public and biota from Hanford Site operations in 2017 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 total annual dose to a hypothetical, maximally exposed individual (MEI) in 2017 at the offsite location where projected doses were highest (Horn Rapids Road) was 0.22 mrem (2.2 μ Sv). This dose is 0.22% of the 100 mrem (1,000 μ Sv)/yr public dose limit specified in [DOE O 458.1, Radiation Protection of the Public and the Environment](#). For context, a 2009 National Council on Radiation Protection and Measurements report (NCRP 2009) estimated that the overall annual exposure to ionizing radiation for the average American is 620 mrem (6,200 μ Sv), approximately half of which is related to natural sources and the other half attributable primarily to medical procedures.

The offsite MEI dose is one of the following eight radiological impacts of Hanford Site operations that are assessed or summarized in this section:

- Dose to a hypothetical MEI at an offsite 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)
- Dose for air pathways calculated using regulation-specified U.S. Environmental Protection Agency (EPA) methods for comparison to the *Clean Air Act* standards in [40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities"](#) (Section 4.2.3)
- Dose from recreational activities (e.g., 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)
- Dose 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 onsite surfacewater 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 routine ambient air measurements of tritium at locations near the 300 Area, radionuclide concentrations may be distinguishable from

background levels; these measurements are used to support interpretation of the dose assessment results.

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 International Convention on Radiological Protection (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](#) [ICRP 1979a] and [Supplement to Part 1](#) [ICRP 1979b]), which were 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 applied to dose assessments 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 used for the annual report dose calculations beginning in 2009 uses ICRP Publication 60 methods (ICRP 1991) and updated EPA dose factors (EPA 1999).

Offsite dose for an 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 Areas for tabulation of radiological dose. No direct permitted discharge of radioactive materials from the 100 or 300 Areas to the Columbia River has occurred since 2011. Radiological doses from the air pathways are calculated based on annual stack emissions measurements from approximately 60 emission points in the four 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 was measured in the Columbia River downstream of the Hanford Site (Richland Pumphouse station, HRM 46.4) in 2017 at low concentrations that were nevertheless 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 2.10.1 ([PNNL-14583](#)) 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 (Offsite 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 2017. This individual's exposure pathways were chosen to maximize the combined doses from all potential 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 offsite locations were evaluated to determine the location of the offsite MEI (Figure 4-2). The Ringold location receives maximal air pathway impacts from the 200 Areas. 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 population of West Pasco residents obtain their drinking water from the Riverview location via a community water system that draws water from the Columbia River; the domestic drinking water pathway for Columbia River water is, therefore, applied at this location. Residences in the vicinity of Horn Rapids Road receive drinking water from the City of Richland, which has an intake on the Columbia River downstream of the Hanford Site; the domestic drinking water pathway is, therefore, also applied here. Ringold, Riverview, and Horn Rapids Road are locations where Columbia River water is withdrawn for irrigation, and agricultural exposure pathways are applied at these locations.

Dose calculations for 2017 releases indicate that the MEI is located in the vicinity of the Pacific Northwest National Laboratory (PNNL) Laboratory Support Warehouse, an offsite 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 radiological dose was modeled using the aforementioned Columbia River and air emissions data for the following exposure routes:

- 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 grown on soil irrigated with Columbia River water and 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 nonmigratory fish.

A graphical depiction of the conceptual site model showing all potentially complete exposure pathways for the Horn Rapids Road MEI evaluated using GENII Version 2.10.1 (PNNL-14583) 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, and 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 2017 was calculated to be 0.22 mrem (2.2 μ Sv)/yr (Table 4-2; Figure 4-4). This dose is 0.22% of the 100 mrem (1,000 μ Sv)/yr public dose limit specified in DOE O 458.1 and 0.88% of the 25-mrem (250- μ Sv)/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 virtually 100% of the total dose of 0.22 mrem (2.2 μ Sv)/yr.

The primary radionuclides and exposure pathways contributing to the modeled MEI dose for air emission releases and Columbia River water releases are as follows:

- **Air Releases.** Inhalation and external exposure pathways related to radon isotopes and their radioactive progeny accounted for 75% of the total air pathways dose of 0.22 mrem (2.2 μ Sv)/yr. Consumption of food products containing tritium released from the 300 Area contributed approximately 23% of the total air pathways dose.
- **Water Releases.** Consumption of food grown using Columbia River water withdrawn downstream from the Hanford Site contributed approximately 53% of the total water pathways dose of 0.0011 mrem (0.011 μ Sv)/yr, and drinking water ingestion contributed about 44%. Most of the remaining 3% of the water pathways dose is related to consumption of fish from the Columbia River. Tritium was the only contaminant identified in Columbia River samples in 2017 and, therefore, contributed 100% of the water-pathways dose. A sampling instrument failure may have affected identification of Hanford-related contaminants in Columbia River samples, as discussed in Section 4.2.1.1.

4.2.1.1 MEI Dose Discussion. The 2017 MEI dose of 0.22 mrem (2.2 μ Sv)/yr is larger than the 0.12 mrem (1.2 μ Sv)/yr 2016 MEI dose (DOE/RL-2017-24) and approximately equivalent to the 0.21 mrem (2.1 μ Sv)/yr MEI dose calculated in 2015 ([DOE/RL-2016-33, Hanford Site Environmental Report for Calendar Year 2015](#)). The difference between the 2017 and 2016 dose estimates is mostly attributable to larger 2017 releases of radon isotopes from the 300 Area.

In August 2017 the Richland Pumphouse sampling station continuous water sampler failed and water samples for the period of August through December were instead collected as 0.5-gal (2-L) grab samples. The continuous sampler collected 55-mL water samples at 1-hr intervals, which were composited bimonthly and then combined for a single monthly composite (DOE/RL-2017-24; Section 7.2.1). Historically, water pathways dose has been mainly related to river concentrations of uranium isotopes. Unlike in previous years, in 2017 neither uranium-234 nor uranium-238 were identified at higher levels in Columbia River samples downgradient of the Hanford Site. It is possible that identification of uranium isotope releases in 2017, and therefore dose from the water pathways, has been impacted by this change in downstream (Richland Pumphouse) sampling methods. The 2017 uranium river water data are evaluated in the context of trends in previous years data to evaluate the possible influence of the change in downstream sampling methods on identification of uranium isotope releases.

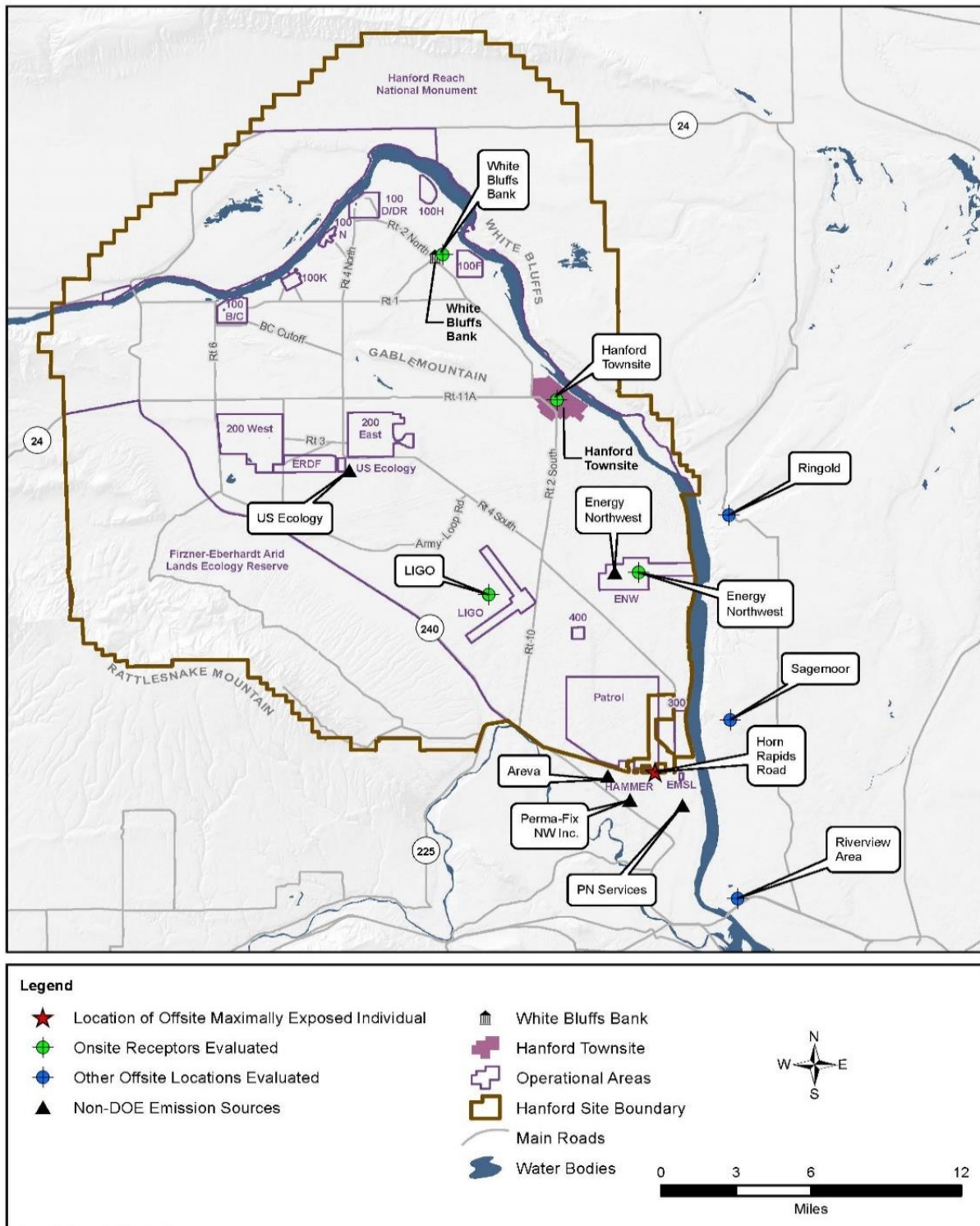


Figure 4-4. Locations Evaluated for Onsite and Offsite Receptors.

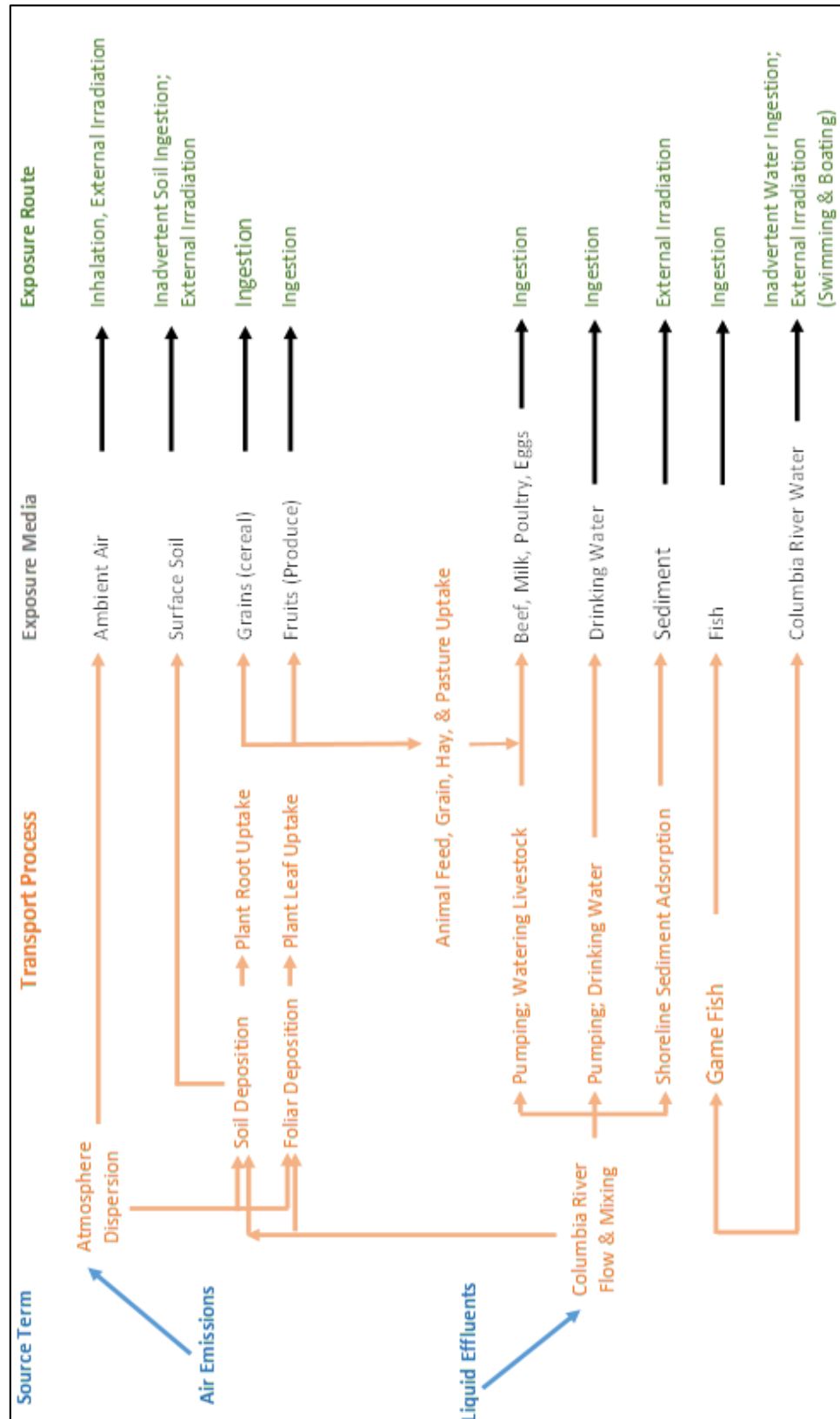
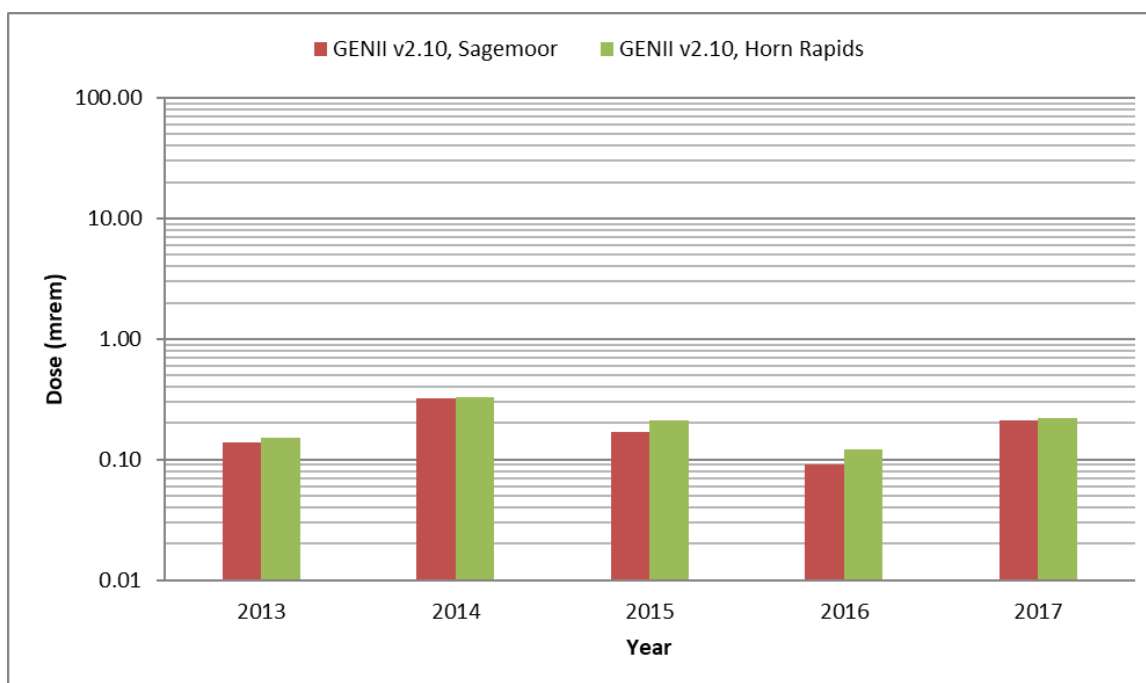


Figure 4-5. Conceptual Site Model of Exposure Pathways Evaluated in Dose Calculations (Horn Rapids Road MEI).

Table 4-2. Pathway Doses for the Hypothetical MEI Residing at Horn Rapids Road.

Release Type	Exposure Pathway	Dose Contributions from Operational Areas (mrem) ^a				
		100 Area	200 Areas	300 Area	400 Area	Pathway Total
Air	Food Ingestion	5.1E-07	1.4E-04	0.051	8.0E-07	0.051
	Inhalation	3.6E-06	4.2E-05	0.15	1.3E-06	0.15
	External, Soil Ingestion	5.9E-09	8.7E-08	0.023	1.0E-08	0.023
	Subtotal Air	4.1E-06	1.8E-04	0.22	2.1E-06	0.22
Water	Irrigation (food and soil ingestion; external)	NA ^{b, d}	6.0E-04 ^c	NA ^d	NA ^d	6.0E-04
	Drinking Water Ingestion	NA ^{b, d}	4.9E-04 ^c	NA ^d	NA ^d	4.9E-04
	Recreation (river water, sediments; external, ingestion)	NA ^{b, d}	1.4E-06 ^c	NA ^d	NA ^d	1.4E-06
	Fish Ingestion	NA ^{b, d}	2.7E-05 ^c	NA ^d	NA ^d	2.7E-05
	Subtotal Water	NA ^d	0.0011	NA ^d	NA ^d	0.0011
Air + Water Total		4.1E-06	0.0013	0.22	2.1E-06	0.22

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

**Figure 4-6. Total Dose for the Hypothetical MEI Over Time.**

The water pathways dose has historically been predominantly attributable to uranium isotopes. For comparison to the 2017 water pathway MEI dose of 0.0011 mrem (0.011 μ Sv)/yr, the 2016 dose including the contribution of uranium isotopes was 0.026 mrem (0.26 μ Sv)/yr. Figure 4-5 shows the individual sample results and the annual-average downstream concentrations of uranium-234. Uranium-238 has an analogous time history pattern to that of uranium-234. The difference between the average downstream concentrations (the blue line in Figure 4-5) and average upstream concentrations (the red line in Figure 4-5) for each year represents the source concentration of uranium-234 used in the water pathways risk assessment for that year. Downstream uranium isotope concentrations have been larger than upstream concentrations until 2017.

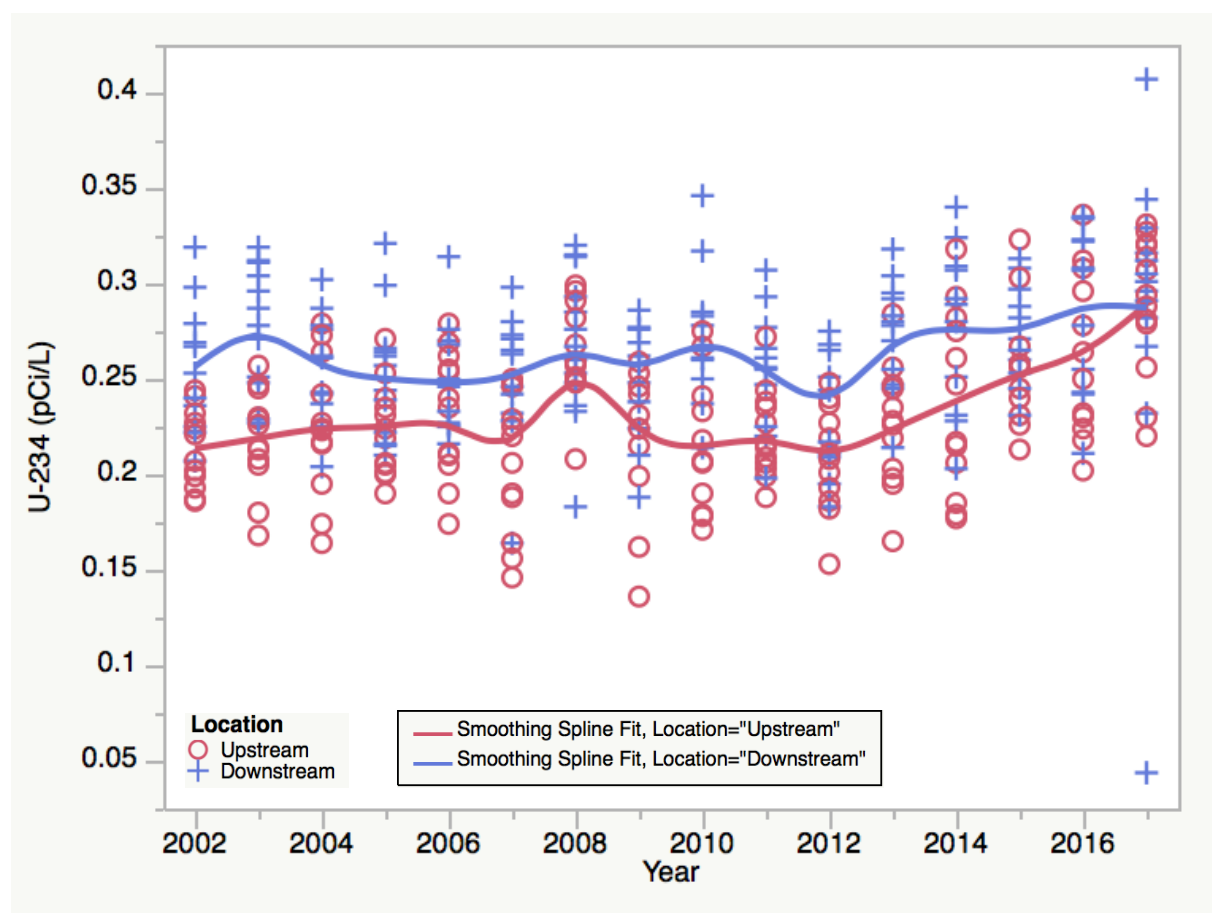


Figure 4-7. Comparison of Upstream (Priest Rapids Dam) and Downstream (Richland Pumphouse) Annual-Average Uranium-234 Concentrations Over Time.

Clearly, the continuous (hourly) samples are better estimates of average monthly river concentrations than a single 0.5-gal (2-L) grab sample. However, review of Figure 4-5 does not support a conclusion that the switch to grab samples in August 2017 affected the annual-average downstream concentration. Annual average upstream uranium-234 concentrations have been increasing for the past 5 years, and downstream concentrations have been relatively unchanged for 5 years. The confluence of upstream and downstream uranium isotope concentrations in 2017 may therefore be the result of the

continuation of this pattern of the past 5 years. Alternatively, because the difference in downstream versus upstream contaminant concentrations is commonly larger during the lower-flow time periods (including the fall), any impact of switching to grab samples at Richland Pump house after July 2018 might have had a comparatively large impact on the 2017 annual-average difference in downstream and upstream concentrations. Interestingly, the very low measured concentration of 0.044 pCi/L in 2017 was measured in a continuous sample in April and not a grab sample, as might be expected if grab samples contribute to larger sample-to-sample variability. The high 2017 value of 0.41 pCi/L was, however, measured in a grab sample.

There are several reasons why continuous samples are preferable in principle to grab samples for characterizing average river water concentrations. Water levels vary during the day due to impoundment and releases for power generation and other purposes. Having water samples collected each hour represents this daily cycle and collecting many sample increments each month better captures seasonal changes in flow. Contaminant discharges along the Hanford Reach will be more or less diluted depending on river flow and elevation. For example, grab samples collected at a time of day with higher Hanford Reach river elevation could inadvertently create a low result in the measured downstream concentrations. It is also possible that differences in the location of radionuclide discharges along the Hanford Reach might influence how river elevation affects Richland Pump house river concentrations of different radionuclides (e.g., tritium and uranium isotopes) at the time a grab sample is collected.

The MEI dose estimate incorporates a number of conservative assumptions to ensure that pathway doses are protective; 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 in 2017 from all stacks are a small fraction (27% and 12%, 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. 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 (e.g., carp and bass).

Because tritium is measured in ambient air samples from air monitoring station samples, and releases of tritium from the 300 Area are a significant 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 measured concentrations. Figure 4-6 shows the 2017 modeled annual average air concentrations of tritiated water vapor (HTO) at the Horn Rapids Road MEI location and 2017 annual averages based on measured values at locations near 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 in Figure 4-6 in addition to the annual average.

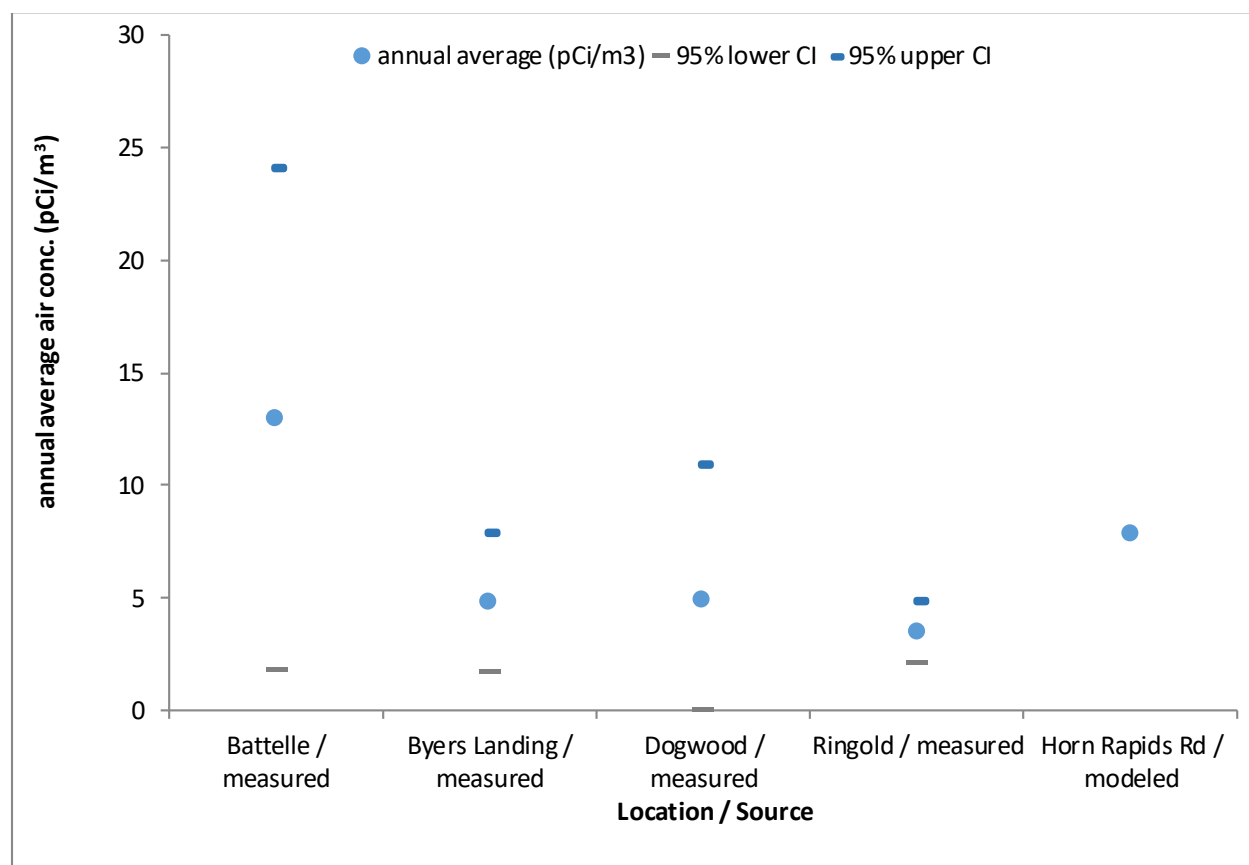


Figure 4-6. Comparison of Measured and Modeled Tritium Air Concentrations Near the 300 Area.

NOTE: 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 Ringold location. The Horn Rapids Road modeled annual-average tritium concentration is approximately equal to the 95% upper confidence interval of the mean of the measured values at the Byers Landing monitoring station, and within the range of the lower and upper confidence limits at the remaining two locations. A relationship between 300 Area monthly tritium air emissions and onsite 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 offsite monitoring locations. Figure 4-6 shows that the modeled MEI tritium air concentration is within the confidence intervals for annual-average tritium concentrations measured at the Battelle Complex, which is nearest the Horn Rapids Road MEI location. The high variability of measured tritium concentrations at this location may reflect month-to-month variability in operational releases.

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. Also, 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).

Samples of locally raised foodstuffs were collected in 2017 from four locations including the Sagemoor, Riverview, Sunnyside, and East Wahluke areas. Sampled foodstuffs included fruits (cherries, melons, and tomatoes), leafy vegetables, potatoes, corn, milk, and wine. With the exception of strontium-90 analyses for wine, gamma-emitting radionuclides and strontium-90 were analyzed in all foodstuffs, and tritium was analyzed in tomatoes, wine, and milk. Additionally, carbon-14 was analyzed in melons, corn, and leafy vegetables. Reported results for the Hanford-related radionuclides carbon-14, strontium-90, 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 carbon-14, tritium, and strontium-90 are related to air emissions. Modeled concentrations of tritium are also related to irrigation with Columbia River water. The following observations are drawn from the comparisons:

- Carbon-14 was not detected in any of the 10 crop samples collected from the Sagemoor, Riverview, Sunnyside, and East Wahluke areas. The minimum detectable activities for these samples ranged from approximately 1.3 to 6.2 pCi/g. The modeled carbon-14 concentrations in crops grown at the MEI location of Horn Rapids Road are far below these activities, with a highest value of 0.0001 pCi/g, corresponding to a calculated annual dose of 1E-05 mrem (0.0001 μ Sv)/yr.
- Strontium-90 was analyzed in 22 crop samples and detected in 1 leafy vegetable sample (0.00458 pCi/g) and 1 cherry sample (0.00225 pCi/g) from the Riverview and East Wahluke areas, respectively. Strontium-90 was not elevated in downstream Columbia River water samples in 2017 and, therefore, was not included in the water pathways dose calculations. Low levels of strontium-90 in the environment are widespread due to past above-ground weapons testing. The measured concentrations in these samples are consistent with trends based on observations in offsite vegetation samples ([PNNL-20577, Radionuclide Concentrations in Terrestrial Vegetation and Soil Samples On and Around the Hanford Site, 1971 Through 2008](#)). For comparison, modeled concentrations of strontium-90 in crops grown at Horn Rapids Road are hundreds of thousands of times below these ambient levels.
- Tritium was analyzed in samples of tomatoes from the Sunnyside and Riverview areas but was not detected at either location with a minimum detectable activity of approximately 0.6 pCi/g. Tritium was detected in samples of milk at average concentrations of approximately 25 pCi/L (Sunnyside), 23 pCi/L (East Wahluke), and 27 pCi/L (Sagemoor). These concentrations are about 10 times below the modeled worst-case tritium concentration in milk for cows grazing at the MEI location of Horn Rapids Road (approximately 330 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 2017 Hanford Site operations was estimated by calculating the radiological dose to the population residing within a 50-mi (80-km)

radius of onsite operating areas (DOE O 458.1). 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 2.10.1 computer code (PNNL-14583).

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 2017 was 1.2 person-rem (0.012 person-Sv)/yr (Table 4-3), below the collective dose calculated from 2013 through 2015 and approximately equal to that calculated in 2016 (Figure 4-7). Air pathway contributions from releases in the 300 Area contributed effectively 100% of the population dose, with water pathway contributions being only 0.056 person-rem (0.00056 person-Sv) in 2017. As discussed in Section 4.2.1.1, the relatively low water pathways contribution may be related to the August 2017 failure of the Richland Pumphouse sampling station continuous water sampler and the replacement of the time-integrated water samples with 0.5-gal (2-L) grab samples for the period of August through December 2017.

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

- **Air Releases.** Inhalation exposure contributed approximately 66% of the of the air pathways collective dose of 1.2 person-rem (0.012 person-Sv). The remaining air pathways collective dose is primarily related to consumption of food products grown downwind of the 300 Area. About 60% of the air pathways doses are due to inhalation of the radioactive progeny of radon-220 released from the 300 Area. Approximately another 35% of the total air pathways collective dose is associated with releases of tritium 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 96% of the total water pathways collective dose of 0.056 person-rem (0.00056 person-Sv). Tritium was the only contaminant identified in Columbia River samples in 2017 and, therefore, contributed 100% of the water-pathways dose. A sampling instrument failure may have affected identification of Hanford-related contaminants in Columbia River samples, as discussed in Section 4.2.1.1.

The collective dose in 2017 of 1.2 person-rem (0.012 person-Sv) is the same as the collective dose in 2016, although the relative influence of tritium and radon were different. There is no specific

collective dose metric analogous to the 100 mrem (1,000 mSv)/yr public dose limit for individual exposures described in Section 4.2.

Table 4-3. Collective Pathway Doses within a 50-mi (80-km) Radius.

Release Type	Exposure Pathway	Dose Contributions from Operational Areas, person-rem ^a				
		100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	Food Ingestion	8.4E-05	0.013	0.36	3.5E-05	0.37
	Inhalation	0.0011	0.0072	0.79	7.9E-05	0.80
	External, Soil Ingestion	1.2E-06	7.4E-06	0.017	3.9E-07	0.017
	<i>Subtotal Air</i>	<i>0.0012</i>	<i>0.020</i>	<i>1.2</i>	<i>1.1E-04</i>	<i>1.2</i>
Water	Irrigation (food and soil ingestion; external)	NA ^{b, d}	0.0021 ^c	NA ^d	NA ^d	0.009
	Drinking Water Ingestion	NA ^{b, d}	2.5E-05 ^c	NA ^d	NA ^d	4.9E-04
	Recreation (river water, sediments; external, ingestion)	NA ^{b, d}	3.8E-06 ^c	NA ^d	NA ^d	0.0053
	Fish Ingestion	NA ^{b, d}	0.054 ^c	NA ^d	NA ^d	0.44
	<i>Subtotal Water</i>	<i>NA^d</i>	<i>0.056</i>	<i>NA^d</i>	<i>NA^d</i>	<i>0.45</i>
Air + Water Total		0.0012	0.076	1.2	1.1E-04	1.2

^a To convert person-rem to International System dose units (person-Sv), divide by 100.
^b No measured releases; the last 100 Area NPDES-permitted outfall (1908-K Outfall) ceased releases in March 2011.
^c Integrates releases from all operational areas based on difference between down- and upstream Columbia River radionuclide concentrations.
^d All liquid discharges reflected in difference between up- and downstream radionuclide concentrations assigned to 200 Areas.

NA = not applicable.
 NPDES = National Pollutant Discharge Elimination System

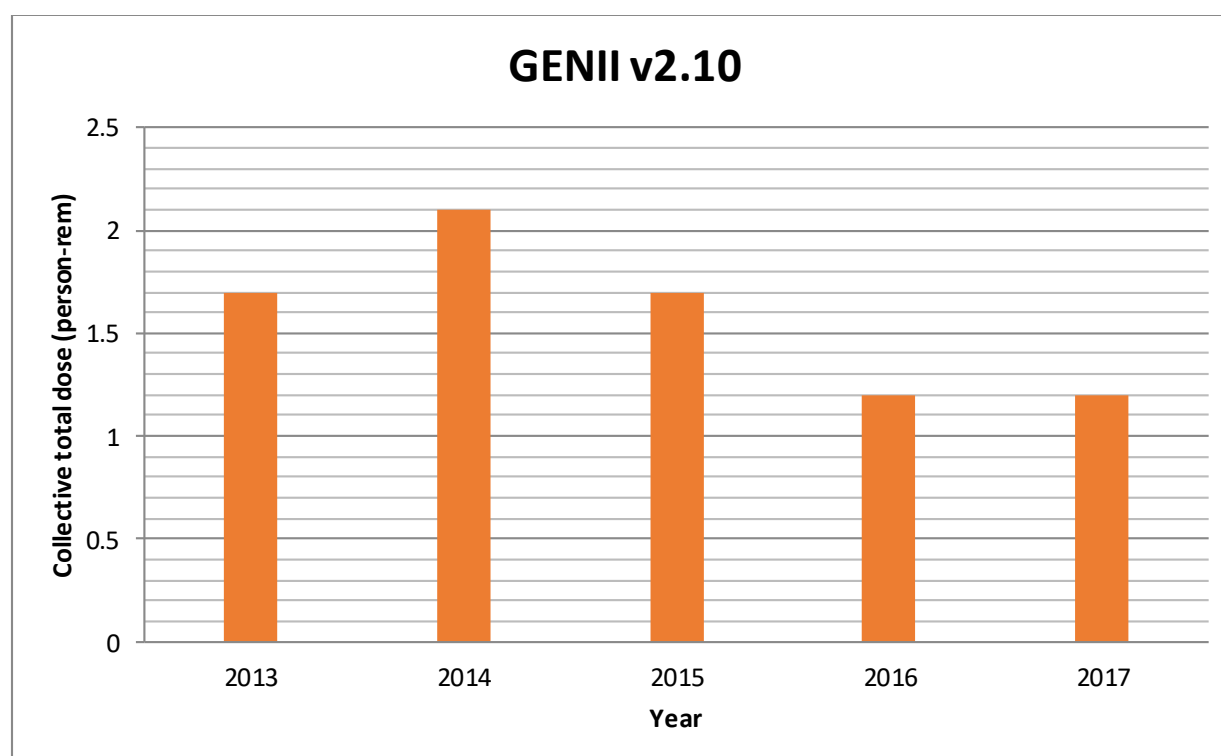


Figure 4-7. Collective Total Dose within a 50-mi (80-km) Radius.

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 offsite individual; however, the MEI dose 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 offsite 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 μ Sv)/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 offsite 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 offsite dose. For more detailed information about 2017 air emissions at the Hanford Site, refer to DOE's report to EPA (DOE/RL-2018-05).

4.2.3.1 Dose from Stack Emissions to an Offsite Maximally Exposed Individual. Using CAP-88, the offsite MEI for air pathways in 2017 was at the PNNL Richland Campus' Laboratory Supply Warehouse, an offsite business located in north Richland, Benton County, Washington, 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 an MEI at that location calculated using the CAP-88 computer code was determined to be 0.072 mrem (0.72 μ Sv)/yr, less than 1% of the EPA standard of 10 mrem (100 μ Sv)/yr. The CAP-88 result is approximately one-third of the air pathway dose of 0.22 mrem (2.2 μ Sv) for stack emissions calculated with GENII (Table 4-2).

Dose related to radon-222 and 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- μ Sv)/yr standard established in [WAC 246-247, "Radiation Protection – Air Emissions."](#) A release of 885 curies of radon-220 and 0.000036 curies of radon-222 was calculated from engineering estimates for stack emissions from the 325 Building in the 300 Area. A radon-220 and radon-222 dose of 0.14 mrem (1.4 μ Sv)/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, radon-222, and dose calculated for compliance with 40 CFR 61, Subpart H using the CAP-88 computer code is approximately 0.21 mrem (2.1 μ Sv), which is approximately the same as the Horn Rapids Road air pathways MEI dose of 0.22 mrem (2.2 μ Sv) calculated using the GENII computer code.

4.2.3.2 Dose from Diffuse and Fugitive Radionuclide Emissions to an Offsite 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-2018-05). Modeled contributions from monitored stack emissions and contributions from background levels of radionuclides are subtracted from perimeter ambient air concentrations measured for each radionuclide. 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-2018-05). The estimated dose from diffuse emissions to an MEI was calculated using the CAP-88 computer code to be 0.021 mrem (0.21 μ Sv)/yr. Therefore, the potential combined dose from stack emissions, radon-220 and radon-222 emissions, and diffuse emissions (excluding these radon isotopes) during 2017 at the Laboratory Supply Warehouse location was 0.24 mrem (2.4 μ Sv)/yr, far below the 10 mrem (100 μ Sv)/yr 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 allows private businesses to locate their activities and personnel on some regions of the Hanford Site. The EPA Region 10 Office and the Washington State Department of Health provided guidance to the U.S. Department of Energy, Richland Operations Office (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 onsite 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 2017 EPA air emissions report (DOE/RL-2018-05) as possible MEI locations. Included in these locations were the Columbia Generating Station operated by Energy Northwest and the 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 Washington State Department of Health 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 2017 stack emissions, fugitive source emissions, and radon-220 and radon-222 at LIGO was calculated using CAP-88 to be 0.068 mrem (0.68 μ Sv) (DOE/RL-2017-17). Even assuming that a LIGO employee is continuously present, the estimated total dose to non-DOE onsite workers in 2017 was lower than the 0.24 mrem (2.4 μ Sv)/yr total dose calculated with CAP-88 to an offsite 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 offsite. Wildlife sampling was conducted at the Hanford Site to estimate radionuclide tissue concentrations in animals from the site that could potentially have been hunted offsite. 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.

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 2017 sediment data indicates that concentrations of key radionuclides frequently detected in sediment (including cesium-137, plutonium-239/240, and uranium isotopes) have approximately equal or larger concentrations in upstream (Priest Rapids Dam) samples in comparison to samples from downstream (McNary Dam) locations and samples at slough locations along the Hanford Site near White Bluff and the Hanford Townsite. The 2017 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.

Gamma-emitting radionuclides were analyzed in muscle tissue samples collected in 2017 from Canada goose and cottontail rabbit. In addition to muscle tissue, samples of bone tissue were obtained from these animals and analyzed for strontium-90, a radionuclide that accumulates in bone. For estimating dose from ingestion of game meat, radionuclide concentrations in muscle tissue are most applicable. However, the only radionuclide detected in the muscle tissue of any animal was potassium-40, a naturally occurring primordial radioisotope that is not of Hanford Site origin. Because site-related radionuclides were not detected at levels greater than analytical minimum detectable activities, calculations of dose related to ingestion of game meat were not performed.

Fillet tissue and carcass samples were obtained from whitefish and walleye in two river sections of the Hanford Reach and reference locations in 2017. 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 potassium-40, uranium-234, and uranium-238. Potassium-40 is a naturally occurring radionuclide that is not of Hanford

Site origin. However, uranium isotopes are associated with Hanford Site operations and dose calculations were performed for these analytes.

Uranium-234 and uranium-238 were detected in one whitefish fillet sample from the 100 Area. Uranium-234 was also detected in one walleye fillet sample from the 300 Area and one whitefish fillet sample from the reference area. The whitefish fillet uranium-234 concentration measured in the reference area fish was 0.0102 pCi/g, which is practically identical to the whitefish fillet uranium-234 concentration measured at the 100 Areas (0.0105 pCi/g) and the whitefish fillet uranium-238 concentration measured at the 100 Areas (0.0105 pCi/g). The walleye fillet uranium-234 concentration measured at the 300 Area was 0.00517 pCi/g, about one-half of the uranium isotope concentrations measured in whitefish.

These uranium-234 and uranium-238 results for whitefish in 2017 are larger than the values measured in whitefish fillets in the reference and 100 Areas in 2015 (0.000422 to 0.000957 pCi/g), which is the last year when whitefish fillets were acquired. In neither 2015 nor 2017 do the data indicate that uranium isotope concentrations are higher in whitefish fillets from fish collected in the 100 or 300 Areas than in reference area fish. Nevertheless, potential radiation dose received from consumption of fish fillets with isotopic uranium concentrations measured in 2017 was calculated to provide a measure of the significance of these levels.

The potential radiation dose received from consumption of fish fillets with the largest isotopic uranium concentrations measured in 2017 would be negligible. Assuming annual fish consumption of 88 lb (40 kg) for an MEI (Table D-4), the annual radiation dose related to fish ingestion for fish with tissue concentrations of 0.0105 pCi/g of uranium-234 and uranium-238 is estimated to be 0.147 mrem (1.47 μ Sv). The annual dose estimate for fish ingestion was derived using an ingestion dose factor of 1.8×10^{-4} mrem/pCi (4.9×10^{-2} μ Sv/Bq) for uranium-234 and 1.7×10^{-4} mrem/pCi (4.6×10^{-2} μ Sv/Bq) for uranium-238 from ICRP Publication 72 (ICRP 1995) in the following manner:

$$((0.0105 \text{ pCi uranium-234/g} \times 1.8 \times 10^{-4} \text{ mrem/pCi}) + (0.0105 \text{ pCi uranium-238/g} \times 1.7 \times 10^{-4} \text{ mrem/pCi})) \times 40 \text{ kg/yr} \times 1,000 \text{ g/kg} = 0.147 \text{ mrem (1.47 } \mu\text{Sv)/yr}$$

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 2017 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 (primary well P-14 and emergency backup well P-15). 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, and 400 Areas 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 onsite 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 2017 in one sample from each of the four drinking water sources described above 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 minimum detectable activity in any sample.

Tritium was measured in four quarterly samples from backup well P-15 in the 400 Area, and one (fall) sample from each of the other three drinking water sources described above. Tritium was not measured above its analytical minimum detectable activity in the samples obtained from the 100-K Area and 200-West Area. Tritium was detected in all four drinking water samples collected from the backup drinking water sources for the 400 Area (well P-15) and also in the one sample from well P-14. The tritium concentration measured for the sample from well P-14 (6,710 pCi/L) was within the range of values measured in the quarterly samples from well P-15 (6,210 to 7,100 pCi/L). Based on the average of the five 400 Area samples, the annual average 400 Area drinking water tritium concentration was 6,690 pCi/L (248 Bq/L). Assuming a consumption rate of 0.26 gal (1 L)/day for 250 working days at the Fast Flux Test Facility in the 400 Area, the potential annual worker dose in 2017 would be approximately 0.112 mrem (1.12 μ Sv). This estimate is well below EPA's drinking water dose limit of 4 mrem (40 μ Sv)/yr for beta-emitting radionuclides in public drinking water supplies.

The dose estimate for the 400 Area drinking water sources was derived using a tritium ingestion dose factor of 6.7×10^{-8} mrem/pCi (1.8×10^{-5} μ Sv/Bq) from ICRP Publication 72 (ICRP 1995) in the following manner:

$$6,690 \text{ pCi tritium/L} \times 1 \text{ L/day} \times 250 \text{ d/year} \times 6.7 \times 10^{-8} \text{ mrem/pCi} = 0.112 \text{ mrem (1.12 } \mu\text{Sv)/yr}$$

4.2.4.3 Manhattan Project National Historical Park Visitor Dose. The Manhattan Project National Historical Park at the Hanford Site 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 the 100-K and 200 Areas. These historical locations are geographically closer to these air emissions sources than the offsite MEI locations evaluated in Section 4.2.1. However, unlike an offsite 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 offsite MEI.

Inhalation dose related to 100-K and 200 Areas stack emissions was calculated for a hypothetical individual at the Hanford Townsite and White Bluffs Bank locations using the GENII Version 2.10.1 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 engaging 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 (2017).

Release Type	Exposure Pathway	Location	Dose Contributions from Operational Areas, mrem ^a		
			100 Area	200 Areas	Pathway Total
Air	Inhalation	Hanford Townsite	3.8E-05	7.1E-05	1.1E-04
		White Bluffs Bank	1.1E-04	5.9E-05	1.7E-04

^a To convert mrem to International System dose units (μSv), multiply by 10.

Radiological doses assuming continuous inhalation exposure at either the Hanford Townsite or White Bluffs Bank locations are far below the hypothetical offsite MEI air pathways annual dose of 0.22 mrem (2.2 μSv; 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 2017 because the MEI dose of 0.22 mrem (2.2 μSv)/yr from DOE-related sources (Section 4.2.1) was far below the threshold of 25 mrem (250 μSv)/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 μSv) in a year or less. If the DOE-related dose is greater than 25 mrem (250 μSv) in a year, the dose to members of the public must include major non-DOE sources of exposure and dose from DOE-related sources.

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 exposures associated with West Lake. Upper estimates of the radiological dose to aquatic organisms were made in accordance with the DOE O 458.1 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])/day ([DOE-STD-1153-2002, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota](#)). 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, DOE-STD-1153-2002 provides a dose limit for terrestrial plants of 1 rad (10 milligray [mGy])/day and 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](#)) to compare radionuclide concentrations measured by routine monitoring programs to a set of biota concentration guides (BCG).

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 2017 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, cesium-137, plutonium-238, plutonium-239/240, strontium-90, technetium-99, tritium, uranium-234, uranium-235, uranium-236, and uranium-238. RESRAD-BIOTA v1.8 lacks uranium-236 BCGs for estimating radiological dose. As a result, uranium-236 values were added to uranium-235 values due to similar radiological decay emissions between the isotopes and assessed using the uranium-235 BCG from RESRAD-BIOTA v1.8. Beryllium-7 was detected but is of cosmogenic origin and is not associated with the Hanford Site. Potassium-40 was also detected in sediments upstream, onsite, 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 (i.e., upstream, 100 Area, 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 Area is from carbon-14 (77%) and strontium-90 (18%); 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.

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 Areas 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 [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (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 2017 and data tabulated (Appendix C, Tables C-1, C-2).

The results of the 2017 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 six water and seven 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 4-5. Estimated Doses to Biota Associated with Columbia River Sediment and Water^a.

Location	Media Sampled for Key Radionuclides ^b	Tier 1 Screen Sum of Fractions ^c		Pass or Fail
		2016	2017	
Upstream	Sediment, Water	0.018	0.018	Pass
100 Area	Sediment, Water	0.71	0.46	Pass
Hanford Townsite	Sediment, Water	0.014	0.014	Pass
300 Area	Sediment, Water	0.25	0.27	Pass
Downstream	Sediment, Water	0.015	0.016	Pass

^a Using RESRAD-BIOTA 1.8 computer code, a screening method to estimate radiological doses to aquatic and riparian biota.

^b A sum of fractions is calculated to account for the contribution to dose from each radionuclide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded and further screening (Tier 2 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.

^c 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.

Table 4-6. Estimated Doses to Biota Associated with West Lake^a.

Tier	Exposure Assumptions	Sum of Fractions ^b		Pass or Fail
		2016	2017	
1	Maximum Sediment, Water Concentration and Default Bioaccumulation	115	6.32	Fail
2	Average Sediment, Water Concentration and Default Bioaccumulation	41	4.25	Fail
3	Average Sediment, Water Concentration and Site-specific Bioaccumulation	0.49	0.095	Pass

^a Using RESRAD-BIOTA 1.8 computer code, a screening method to estimate radiological doses to aquatic and riparian biota.

^b A sum of fractions is calculated to account for the contribution to dose from each radionuclide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded and further screening (Tier 2 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 2015; however, the 2017 doses were about 3 times less than those calculated for 2016 (Table 4-6). The reason for the change 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 isotopic ratios of uranium indicate a natural source (PNL-7662). The last 3 years of concentrations were 2015 (uranium-234 at 1,650 pCi/L, uranium-235 at 87.1 pCi/L, uranium-238 at 1,570 pCi/L), 2016 (uranium-234 at 10,700 pCi/L, uranium-235 at 43.5 pCi/L, uranium-238 at 13,700 pCi/L), and 2017 (uranium-234 at 658 pCi/L, uranium-235 at 34.7 pCi/L, uranium-238 at 623 pCi/L). The maximum concentration measured in 2017 was about 20 times less than that measured in 2016. 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 the Hanford Site. The RESRAD-BIOTA computer code evaluates potential effects on biota from the maximum concentrations of radionuclides measured in onsite soil samples as tabulated in Appendix C. The radionuclides evaluated in soil are cesium-137, plutonium-238, plutonium-239/240, strontium-90, uranium-234, uranium-235, and uranium-238, and americium-241. The results of 2017 screening calculations listed in Table 4-7 show the onsite soil concentrations passed the Tier 1 screen based on the maximum concentration. Basically, the entire estimated dose for onsite locations is from cesium-137 (90%) and strontium-90 (9.7%). See PNNL-20577 for a long-term trend in soil concentrations and associated biota doses on and off the Hanford Site.

Table 4-7. Estimated Doses to Terrestrial Biota Associated with On- and Offsite Soil^a.

Location	Tier 1 Screen Sum of Fractions ^b		Pass or Fail
	2016 ^b	2017	
Onsite	0.57	0.86	Pass
Offsite	Not measured ^c	Not measured ^c	--

^a Using RESRAD-BIOTA 1.8 computer code, a screening method to estimate radiological doses to aquatic and riparian biota.

^b A sum of fractions is calculated to account for the contribution to dose from each radionuclide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded and further screening (Tier 2 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.

^c Offsite soil samples are collected approximately every 3 to 5 years and are planned for collection in 2018.

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 strontium-90 (0.103 pCi/g), uranium-234 (0.0105 pCi/g), and uranium-238 (0.0105 pCi/g) in fish was 0.0001 rad/day. Internal dose to terrestrial plants based on the maximum concentrations of cesium-137 (0.804 pCi/g), plutonium-238 (0.000772 pCi/g), plutonium-239/240 (0.00612 pCi/g), strontium-90 (0.59 pCi/g), uranium-234 (0.0467 pCi/g), uranium-235 (0.0195 pCi/g), and uranium-238 (0.0308 pCi/g) in plants was 0.0006 rad/day. Dose to terrestrial animals based on the maximum concentration of strontium-90 (0.0627 pCi/g) in goose bones was 0.000004 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 hypothetical annual dose for the MEI in 2017 was 0.22 mrem (2.2 μ Sv; Section 4.2.1). The annual dose for an average individual from Hanford Site operations in 2017, 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 0.0031 mrem (0.031 μ Sv). 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 National Council on Radiation Protection and Measurement report *Ionizing Radiation Exposure of the Population of the United States* (NCRP 2009) estimated that the overall average exposure to ionizing radiation for the average American is 620 mrem (6,200 μ Sv)/yr. Approximately 50% of the 620 mrem (6,200 μ Sv)/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 4-8). Average annual individual background dose related to terrestrial radiation (19 mrem [190 μ Sv]), cosmic background radiation (30 mrem [300 μ Sv]), and radon (radon-222) and thoron (radon-220) gases (230 mrem [2,300 μ Sv]) are shown relative to Hanford Site operational doses in Figure 4-9. The calculated radiological doses from Hanford Site operations in 2017 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 4-9 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 μ Sv]) is approximately 86 times larger than the 2017 Hanford Operations dose to the MEI receptor (0.22 mrem [2.2 μ Sv]).

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.

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 (UNSCEAR 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 μ Sv; 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 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 μ Sv).

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.

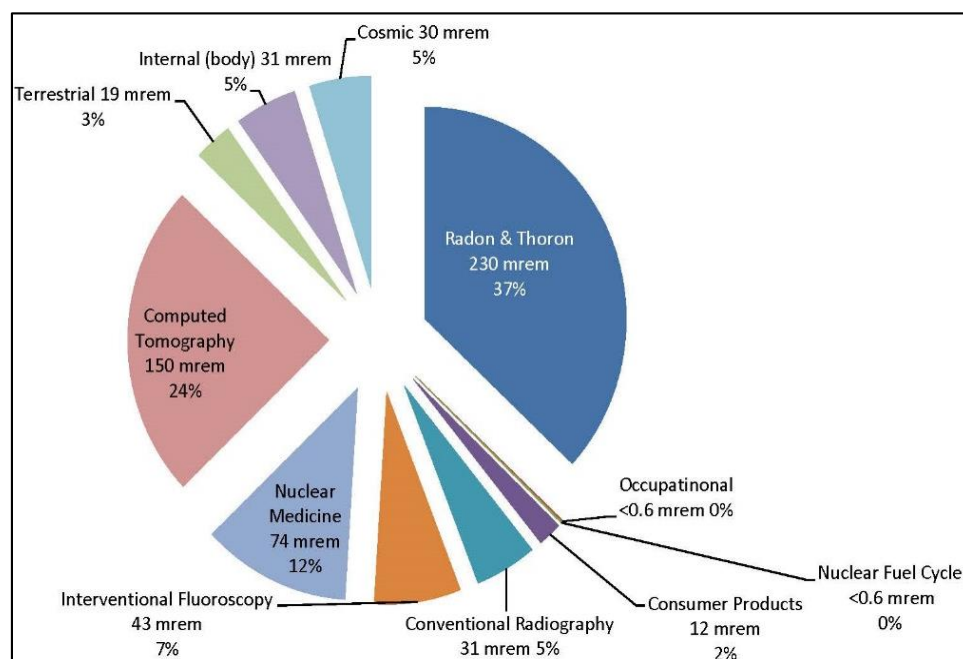


Figure 4-8. U.S. Annual Average Radiological Doses from Various Sources (2009 National Council on Radiation Protection and Measurements).

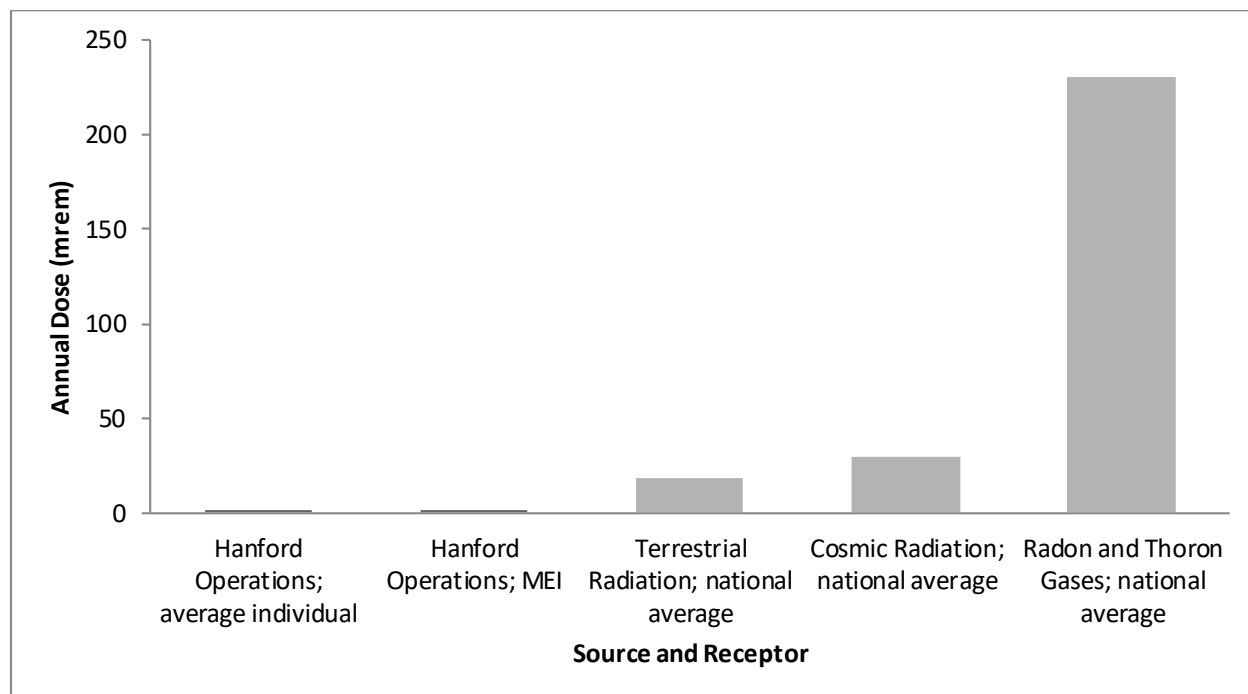


Figure 4-9. Radiological Doses from Hanford Site Operations Compared to Annual Average from Natural Sources.

Table 4-8. Estimated Risk from Various Activities and Exposures.

Activity or Exposure Per Year	Risk of Fatality
Home accidents	100×10^{-6a}
Firearms (sporting accidents)	10×10^{-6a}
Flying as an airline passenger (cross-country roundtrip – accidents)	8×10^{-6a}
Recreational boating (accidents)	6×10^{-6a}
Riding or driving 300 mi (483 km) in a passenger vehicle	2×10^{-6a}
Dose of 1 mrem (10 μ Sv) for 70 yrs	$0 \text{ to } 0.6 \times 10^{-6b}$
Natural background radiological dose (310 mrem [3,100 μ Sv]) for 70 yrs	$0 \text{ to } 200 \times 10^{-6b}$
Dose to hypothetical MEI (2017 rate) of 0.22 mrem (2.2 μ Sv)/yr living near Hanford Site for 70 yrs	$0 \text{ to } 0.2 \times 10^{-6b}$

^a Real actuarial values.

^b Upper bound calculated using 6×10^{-7} risk of developing a fatal cancer after receiving a 1 mrem (10 μ Sv) dose (ISCORS 2002).

MEI = maximally exposed individual

4.3 Radiological Clearance of Hanford Site Property

TA Ikenberry

Radiological clearance is a process where property with the potential to contain residual radioactive material is released from DOE control. It may be conducted for personal property, such as materials and equipment, or for real property (i.e., land and buildings). After clearance, property is considered suitable

for unrestricted use by members of the public, although in some cases restrictions on some types of use may be included. The requirements for release and clearance of DOE property are found in DOE O 458.1. Key aspects of these requirements are as follows:

- Demonstrate property does not contain residual radioactive material. This accounts for most of the property released from the Hanford Site.
- Evaluate property for the potential presence of residual radioactive material. As determined necessary, appropriately monitor and survey to determine presence (if any), type, and quantity of residual radioactive material. Most surveyed property has no detectable radioactivity above background levels and is considered to be free of residual radioactivity.
- Do not exceed the dose constraints for clearance (Table 4-9) and keep residual radioactivity as near background levels as reasonably practicable as determined through DOE's as low as reasonably achievable process requirements and authorized limits. In addition to pre-approved authorized limits, Hanford Site-specific authorized limits have been approved for use by Hanford Site contractors.
- Document radiological clearance of property, independently verify clearance of real property, and properly report; address public participation needs; and provide processes to maintain appropriate records.

Table 4-9. Dose Constraints for Release and Clearance of Property, DOE O 458.1.

Exposure from release of real (land and buildings) and personal property shall be controlled to be ALARA and meet dose constraints.	Total Effective Dose	
	mrem/year	mSv/year
Public dose constraint from real property	25	0.25
Public dose constraint from personal property	1	0.01
NOTE: International dose units shown in italics are not in the order but are provided for information. mrem = millirem mSv = millisievert		

4.3.1 Personal Property

Personal property is considered to be everything except real property, namely material and equipment. Surveys are performed to verify common items released from the Hanford Site do not have residual radioactivity (e.g., electronics, pallets, batteries, office items, respiratory protection equipment, compressed gas cylinders, vehicles, tools, and physical security items). Some types of debris may be cleared to go to sanitary waste disposal sites. Formal clearance surveys may also be conducted on property such as power poles, transformers, miscellaneous electrical equipment, air conditioning units, industrial vehicles, excavation equipment, man lifts, scaffolding, and any of the common items as determined necessary and prudent. In total, more than 30,000 individual items of personal property were surveyed and verified to be free of residual radioactivity or to undergo the formal clearance process for unrestricted release from the Hanford Site during 2017. All items released are considered free from residual radioactivity.

Scrap metal that has been confirmed as not being in radiological areas can be verified to be free of residual radioactivity and cleared for release from the Hanford Site. All DOE sites are currently (since 2000) under a moratorium prohibiting the release of volume-contaminated metals for recycling from DOE radiological areas. No scrap metal is released from radiological areas.

4.3.2 Real Property

Real property is land and buildings. There was no radiological clearance of real property in 2017.

4.3.3 Granular-Activated Carbon for Offsite Shipment and Regeneration

Another important area of radiological clearance from the Hanford Site is that of granular-activated carbon (GAC), used to remove carbon tetrachloride from groundwater. 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. This action continued during 2017 in the 200-West Area.

Since 2012, the 200-West Area Pump-and-Treat facility has used GAC 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 large GAC canisters. The GAC captures the volatile organic compounds removed during the extraction process. When a GAC canister has reached volatile organic compound saturation, it is removed from the system and the GAC is prepared for shipment to an offsite facility for regeneration and reuse. Regeneration of the GAC 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, it was determined the GAC could potentially contain residual radioactivity. Characterization sampling results were used to determine radionuclides that could be present and of potential concern. Authorized limits for these radionuclides were established under DOE O 458.1 to allow radiological clearance for offsite shipment and regeneration of GAC. The current authorized limits (Table 4-10) resulted from modifications in 2010 because of an increase in volume of GAC from the 200-West Area Pump-and-Treat facility compared to the predecessor treatment systems. This modification did not change the expected dose to the public, which is expected to remain negligible. Approximately 100,100 lb (45,400 kg) of GAC was shipped offsite in 2017 for regeneration.

Table 4-10. Authorized Limits for Offsite Shipment and Regeneration of Granular-Activated Carbon. (2 Pages)

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

Table 4-10. Authorized Limits for Offsite Shipment and Regeneration of Granular-Activated Carbon. (2 Pages)

Radionuclide	Authorized Limit (pCi/g)
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

The predecessor treatment systems are no longer operable. The 200-ZP-1 Operable Unit groundwater pump-and-treat system was installed in 1996 and operated until 2009. The 200-PW-1 Operable Unit soil-vapor extraction system was in full operation by 1995 and operated until 2014. These systems also used GAC to remove organic vapors from groundwater and soil.

4.4 References

- 40 CFR 61. "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr61_main_02.tpl.
- DOE O 458.1, Chg. 3. 2013. *Radiation Protection of the Public and the Environment*. U.S. Department of Energy, Washington, D.C. Online at <https://www.directives.doe.gov/directives-documents/400-series/0458-1-border-admc3>.
- NCRP. 1975. *Natural Background Radiation in the United States: Recommendations of the National Council on Radiation Protection and Measurements*. Report No. 45. National Council on Radiation Protection and Measurements, Washington, D.C.
- NCRP. 2009. *Ionizing Radiation Exposure of the Population of the United States*. Report No. 160. National Council on Radiation Protection and Measurements, Washington, D.C.

2017 Highlight

Closure of WMAs

- A draft DOE O 435.1 Tier 2 Closure Plan for the 241-C-200 series tanks was prepared.
- The draft DOE O 435.1 Tier 1 Closure Plan for Waste Management Area (WMA) C and the draft Waste Incidental to Reprocessing evaluation document for WMA C were updated based on DOE review.
- A draft *Resource Conservation and Recovery Act of 1976* (RCRA) Tier 2 Closure Plan for WMA C and a draft RCRA Tier 3 Closure Plan for the 241-C-200 series tanks were submitted to the Washington State Department of Ecology for review.
- A grout testing program to develop grouts for closure of the C-200 Series Tanks and associated pipe encasements began.
- Characterization activities for the 241-C-301 Catch Tank began.
- An evaluation for the removal of remaining equipment in WMA C began.
- A data quality objectives process and the associated summary report for the focus area around tanks 241-A-104 and 241-A-105 in WMA A-AX were completed.

Performance Assessments

- The Integrated Disposal Facility Performance Assessment documentation was completed and the review by the Low-Level Waste Federal Review Group was initiated.

Interim Surface Barriers

- Construction of two interim surface barriers in SX Farm began.
- Design of a third interim surface barrier for SX farm was developed.

5.0 Environmental Restoration and Waste Management

Environmental restoration and waste management activities continued on the Hanford Site during 2017. 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 Hanford Tank Waste Treatment and Immobilization Plant (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 (570-km²) River Corridor includes the Hanford Site's 100, 300, and 400 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. The U.S. Department of Energy's (DOE) focus was to complete source cleanup actions in the 100 and 300 Areas with the following principal goals:

- Deactivate, decommission, decontaminate, and demolish (D4) 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 U.S. Department of Energy, Richland Operations Office (DOE-RL) Long-Term Stewardship Program (surveillance and maintenance [S&M]).

In 1991, the Tri Parties agreed to the [Hanford Federal Facility Agreement and Consent Order Action Plan](#) (Tri-Party Agreement [TPA] Action Plan)(Ecology et al. 1989c) 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 records of decision (RODs) were initiated in the 100 and 300 Areas during the mid-1990s. The 100 Area interim ROD continues today within the River Corridor, while the 300 Area ROD is final. As the interim actions are completed, associated geographical areas are transitioned into the DOE-RL Long-Term Stewardship Program. In 2017, transitions for the River Corridor have been completed with the exception of a portion of the 100-K Reactor Area.

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 and EPA 2013) for the 300 decision area and in September 2014 (DOE and EPA 2014) for the 100-F/IU-2/IU-6 decision area. Completion of remedial investigation/feasibility study reports, public review of proposed actions, and development of RODs for the remaining four decision areas are anticipated to be completed between 2018 and 2019.

5.1.2 100 Area

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

5.1.2.1 100-K Basins

SA McMahan

The 100-K Area remediation activities included facility demolition, waste site remediation, cleanout of the 105-K West Basin, and groundwater pump-and-treat operations. The K-West Basin is the only remaining operating nuclear facility, as explained below. 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 metric tons) 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 engineered containers in the K-West Basin for subsequent removal and disposition. The project's Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) remedial design/remedial action work plan (RD/RAWP) documentation will describe the means of sludge treatment activities, including transferring sludge from KW-Basin engineered containers (ECs) into sludge transfer and storage containers (STSCs) and transporting the STSCs to T-Plant for storage as remote-handled transuranic (RH-TRU) prior to treatment and disposal. The STSCs will eventually be disposed of at the Waste Isolation Pilot Plant (WIPP). 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 (i.e., uranium oxides, hydrates, and hydrides), ion-exchange resin beads, polychlorinated biphenyls (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.

100-K Area Remediation Progress and Accomplishments (2017)

- Completed installing the Engineered Container Retrieval & Transfer System hardware in both the 105-K West Basin and Annex.
- Completed the K-Basin Preoperational Acceptance Testing.
- Continued groundwater pump-and-treat operations.
- Started removal of asbestos from the 165-KE Building in preparation for demolition forecast to start in 2019.
- Continued remediation of waste sites to protect human health and the environment.
- Completed interim closure and backfill of waste sites 100-K-14, 100-K-25, 100-K-27, 100-K-35, 100-K-50, 100-K-79.3&4, 100-K-98, 100-K-101, 1607-K2, 120-KE-1, 120-KE-2, 120-KE-3, 120-KE-4, 120-KE-5, 120-KE-6, 120-KE-9; and 126-KE-2.
- Waste sites 100-K-103, 100-K-79.9, 1607-K1, and 1607-K5 are interim closed and scheduled to be backfilled in 2018.

K-Basins Progress on Defense Nuclear Facilities Safety Board Recommendations

RA Quintero

In the [27th Annual Report to Congress](#) (DNFSB 2017a), the Defense Nuclear Facilities Safety Board (DNFSB) identified an unresolved issue with the Hanford Site K-Basin Closure Sludge Treatment Project concerning control of Columbia River access during slurry transfers to protect the public. In a [July 6, 2017 letter](#), the DNFSB concurred with DOE that the control set for spray release accidents, as documented in the Engineered Container Retrieval and Transfer System Preliminary Documented Safety Analysis, provided adequate protection for the public on the river. With the letter, the Board provided technical report DNFSB/TECH-41, *Spray Release Accidents at the Hanford Sludge Treatment Project*, (DNFSB 2017b) to DOE for information.

5.1.3 200 Areas – Central Plateau

MJ Hickey

The Central Plateau is a 75-mi² (194 km²) region near the center of the Hanford Site and includes the area designated in the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (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 in the past primarily for Hanford Site nuclear fuel processing and currently used for waste management and disposal activities. The Central Plateau also encompasses the CERCLA 200-Area National Priorities List 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. Table 5-1 shows the crosswalk from 23 source operable units on the central plateau to the 10 source operable units.

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.

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 the Plutonium Finishing Plant (PFP) and the Plutonium Uranium Extraction (PUREX) Plant. Specific sites are listed in TPA Action Plan (Ecology et al. 1989c). At the U.S. Environmental Protection Agency's (EPA) 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. Central Plateau Operable Unit Structure.

New Operable Unit Group	Description	Predecessor Operable Units		Lead Regulatory Agency
Inner Area				
200-PW-1/3/6 200-CW-5	Plutonium-contaminated soil sites located near the PFP and cesium-contaminated sites near the Plutonium Uranium Extraction Plant	No change		EPA
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
200-CU-1	U –Plant Canyon: associated waste sites	No change		EPA
Outer Area				
200-OA-1 200-CW-1 200-CW-3	Sites located in the Outer Area 200-OA-1 contains soils sites not in 200-CW-3 that were in the previous OUs 200-CW-1 contains ponds not in 200-CW-3 200-CW-3 contains sites associated with the 200 North Areas.	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

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 et al. 2011) was issued in September 2011. The [Remedial Design/Remedial Action Work Plan for the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units](#) (DOE/RL-2015-23) and the [Sampling and Analysis Plan for the 200-CW-5, 200-PW-1, and 200-PW-6 Operable Units](#) (DOE/RL-2015-22) was approved by DOE-RL and EPA on May 19, 2016.

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 offsite disposal at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico; and disposing at ERDF or WIPP. The 200-CW-5 Operable Unit (also known as the U Pond and Z-Ditches) will use the remove, treat, and dispose approach to excavate contaminated soils and dispose at ERDF or the WIPP, as appropriate.

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 a depth of at least 15 ft (4.57 m). 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 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 (SVE) system was used to remove and treat carbon tetrachloride contamination at waste sites in the High-Salt Waste Group. During SVE operations, vapor-phase carbon tetrachloride was extracted through multiple vadose zone wells and adsorbed onto granular activated carbon before the treated, clean vapor was released to the atmosphere. Between 1992 and 2012, the last year of SVE operation, 88.3 tons (80,107 kg) of carbon tetrachloride were removed from the vadose zone. This remedy was evaluated using the process outlined in [PNNL-21843, Soil Vapor Extraction System Optimization, Transition, and Closure Guidance](#), and [DOE/RL-2014-18, Path Forward for Future 200-PW-1 Operable Unit Soil Vapor Extraction Operations](#). In November 2015, EPA concurred that the SVE remedy met the remedial action objectives in the ROD and that SVE activities could be ended. EPA concurrence with the response action report ([DOE/RL-2014-48, Response Action Report for the 200-PW-1 Operable Unit Soil Vapor Extraction Remediation](#)) in August 2016 closed out the SVE portion of the 200-PW-1 Operable Unit remedy in the ROD and initiated activities to terminate SVE operations and vadose zone monitoring. 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.

200-WA-1/200-BC-1 Operable Unit (200-West Inner Area). This operable unit group includes source 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 the TPA Action Plan (Ecology et al. 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). DOE/RL-2010-49, [Remedial Investigation/Feasibility Study Work Plan 200-WA-1 and 200-BC-1 Operable Units](#) was issued in January 2017. In addition, DOE obtained approval of DOE/RL-2009-94, [216-U-8 Crib and 216-U-12 Crib Vadose Zone Characterization Sampling and Analysis Plan](#), which supports the 200-WA-1 Operable Unit remedial investigation.

200-EA-1 Operable Unit (200-East Inner Area). This operable unit consolidates the remaining Inner Area source 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, 200-IS-1 waste sites, 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 to the TPA Action Plan (Ecology et al. 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 been initiated.

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 that are not included in the canyon area operable units (i.e., 200-EA-1, 200-WA-1, 200-SW-2) or in the tank farm WMAs. Specific sites are listed in the TPA Action Plan (Ecology et al. 1989c).

The TPA agencies agreed to use a coordinated CERCLA remedial action and [Resource Conservation and Recovery Act of 1976](#) (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. The work plan is undergoing revision and finalization.

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 the TPA Action Plan (Ecology et al. 1989c). Portions of the burial grounds listed in the RCRA Permit (WA7890008967) include treatment, storage, and disposal (TSD) facilities. DOE is working with the Washington State Department of Ecology (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, *200-SW-2 Radioactive Landfills Group Operable Unit RCRA Facility Investigation/Corrective Measures Study/Remedial Investigation/Feasibility Study Work Plan*, was issued in June 2016 and mobilization of field activities to conduct the remedial investigation was initiated. A helicopter radiological survey was completed over the majority of the inner area and a summary report to present the findings of the survey was issued in March 2018.

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, 200-TW-2, and 200-PW-5 Operable Units. Specific sites are listed in the TPA Action Plan (Ecology et al. 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 approved by Ecology on September 13, 2016. 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. Field activities associated with the remedial investigation will be completed in 2018.

200-CB-1 Operable Unit (B-Plant Canyon). This operable unit includes the B-Plant Canyon Building (221-B) and the Waste Encapsulation and Storage Facility (WESF), along with exterior ventilation system components for each structure (e.g., high-efficiency particulate air [HEPA] filters and sand filter) and 17 soil waste sites within the vicinity. Specific sites are listed in the TPA Action Plan (Ecology et al. 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 are in the process of being reassigned to the 200-CB-1. Additionally, sites 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.

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 et al. 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. Additionally, sites 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.

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 the TPA Action Plan (Ecology et al. 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 PUREX currently assigned to the 200-EA-1 Operable Unit are in the process of being reassigned to the 200-CP-1 Operable Unit. Additionally, sites 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.

200-CR-1 Operable Unit (REDOX Canyon). This operable unit includes the Reduction-oxidation (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 the TPA Action Plan (Ecology et al. 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. Additionally, sites 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.

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.

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 (e.g., trenches, small ponds, septic tanks, and sewer lines) were cleaned up as part of interim actions conducted from 2005 through 2010.
- 200-OA-1, Operable Unit – Incorporates soil waste sites from several previous operable units (Table 5-1).

DOE/RL-2011-58, *200-CW-3 Operable Unit Interim Remedial Action Report*, 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 Areas' National Priorities List site.

Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill. The Nonradioactive Dangerous Waste Landfill (NRDWL) and Solid Waste Landfill (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 through 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 nonradioactive 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, "Dangerous Waste Regulations"; the SWL is regulated under [WAC 173-350, "Solid Waste Handling Standards."](#)

5.1.4 300 Area

LM Dittmer and RL Cathel

5.1.4.1 618-10, 316-4, and 600-63 Waste Sites. The 618-10, 316-4, and 600-63 are co-located in the 600 Area of the Hanford Site, approximately 4 miles northwest of the 300 Area. (Figure 5-1)



Figure 5-1. Aerial View of the 618-10 Burial Ground and 316-4 Liquid Waste Crib Excavation.

When operational, the 5.7-ac (2.3-ha) 618-10 Burial Ground received a variety of waste from 300 Area operations, primarily waste material contaminated with fission products, disposed in 12 burial trenches and 94 vertical pipe units. Intrusive remediation of the 618-10 Burial Ground was initiated in 2011 and completed in 2017. At the completion of field remediation, the total excavation area was approximately 2,380,000 ft² (221,100 m²) in area with a maximum depth of approximately 36 ft (11 m) below the surrounding grade. Final remediation resulted in a total of 526,700 tons (477,820 metric tons) of material being disposed at the Environmental Restoration Disposal Facility.

The 316-4 Liquid Waste Disposal Crib, located adjacent to the 618-10 Burial Ground, consisted of two 8 ft (2.4 m) diameter by 7 ft (2.1 m) tall bottomless tanks, buried 10 ft (3 m) below grade, resting on a gravel base. The crib was used for disposal of uranium-bearing organic waste from the 321 Building between 1948 and 1962. An initial remediation effort conducted in 2004 and 2005 removed the crib structure, as well as contaminated soil to a depth of 26- ft (7.9 m) below ground surface.

Although contamination extended to groundwater, the remediation of contaminated soil was not completed due to the proximity to the 618-10 Burial Ground, the boundary of which interfered with the required excavation layback for 316-4. The excavation was backfilled in 2005; final remediation to remove contamination to the soil/groundwater interface at a depth of 66 ft (20.1 m) began in November 2016 and was completed in May 2017. The total area of the excavation was approximately 404,700 ft² (37,600 m²), resulting in a total 730,700 ft³ (20,700 m³) of material being disposed at the Environmental Restoration Disposal Facility. The clean overburden and layback material (5,907,600 ft³ [167,300 m³]) was stockpiled for use as backfill material.

The 600-63 Buried Waste Test Facility, also called the 300-N Lysimeter Area, was constructed in 1978 to investigate moisture recharge and radionuclide migration at the Hanford Site and was identified as a waste site requiring remediation in the 300 Area Final ROD (EPA 2013). Tracers, consisting of cobalt-60 and tritium, were placed in lysimeters, measured amounts of water were added, and migration of the contaminants was monitored. The original excavated depth of the site was 30 ft (9.1 m). Remediation of the 600-63 Buried Waste Test Facility was completed in July 2017 and resulted in 250,600 ft³ (7,100 m³) of material being disposed at the Environmental Restoration Disposal Facility.

Following backfill, the three waste site footprints and the supporting infrastructure (trailer areas, container transfer area, parking and roads) are being re-graded and re-contoured to return the area to a natural landscape. Revegetation will be completed between November 2018 and January 2019.

5.1.4.2 300-296 Waste Site. Today, the focus of the project is the remote excavation of the highly contaminated soil beneath the 324 Building B-Cell. The 300-296 Remote Soil Excavation Project is designing and procuring equipment and components that will be used to remove debris and grout from the B-Cell, cut and remove the B-Cell floor, and remotely excavate the highly contaminated soil to establish conditions for demolition in the future. In addition to facility modifications to support the installation of soil removal equipment, structural modifications will be performed to underpin the B-Cell to prevent settling during the removal of the underlying contaminated soil.

The first 324 Building Airlock entry took place on April 10, 2017, which represented an important transition from planning to execution for critical prerequisite actions to prepare for 324 Building modifications and, ultimately, B-Cell activities leading to soil removal. All debris has been removed from the airlock as of November 2017.

History was made in December 2017 with the first person entry into 324 Building C-Cell in over 15 years, marking the initiation of C-Cell cleanout activities. Fifty percent of the C-Cell debris has been removed. During 2017, 33 manned entries were made into the airlock and/or C-Cell. In addition to 6,180 ft³ (175 m³) of waste and debris removed, the Televator was also removed.

The project scope also includes the utilization of a Mockup of the B-Cell and the Airlock for equipment performance validation, training, and proficiency development for operations planned for the 324 Building during soil removal. The Mockup will be maintained and operated throughout the project to support refresher training, contingency development and response planning, and provide spare equipment during operations for any unplanned occurrences or challenges.

Mockup modifications required to support remote soil removal system installations (including core drilling, master slave manipulator installation, and camera mount installation) were completed. The trailer to support the mockup training mission was reconfigured.

Full-scale floor saw testing was completed at the Maintenance and Storage Facility that demonstrated successful system performance. Floor break-up and removal with remote excavator arm tools was demonstrated.

5.1.4.3 300 Area Waste Sites. Planning was initiated in 2017 for the interim stabilization of three waste sites in the 300 Area, including the 300-5, 331-LSLT1 and 331-LSLT2 sites. The 300-5 site consists of fuel contaminated soil from previously removed buried fuel tanks and the 331-LSLT1 and 331-LSLT2 sites are

former waste trenches that accepted liquid animal waste. All three of these sites will be covered by impermeable barriers to prevent water intrusion into the contaminated soil. Activities completed in calendar year (CY) 2017 in preparation for installation of the barriers include preparation of an ecological/cultural assessment of the areas, completion of topographical surveys, and preparation of design sketches for barrier and water drainage construction.

5.2 Facility Decommissioning Activities

This section provides information regarding the transition of Hanford Site facilities from stabilization to S&M 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 2017, all D4 activities in the 100 Area have been completed with the exception of a portion of the 100-K Area.

5.2.2 200 Areas – Central Plateau

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 (Arid Lands Ecology 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. The DOE issued a shutdown order for PFP in 1990. In 1996, DOE 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; security was downgraded by the end of 2009. Preparations for demolition were completed and demolition of the four main PFP buildings commenced in 2017. Figure 5-2 was taken in February 2018 but provides an overview of the progress made in 2017.



Figure 5-2. Aerial View of the Plutonium Finishing Plant.

Plutonium Finishing Plant Complex. The final demolition preparations were completed for 234-5Z and 291Z Buildings. Demolition activities continued on 236Z, demolition of 242Z/ZA and 291Z commenced and were completed, and demolition of 234-5Z was started in 2017. Work was stopped in December when contamination was found outside the radiologically controlled area.

A summary of activities completed in 2017 for each of the four remaining buildings in the PFP Complex is provided below:

- 234-5Z, Plutonium Finishing Plant
 - Completed demolition preparations in September
 - Initiated demolition on the east side of the building.
- 236Z, Plutonium Reclamation Facility
 - Completed removal and packaging of gallery gloveboxes in November
 - Completed removal and packaging of strongbacks in December
 - Completed 90% of demolition activities and remaining rubble was covered under soil.
- 242Z/ZA, Americium Facility
 - Completed demolition in April.
- 291Z, Exhaust Fan House
 - Completed demolition in July (only top few feet of building removed).

More than 1,500 roll-on/roll-off containers of rubble were shipped to the Environmental Restoration Disposal Facility in 2017.

5.2.2.2 Canyon Disposition Initiative

D Singleton

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 et al. 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 (i.e., 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 DOE/RL-2006-21, Remedial Design/Remedial Action Work Plan for the 221-U Facility. Due to the concerted effort to remove PFP, no action has been taken on this initiative since 2011.

5.2.3 300 Area

Bob Cathel

Future activities in the 300 Area will address the 324 facility and the underlying 300-296 waste site, as well as retained facilities discussed in DOE/RL-2004-77, *Removal Action Work Plan for 300 Area Facilities* and DOE/RL-2014-13-ADD1, *Remedial Design Report/Remedial Action Work Plan for 300-FF-2 Soils*.

5.2.4 400 Area

SA McMahan

FFTF is a formerly operating 400-megawatt (thermal) liquid-metal cooled (sodium) research and test reactor located in the 400 Area (Figure 5-3). Built in the late 1970s, the original mission of the facility was 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 S&M condition, all of which was completed in June 2009. FFTF remains in long-term S&M and routine surveillances are performed annually.

The FFTF decommissioning was included in [DOE/EIS-0391, Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington](#), issued on November 12, 2012. The supplement analysis ([DOE/EIS-0391D-SA-01](#)), issued in February 2012,

concluded that there were no substantial changes. The DOE issued the final ROD 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 the Integrated Disposal Facility (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.

Also at the 400 Area (outside the FFTF Property Protected Area) is a mammoth structure called the Fuels and Materials Examination Facility (FMEF). Although the FMEF was intended to be a support building for the FFTF and the future Liquid Fast-Breeder Reactor Program, the FMEF was never used in any kind of a nuclear capacity. When the nation abandoned the breeder reactor program, FMEF was also left without a mission and remains unused and largely vacant today.

Future activities will address demolition of 400 Area surplus facilities.



Figure 5-3. Aerial View of the Fast Flux Test Facility.

5.3 Waste Management Activities

WE Toebe

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

5.3.1 Waste Classifications

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 (i.e., hazardous) 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, high-level waste (HLW), or low-level waste (LLW) under the [Atomic Energy Act of 1954](#) (AEA). 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 (DSTs). 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. [DOE/RL-2018-12, Hanford Site Annual Dangerous Waste Report](#), lists the dangerous and mixed wastes that are generated, treated, and disposed of onsite or shipped offsite. Dangerous and mixed wastes are treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous waste generated at the site is shipped offsite 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 offsite 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 onsite. 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. 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-regulated 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 (e.g., oxalates). Non-regulated demolition waste from the 100 Area decommissioning projects was buried in situ (in place) or in designated disposal locations on the Hanford Site. Unregulated medical waste is similar to typical household waste consisting of papers and plastics that are categorized as non-infectious. Regulated medical waste is waste that may transmit infection from a virus, bacteria, or parasite to humans. Since 1996, medical waste found at Hanford has been shipped to a commercial medical waste treatment and disposal facility.

5.3.2 Solid Waste Inventories

K Clem, KL Chase

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 CH2M Plateau Remediation Company (CHPRC), Mission Support Alliance (MSA), and Washington River Protection Solutions, LLC (WRPS). The database includes all waste necessary for all annual reporting requirements from DOE. The database does not include high-level radioactive waste volumes managed at Hanford Site tank farms.

As of December 31, 2017, quantities for both mixed and radioactive wastes generated onsite or received from offsite 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 offsite as tracked by the database are shown in Table 5-4. Hanford Site solid waste management is discussed in Section 5.3.3. All data is as of December 31, 2017.

Table 5-2. Solid Waste^a Quantities Generated on the Hanford Site.

Waste Category		2011	2012	2013	2014	2015	2016	2017
Mixed	Tons	522	305	206	140	657	609	452
	Metric tons	474	277	187	127	596	552	410
Radioactive	Tons	4,022	343	513	572	1550	665	828
	Metric tons	3,649	311	465	519	1408	603	751

^a Solid waste includes containerized liquid waste.

Table 5-3. Solid Waste^a Quantities Received on the Hanford Site from Offsite Sources.

Waste Category ^b		2011	2012	2013	2014	2015	2016	2017
Mixed	Tons	320	66	36.5	38.4	97.9	105	83.3
	Metric tons	290	60	33	35	88.9	95.3	76
Radioactive	Tons	257	82	62.8	57	91.4	113	133
	Metric tons	233	74	60	52	82.9	102	121

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

^b Total includes Hanford Site-generated waste treated by an offsite contractor and returned as newly generated waste. Includes both low-level radioactive and transuranic waste.

Table 5-4. Dangerous Waste^a Quantities Shipped Off the Hanford Site.

Waste Category		2011	2012	2013	2014	2015	2016	2017
Containerized (DW Only)	Tons	53	18	65.4	103	76.8	69.4	68.5
	Metric tons	48 ^b	16.3 ^b	59.3 ^b	93.4 ^b	69.7 ^b	63.0	62
Containerized (MW Only)	Tons	43	91	50.6	33.7	65.7	69.7	90.4
	Metric tons	39 ^c	82.5 ^c	45.9 ^c	30.6 ^c	59.6 ^c	63.2	82
Bulk Solids (DW Only)	Tons	26	3	—	22.1	—		0
	Metric tons	23.6	2.7	—	20.1	—		0
Bulk Solids (Non-Rad/Non-DW)	Tons	120	17	—	—	—		0
	Metric tons	108.9	15.4	—	—	—		0
Bulk Liquids (DW Only)	Tons	—	—	—	22	—	1	0
	Metric tons	—	—	—	20	—	1.36	0
Bulk Liquids (Non-Rad/Non-DW)	Tons	—	—	—	—	—		0
	Metric tons	—	—	—	—	—		0
Totals	Tons	242	129	116	181	142	140	158.9
	Metric tons	219	117	105	164	129	127	144

^a Does not include *Toxic Substances Control Act* waste

^b Dangerous waste only

^c Mixed waste (radioactive and dangerous)

— = no data met the criteria

DW = dangerous waste

MW = mixed waste

5.3.3 Solid Waste Management

S Kosjerina

Solid waste management includes treatment, storage, and disposal of solid waste and nuclear material produced during Hanford Site operations or received back from offsite sources authorized by DOE to ship waste to the site (e.g., Perma-Fix Northwest, U.S. Navy). 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. A solid waste storage facility located in the 200-West Area (Figure 5-4), the CWC operates under interim status standards specified in the RCRA Permit (WA7890008967), CWC Part A Form. CWC receives waste from the Hanford Site and offsite 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 ft³ (20,800 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. As of December 31, 2017, the volume of waste currently stored in the CWC Outside Storage Areas is approximately 198,126 ft³ (5,610 m³) and the volume of waste currently stored at CWC is approximately 446,629 ft³ (12,647 m³). All data is as of December 31, 2017.



Figure 5-4. Aerial View of the Central Waste Complex.

5.3.3.2 Waste Receiving and Processing Facility.

M Marrott

The Waste Receiving and Processing (WRAP) Facility began operating in 1997 with the mission to analyze, characterize, and prepare drums and boxes of low-level, mixed, and transuranic wastes for

disposal (Figure 5-5). 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.

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 was processed at the WRAP Facility for onsite burial or prepared for future treatment at other TSD facilities. Waste determined to be transuranic was 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.



Figure 5-5. A worker loads 65 drums of mixed low-level waste debris for shipment from the Waste Receiving and Processing Facility to Perma Fix Northwest.

5.3.3.3 T-Plant Complex.

J Fullmer

The T-Plant Complex (Figure 5-6) is located in the 200-West Area and provides solid waste treatment, storage, and decontamination services for the Hanford Site and offsite 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 5-6. Aerial View of the T-Plant Complex.

5.3.3.4 Canister Storage Building

DJ Watson

The Canister Storage Building (CSB) 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 metric tons) 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.

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

M Marrott, KL Chase

The low-level burial grounds (LLBG) 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.

Low-level Waste Burial Ground 218-W-5, Trenches 31 and 34. Trenches 31 and 34 (Figure 5-7) 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 in both trenches have been covered with compacted gravel and soil, and waste is currently being placed on the second waste layer in both Trenches 31 and 34.

As of December 31, 2017, Trench 31 contains approximately 227,132 ft³ (6,432 m³) of waste in approximately 3,845 waste packages. Trench 34 contains approximately 186,758 ft³ (5,288 m³) of waste in 5,301 waste packages. In 2017, a total of 9,004 ft³ (255 m³) of waste was disposed of in Trenches 31 and 34.



Figure 5-7. Trenches 31 (left) and 34 (right) are Used to Store and Dispose of Dangerous and Mixed Waste from Hanford Site Work.

Low-Level Waste Burial Ground, Trench 94. The LLBG Trench 94 received two defueled U.S. Navy reactor compartments in 2017. The total number of reactor compartments received into Trench 94 (218-E-12B Burial Ground) is 131 as of December 31, 2017. 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 metric

tons). 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 metric tons).

5.3.3.6 Waste Encapsulation and Storage Facility

DJ Watson

Located in the 200-East Area, the WESF 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. The water provides cooling and shielding for the capsules that are considered sealed sources.

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 current mission of WESF is safe storage of the cesium and strontium capsules. The facility is a two-story, 20,000-ft² (1,860-m²) building that is 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. Initial RCRA closure of Hot Cells A through F was achieved on April 10, 2017, through grouting these cells to fix any radioactive materials present. Only Cell G remains active for supporting cesium and strontium capsule storage and eventual removal. The operating areas and other building service areas associated with the hot cells and pool cell provide areas for instrumentation monitoring, utility support, or manipulator repair, as required. On November 16, 2017, DOE-RL transmitted to Ecology for review and approval: the RCRA Part B Permit application for the packaging and transfer of capsules to dry storage and RCRA Part B Permit application for capsule interim storage. Site selection of the new Capsule Storage Area and site ecological and cultural resources reviews were initiated.

5.3.3.7 Integrated Disposal Facility

S Kosjerina

The IDF (Figure 5-8) is an unused landfill located in the south-central part of the 200-East Area. The IDF is an expandable lined landfill (i.e., a double high-density polyethylene-lined trench with leachate collection and a leak detection system). The landfill is divided lengthwise (north to south) into two distinct cells: the east cell (cell 2) is for disposal of low-level radioactive waste (non-RCRA permitted) and the west cell (cell 1) is for disposal of low-level mixed waste (radioactive and RCRA-regulated hazardous waste). The west cell is a permitted TSD facility under the Hanford Site RCRA Permit (WA7890008967). The landfill was constructed to accept low-level waste as well as mixed waste (e.g., vitrified low-activity waste [LAW] from the Waste Treatment Plant [WTP] and Demonstration Bulk Vitrification System [DBVS]). Additionally, mixed waste generated by IDF operations will be disposed of in IDF.

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.

A PA for the IDF was completed in CY 2017 and review by the Low-Level Waste Federal Review Group (LFRG) was initiated. This PA addresses the requirements outlined in DOE O 435.1. The overall objective of this PA is to provide a basis for making informed decisions pertinent to operation and eventual closure of the IDF. A series of briefings and webinars on the IDF PA were held for DOE-ORP, several members of the Pacific Northwest National Laboratory, and the LFRG members.



Figure 5-8. Aerial View of the Integrated Disposal Facility.

5.3.3.8 Environmental Restoration Disposal Facility

WA Borlaug, BL Lawrence

The ERDF (Figure 5-9) is the largest disposal facility in the DOE cleanup complex. The landfill located near the 200-West Area covers 108 ac (43.7 ha) and has a current capacity of approximately 21 million tons (19.1 million metric tons).



Figure 5-9. Aerial view of the Environmental Restoration Disposal Facility.

Regulated by the EPA, the facility began operations in July 1996 and serves as the central disposal site for hazardous, low-level radioactive, and mixed low-level waste removed during Hanford Site cleanup operations conducted under CERCLA. The total available expansion area of the ERDF site was authorized in a 1995 ROD (EPA et al. 1995) 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"). The lower liner of the double-liner system is a composite liner system consisting of a 3-ft (0.9-m)-thick layer of compacted bentonite-admixed soil covered with high-density polyethylene (HDPE) geomembrane. An aggregate or geocomposite leak detection system lies immediately above the lower composite liner. A second liner consisting of HDPE geomembrane sits on top of the leak detection system and is covered with a 1-ft (0.3-m)-thick aggregate leachate collection layer. The leachate collection layer is covered with a 3-ft (0.9-m)-thick layer of soil to protect the underlying layers of the liner system.

Designed to be expanded as needed, ERDF consists of disposal areas called cells. There are currently 10 cells at ERDF. At closure a 15-ft (5-m)-thick enhanced RCRA Subtitle-C final cover will be placed over the cells.

As of December 31, 2017, DOE and its contractors have disposed of 18.2 million tons (16.5 million metric tons) of contaminated material at the ERDF since the facility began operations in 1996. The majority of cleanup waste disposed at ERDF is from the 220 mi² (570 km²) River Corridor located along the banks of the Columbia River. The waste consists mainly of soil contaminated during operations of Hanford's nine plutonium production reactors and support facilities from 1943 to 1987, as well as contaminated rubble from building demolition. In addition, ERDF receives cleanup waste from other Hanford locations.

5.3.4 Liquid Waste Management

JE Lesser

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.

5.3.4.1 200 Area Effluent Treatment Facility. The 200 Area Effluent Treatment Facility (ETF) (Figure 5-10) 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.

The effluent discharges from the 200 Area ETF are managed in accordance with limitations set forth in the State Waste Discharge Permit ST-4500 and the 200 Areas 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 operated in 2017.



Figure 5-10. The Effluent Treatment Facility Receives Liquids from the Liquid Effluent Retention Facility.

5.3.4.2 Liquid Effluent Retention Facility. Across from the ETF, the Liquid Effluent Retention Facility (LERF) (Figure 5-12) 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 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, HDPE 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 an amendment to the ERDF Record of Decision (ROD) was approved by EPA (DOE 2017). The amendment allows ERDF to receive both CERCLA and RCRA; therefore, segregation of wastewaters is no longer required.

The volume of wastewater received for the LERF basin storage in 2017 was approximately 3.03 million gal (11.5 million L). The majority of wastewater received at the LERF was pipeline-transported, CERCLA-regulated leachate from ERDF, totaling approximately 1.2 million gal (4.5 million L).

The other major contributor to wastewater received into LERF was approximately 0.77 million gal (2.91 million L) of process condensate from the 242-A Evaporator. Approximately 1.1 million gal (4.2 million L) of wastewater was received by tanker trucks from various other facilities. Approximately 3.34 million gal (12.6 million L) of wastewater in LERF was treated at ETF in 2017. The treated effluent was discharged to the soil at the State-Approved Land Disposal Site. The volume of wastewater being stored in the LERF at the end of 2017 was approximately 18.2 million gal (68.9 million L).



Figure 5-11. The Liquid Effluent Retention Facility is Located in the Central Part of the Hanford Site.

5.3.4.3 200 Areas Treated Effluent Disposal Facility. Located east of the 200-East Area, the 200 Area' Treated Effluent Disposal Facility (Figure 5-12) 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 Treated Effluent Disposal Facility 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 non-radioactive, non-dangerous waste is disposed to this facility in 2017 was approximately 96,212 million gal (803 million L).



Figure 5-12. 200 Areas' Treated Effluent Disposal Facility Ponds A and B.

5.3.4.4 242-A Evaporator. Located in the 200-East Area, the 242-A Evaporator 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 DSTs for storage and reduces the potential need for additional tanks.

The 242-A completed two campaigns in 2017. These campaigns processed a volume of 1,517,000 gal (5,742,467 L), which resulted in a volume reduction of 557,000 gal (2,108,473 L). In 2017, upgrades to the facility included a stack extension to vessel vent 296-A-22 and an upgrade to the process sampling station.

5.3.5 Underground Waste Storage Tanks

Hanford's 54.1 million gal (204.8 million L) of highly radioactive and chemical waste is stored in 177 underground tanks until it is prepared for disposal (Figure 5-13). The tank waste is material left over from years of World War II and post-war production of nuclear weapons. There are 149 single-shell tanks (SSTs) of which 11 tanks have been declared retrieval complete and 7 tanks have been declared retrieved to the limit of retrieval technology per HNF-EP-0182, *Waste Tank Summary Report for Month Ending December 31, 2017*. There are 28 double-shell tanks (DSTs). The SST and DST tanks are grouped into 18 farms in the 200-East and 200-West Areas. This section provides information about the SSTs and DSTs and activities that occurred in 2017 related to their operation and closure.

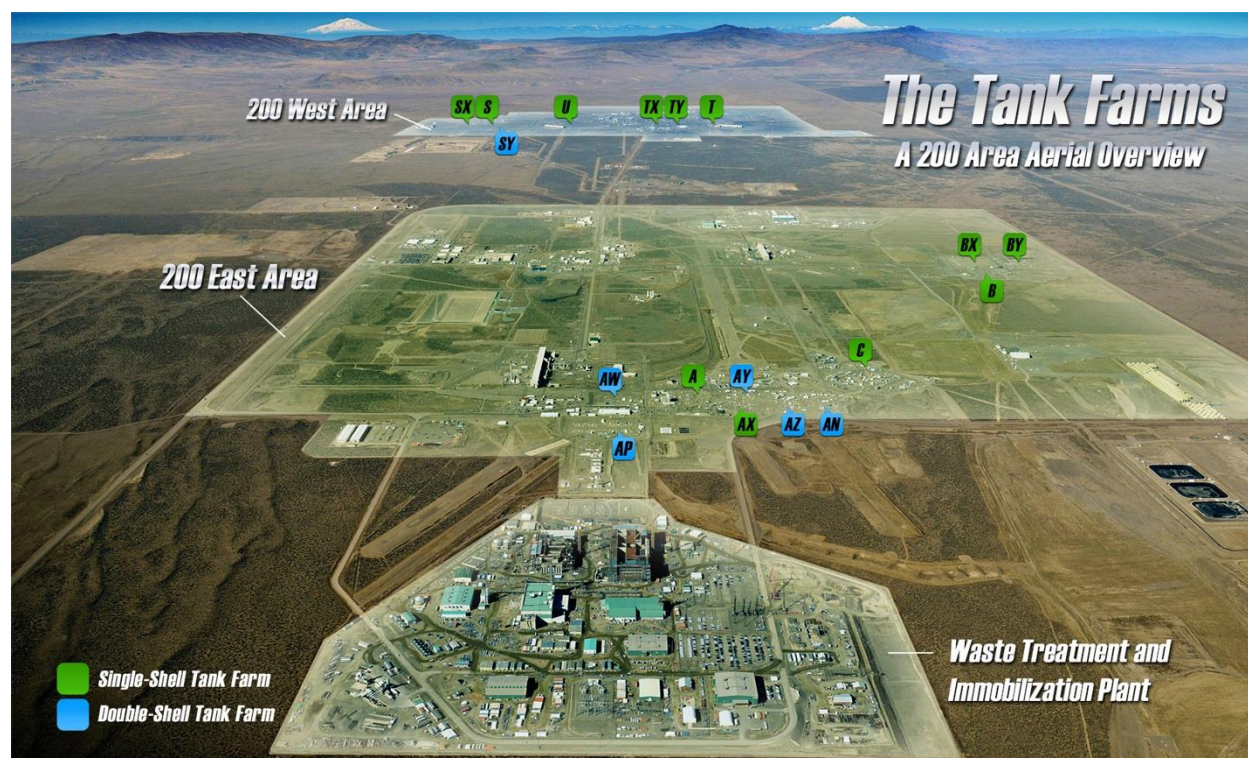


Figure 5-13. Aerial Over of the 200 Areas Tank Farms.

5.3.6 Single-Shell Tank System

The SST system was 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 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 2017, 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 5-14). C Farm is one of 18 tank farms located on the Hanford Site. Fifteen of the 16 tanks have completed retrieval. Retrieval activities continue at tank C-105; however, retrieval was suspended in September 2015 pending the installation of a third technology retrieval system. Retrieval operations are scheduled to resume during summer 2018.

At the end of 2017 there were 28.7 million gal (108.2 million L) of waste in the SSTs. Waste volumes are provided in HNF-EP-1082. Table 5-5 summarizes the waste retrieved and stored in the SST system from 2010 through 2017.



Figure 5-14. Work Continues at the C Farm.

5.3.7 Double-shell Tank System

The DST system includes 28 DSTs (25 tanks in 200-East Area and 3 in 200-West Area) located in six 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.

The tanks contain liquids and settled solids from past nuclear operations, including waste transfers from older SSTs. The DST system storage capacity is approximately 31.5 million gal (119 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 of 1.27 million gal (4.8 million L) available at all times.

In the AY Farm, tank AY-102 was determined to have leaked waste into the annulus. Due to that determination, retrieval activities were performed in 2017. Tank AY-102 was declared retrieved to the limit of retrieval technologies in February 2017.

At the end of 2017, there were 25.5 million gal (96.6 million L) of waste in the DSTs. Waste volumes are provided in HNF-EP-0182. Table 5-5 summarizes the waste retrieved and stored in the DST system from 2010 through 2017.

Table 5-5. Tank Farm System Quantities of Waste Retrieved and Stored.

Type of Waste	Units ^a	2010	2011	2012	2013	2014	2015	2016	2017
Double Shell Tanks									
DSTs year-end waste total volume ^b	gal	25,835	25,948	26,580	26,733	26,575	25,791	25,542	25,487
	L	97,796	98,224	98,000	101,195	100,597	97,630	96,676	96,481
DSTs year-end waste solids volume ^b	gal	12,869	9,331	5,948	5,897	6,215	6,351	6,257	6,294
	L	48,817	98,2234	22,516	22,323	23,526	24,041	23,685	23,825
DSTs year-end waste supernatant volume ^b	gal	12,966	16,617	20,632	20,836	20,360	19,440	19,285	19,193
	L	49,082	62,902	78,101	78,873	77,071	73,588	73,002	72,653
242-A Evaporator									
242-A Evaporator volume evaporated	gal	548	0	0	0	793	1,329	305	557
	L	2,074	0	0	0	3,002	5,031	1,154	2,108
Single Shell Tanks									
SSTs year-end waste total volume ^b	gal	29,434	29,573	29,272	29,185	28,789	28,586	28,533	28,724
	L	111,420	111,945	110,806	110,477	108,978	108,210	108,009	108,732
SSTs year-end waste solids volume ^b	gal	29,403	29,429	29,182	29,073	28,655	28,445	28,418	28,578
	L	111,302	111,401	110,466	110,053	108,471	107,676	107,574	108,179
SSTs year-end waste supernatant volume ^b	gal	31	144	90	112	134	141	115	146
	L	117	545	340	424	507	534	435	553
^a Multiply volumes shown by 1,000. 1 gallon = 3.785 liters.									
^b Tank waste volume data is calculated from HNF-EP-0182, Rev. 360									

5.3.8 Underground Waste Storage Tanks and Associated Facilities

R Hyson

Throughout 2017, the U.S. Department of Energy, Office of River Protection (DOE-ORP) and its contractors met with and provided information to the DNFSB and its technical staff to answer questions regarding the following Hanford Site Tank Farm projects:

- Low Activity Waste Pretreatment System
- Maintenance Program
- Wireless Safety Instrumented System.

5.3.8.1 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 \(IP\) for Recommendation 2012-2](#) (DOE 2013) to the DNFSB. To date, seven IP actions have been completed and provided to the DNFSB.

On March 24, 2016, DOE delivered a letter from the Secretary of Energy that revised the IP for DNFSB recommendation 2012-2. The revised IP described a more efficient approach pertaining to the deployment of safety-significant portable exhauster units for use during off-normal events and the actions completed to date that have been incorporated into the Tank Farms DSA. The margin of safety at the Tank Farms will be further improved as IP actions are completed. The implementation of safety-significant real-time flow monitoring will be of particular benefit, adding both defense-in-depth and a simplified control strategy.

The DNFSB responded to the DOE-ORP via letter on September 16, 2016, concluding that the proposed safety-significant portable exhauster concept was consistent with the DNFSB's recommendation and acknowledging appreciation of the updated deliverable schedule contained in the IP.

On December 11, 2017, DOE-HQ notified the DNFSB of the revision to the expected completion date for DNFSB recommendation 2012-2, Action 3-1, *Provide [safety-significant (SS)] annulus level detectors in each of the [double shell tank (DST)] annuli where the flammable gas hazard exists*. DOE-ORP continues to provide status updates to DNFSB staff on all remaining actions.

Work will continue in 2018 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. DOE-HQ will continue to work with the DNFSB to keep them apprised of ongoing IP efforts for Recommendation 2012-2, currently scheduled for completion in December 2018.

All related information for recommendation 2012-2 is available on the DNFSB website at <https://www.dnfsb.gov/board-activities/recommendations/hanford-tank-farms-flammable-gas-safety-strategy>.

5.3.9 Single-Shell Tank Closure and Corrective Measures Program

P Rutland

The SST Closure and Corrective Measures Program is responsible for the closure of SST WMAs, conducting performance assessments (PAs), and performing agreed upon interim measures in and around SST WMAs.

Current efforts are focused on the development, submittal, and review of closure documents for WMA C; conducting PAs for WMA C, WMA A-AX; and project activities necessary to support the design and construction of additional interim surface barriers. Additional activities include documenting past characterization work, planning for future interim measures, and monitoring the performance of implemented interim measures.

5.3.9.1 Closure of WMAs. Closure activities in CY 2017 continued to focus on the development of closure strategies and closure documents.

Closure documents were prepared and updated to meet the requirements of [DOE O 435.1, Radioactive Waste Management](#), and the RCRA. Closure documents updated during CY 2017 include the draft DOE O 435.1 Tier 1 Closure Plan for WMA C and the draft Waste Incidental to Reprocessing evaluation

document for WMA C. A draft RCRA Tier 2 Closure Plan for WMA C and a draft RCRA Tier 3 Closure Plan for the 241-C-200 Series tanks were submitted to the Washington State Department of Ecology for review. 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.

Work associated with the closure of WMA C initiated in CY 2017 included a Grout Testing program to develop grouts for closure of the C-200 Series tanks and associated pipe encasement, characterization activities for the 241-C-301 Catch Tank, and the evaluation for removal of remaining equipment.

A data quality objectives (DQO) process was completed and an associated DQO summary report (RPP-RPT-60227, Rev 0) was developed for a focus area around tanks 241-A-104 and 241-A-105 in WMA A-AX in CY 2017.

5.3.9.2 Performance Assessments. Work was conducted during CY 2017 to support ongoing PA development and documentation updates associated with WMA C, the IDF, and WMA A-AX. The WMA C and WMA A-AX PAs support closure of WMA C and WMA A-AX, respectively, while the IDF PA supports operations of the IDF.

Review by Ecology of three of the four WMA C HFFACO Appendix I initial drafts of PA documents (RPP-ENV-58806, Rev 0; RPP-RPT-58329, Rev 2; RPP-RPT-59197, Rev 1) was completed and Ecology's comments were received in July 2017 (17-NWP-085). Dispositioning the Ecology comments in a comment resolution process was initiated in the latter half of CY 2017. In addition, Maintenance and Monitoring Plans and an Unresolved Waste Management Question (UWMQ) procedure were developed to support the WMA C PA maintenance effort. This work is being performed to meet federal and state requirements along with the requirements in the TPA (Ecology et al. 1989a), Appendix I. To meet these requirements, DOE-ORP released a set of four complementary reports (RPP-ENV-58782, Rev 0; RPP-ENV-58806, Rev 0; RPP-RPT-58329, Rev 2; RPP-RPT-59197, Rev 1), each focusing on specific requirements for addressing impacts of individual contamination sources that will remain in WMA C after closure (i.e., existing contamination in the vadose zone, past tank leaks and unplanned releases, and tank residuals [radionuclides/hazardous chemicals]).

Preparation of a draft PA for WMA A-AX continued in CY 2017. The WMA A-AX PA is being prepared to meet federal, state, and TPA (Ecology et al. 1989a) Appendix I requirements. The work supports risk assessment and modeling efforts needed to help guide retrieval and RCRA Facility Investigation/Corrective Measures Study characterization activities. The draft PA documents prepared in CY 2017 include model package reports for the geologic framework model and the flow and contaminant transport numerical model, a tank residual data package, a soil inventory data package, and an engineered system data package.

5.3.9.3 Interim Surface Barriers. Interim surface barriers (ISBs) were constructed at T and TY Tank Farms in 2008 and 2010, respectively. The effectiveness of the two interim surface barriers is being assessed through an ongoing barrier-monitoring program, and monitoring results are reported annually. Monitoring indicates that the barriers are effective in drying of the vadose zone beneath the barriers.

Two additional interim surface barriers have been designed to be placed over portions of the SX Tank Farm. Construction of two ISBs in SX Farm began in October 2017. The SX Tank Farm interim surface barriers are being constructed of modified asphalt and a single evapotranspiration basin. Located south

of SX Tank Farm, the evapotranspiration basin will be used to dispose of water collected by the ISBs. In addition, the design of a third ISB for SX Farm was developed in CY 2017.

5.4 Hanford Tank Waste Treatment and Immobilization Plant

M. Schappell

The WTP 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 Facility, HLW Facility, Low-Activity Waste [LAW] Facility, and Analytical Laboratory) along with support buildings and associated infrastructure (Balance of Facilities [BOF]). Construction of the WTP is managed in accordance with the RCRA Permit. In 2017, Bechtel National Inc. (BNI) began executing against its new contract modifications, signed in December 2016 with DOE, that prioritize finishing the LAW Facility, BOF, and Analytical Laboratory to feed waste directly from the Hanford Tank Farms to the LAW facility under an approach called Direct Feed Low-Activity Waste (DFLAW). The DFLAW approach calls for the treatment of tank waste in the LAW facility as soon as 2022. The DFLAW approach also calls for a capability called the Effluent Management Facility (EMF).

A description of the WTP facilities and the progress at each facility in 2017 is provided in the following sections.

5.4.1 Pretreatment Facility

The Pretreatment Facility is where waste will be received from the Tank Farms and separated into low-activity and HLW streams for transport to the LAW and HLW facilities for processing. In 2017, work continued to resolve the remaining technical decisions that have impacted design and construction at the Pretreatment Facility since 2012. The Pretreatment team completed final testing of the Standard High Solids Test Vessel pulse jet mixers and control systems. Significant progress on the technical decisions was made in 2017 with resolution of the last decisions anticipated in the second quarter CY 2018.

5.4.2 High-Level Waste Facility

The HLW Facility is where HLW from the Pretreatment 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. In 2017, the HLW team completed the Facility Completion Plan and the Design and Operability Report. In September 2017, DOE-ORP approved HLW's Preliminary Design Safety Analysis (PDSA). It also received three autosamplers for HLW. The autosampling system will collect verification samples used to ensure the glass produced will meet requirements.

5.4.3 Low-Activity Waste Facility

The LAW Facility is where low-activity waste will be mixed with glass-forming materials in high-temperature melters; poured into containers; and allowed to cool to form a solid, immobile glass form. In 2017, WTP workers completed installation of the caustic scrubber, assembly of the two melters in LAW, and installation of the 48-ft (1,463-cm) elevation electrical bulk cable.

5.4.4 Analytical Laboratory

Once operational, the Analytical Laboratory will process about 10,000 waste samples annually to support glass formulation and waste-form compliance.

5.4.5 Balance of Facilities

The WTP's Balance of Facilities is made up of 22 facilities that provide utilities and services to operate the LAW, HLW, Analytical Laboratory, and Pretreatment facilities. The support utilities include: electrical power distribution system; backup power systems; compressed air; chilled, process, potable, and fire water systems; steam systems; and communication and control systems. Turnovers from construction to startup began in 2016 and will continue through 2019. The BOFs are non-nuclear industrial buildings. By the end of 2017, workers had completed the startup and testing phase for 20% of BOF systems. Of the 56 systems 11 successfully completed startup and testing and were transitioned over to the commissioning phase, 28 were in the startup phase, and 17 were nearing construction turnover to startup by December 2017. That equates to 70% of utility systems that workers had transferred from the construction phase to the startup phase. WTP workers also energized the BOF switchgear building, one of the two switchgear buildings providing power to the Vit Plant. It provides electrical support for BOF structures that will provide utilities and services such as steam, air, and water to the vitrification facilities. This achievement represents the transition from temporary construction-phase utilities to permanent utilities that will operate WTP. As the remaining checks and punch list closeout for the infrastructure facilities is completed, the facilities will be tested for DFLAW operations and declared ready for integrated system testing.

5.4.6 Effluent Management Facility

Concrete placements of the Effluent Management facility began in March 2017. EMF will involve four structures: the main processing facility, a utility building, an electrical building, and the low-point drain building. During the LAW vitrification process, effluent (or liquid secondary waste) is created and will be transferred to the EMF for treatment and disposition. Design is 82% complete as of December 31, 2017, and bulk and equipment procurements are underway. Placement of concrete for the floor slab of the utility and process buildings was completed in 2017. Construction of the EMF is scheduled to be completed in early 2020, with concurrent startup activities commencing in mid-2019 and completing in 2020.

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

R Hyson

Throughout 2017, DOE-ORP and its contractors met with and provided information to the DNFSB and its technical staff to update and review WTP technical topics. The DOE-ORP provided responses in 2017 to address questions in the areas of 1) spray leak methodology, 2) pulse jet mixer control, 3) plugging and wear of process piping, 4) electrical distribution system, 5) erosion/corrosion, and 6) potential criticality in process vessels. The DOE-ORP continues to work with DNFSB and the contractor to provide resolutions and a path forward on technical issues.

5.4.7.1 Defense Nuclear Facilities Safety Board Recommendation 2011-1. The DNFSB issued Recommendation 2011-1, *Safety Culture at the WTP*, on June 9, 2011. On December 27, 2011, the U.S. Department of Energy (DOE) transmitted the Department's Implementation Plan (IP). All IP actions from this plan are complete. In addition, several follow-on Office of Enterprise Assessments (DOE-EA) and internal safety culture reviews were conducted. The latter reviews revealed continued areas to improve, as well as positive improvements overall in both the DOE-ORP and Bechtel National, Inc. (BNI) culture.

Both DOE-ORP and BNI have embedded positive safety culture attributes into their systems and processes, including 1) policies and procedures, 2) required and ongoing training, 3) senior leader performance monitoring, 4) contract and incentives modifications, 5) strong employee engagement activities, and 6) strengthened organizational learning through added assessments and surveys. DOE-ORP and BNI continue to implement and regularly improve their Safety Culture Sustainment Plans (IP Action 2-12), which includes continued effectiveness evaluations and actions to further promote a strong safety culture.

Senior leader performance monitoring, modeled after NEI 09-07, have determined that both DOE-ORP and BNI are continuously improving since Recommendation 2011-1 was issued, and that the organizations are on track to sustaining a positive safety culture. Leaders continue to drive positive safety culture practices.

All related information for recommendation 2011-1, is available on the DNFSB website at: <https://www.dnfsb.gov/board-activities/recommendations/safety-culture-waste-treatment-and-immobilization-plant>.

5.5 Long-Term Stewardship

R Ranade

The Hanford Site's Long-Term Stewardship (LTS) Program has responsibilities within the 220 mi² (570 km²) of the Hanford Site's River Corridor and bounded by 46 mi (74 km) of Columbia River shoreline (Figure 5-15); these responsibilities include managing post-cleanup obligations for 1,638 WIDS sites and six Manhattan Project Era production reactors that have been placed in interim safe storage. More than 24,000 cleanup and historic documents have been identified, indexed, and tagged as LTS records. The LTS program manages and provides S&M of facilities and Institutional Controls to ensure continued protectiveness of human health and the environment once cleanup actions have been completed.

Since 2010, through collaborative efforts with DOE and its prime contractors, cleaned-up waste sites and other facilities in 14 geographic areas and 6 cocooned reactor facilities were transitioned (mid-contract) from the River Corridor Closure Contractor to MSA's LTS program via contract modification, which included the preparation of a transition and turnover package (TTP). This documentation was prepared for each segment or area transitioned to LTS. Transition of 100-N, 100-IU-6 and Segment 4B, and the 300 Area was completed in 2017 giving LTS management responsibilities for the entire River Corridor area with few exceptions. Figure 5-16 illustrates the transition time line.



The TTP was used to document the condition of the land at the time of transition and to convey relevant information about the area. Topics include site assessments, record of cleanup activities, as-left conditions, remaining regulatory actions, resource management, information management, and ongoing S&M requirements. Information management activities continue during the entire process to ensure that documents cited in the TTP are identified, located, stored, protected, and made accessible. The LTS program has conducted inspection and S&M activities for the reactors placed in Interim Safe Storage, also known as cocooning (the 105-F Reactor in October 2014 and the other five reactors in 2015 and 2016). Interim Safe Storage is designed to protect the reactor for 75 years while radioactive decay continues, ultimately making the structures safe for demolition and removal. Next reactor entries and internal inspections will be conducted in 2025 to assess the condition of the structures and evaluate potential deterioration of the reactor core, shield walls, and roof.

Hanford's LTS program has successfully shifted from a program focused on transitioning land and waste sites to a program focused on data management of S&M activities for those buildings and waste sites within the program and which require Institutional Controls. LTS submitted a revised copy of HNF-54166, Rev. 6, *Long Term Stewardship Surveillance and Maintenance Plan*, to DOE in 2017.

The LTS program maintains an internal library of documents referenced in the TTPs and additional information that may be relevant to the closure history. These are the documents that tell the story. The majority of these documents are in the Hanford Administrative Record; however, the LTS library also includes Official Use Only documents that have not yet been released to the public and those that were only placed in DOE's Integrated Document Management System (IDMS). Currently in the LTS information systems there are over 24,000 documents and 22,000 photos; more are added as the program continues to evolve.

5.6 Scientific and Technical Contributions to Hanford Site Cleanup

RA Peterson

5.6.1 Waste Processing

In support of Washington River Protection Solutions (WRPS), PNNL has contributed the following:

- Developed the fundamental knowledge needed to advance low-temperature and low-cost waste forms and improve processing of Hanford's low-activity and secondary wastes. PNNL applied its expertise in mineralogy, geochemistry, waste form fabrication, and waste form performance to support the tank farm contractor in evaluating low-temperature waste forms for Hanford Waste Treatment and Immobilization Plant (WTP) secondary wastes, including processes at the Effluent Treatment Facility and the Effluent Management Facility (EMF), planned for onsite disposal. The data generated and analyses of these waste forms are critical to qualifying these waste forms for disposal in the Integrated Disposal Facility (IDF) and will help provide the scientific basis for IDF performance assessment (PA) maintenance. The technologies can be extended to evaluate the potential for low-cost, low-temperature, supplemental low-activity waste (LAW) treatment options.
- Served as the lead laboratory integrating across the complex to provide the technical basis for the glass waste form strategy, including defining data needs and testing protocols, to support the IDF PA. In fiscal year (FY) 2017, PNNL conducted investigations using alternative testing techniques to address critical data needs identified in the previously issued technical approach document. These

tests include measuring Stage III dissolution rates of immobilized low-activity waste (ILAW) glass in accelerated testing, proposing an updated term to accurately describe ion exchange processes in long-term glass dissolution (an effort with the Vitreous State Laboratory of The Catholic University of America), developing innovative solutions to expedite compilation of rate law parameters required for PA modelling, and characterizing dissolution behavior of enhanced waste loading ILAW glass. The FY 2017 testing focused on delivering critical PA input data for enhanced glasses, which is needed to support implementation of glasses that will allow higher waste loadings to be targeted for facility operational efficiency and to reduce mission life.

- Established a radioactive test platform in the Radiochemical Processing Laboratory (RPL). PNNL has installed a radioactive waste processing test platform that includes ion exchange, crossflow filtration, and melter unit operations. The test platform provides the ability to develop and assess the baseline Direct Feed Low-Activity Waste (DFLAW) flowsheet with respect to integrated unit operations, provides process data (such as technetium speciation) necessary to inform critical decisions on disposal options, and allows testing of a wide variety of proposed changes to the baseline flowsheet (before facility implementation; lowering risks) with actual waste samples from the Hanford tank farms. The first application of this test platform is to treat tank waste and evaluate the disposition routes for melter off-gas materials and alternative waste qualification approaches with actual waste samples. In FY 2017, the RPL received approximately 2.11 gal (8 L) of AP-105 supernatant from the tank farms. PNNL is currently processing this waste through the filtration unit operation. The filtered waste will ultimately be processed through ion exchange, a melter feed will be generated, and then the waste will be processed through a laboratory-scale melter. This platform also will be available to evaluate alternative processing strategies for DFLAW and support waste qualification.
- Summarized prior data and collecting new data on confined sluicing retrieval technology. PNNL developed a report that describes the development and application of confined sluicing retrieval technology. To support confined sluicing evaluations, PNNL completed a study to estimate/bound the waste characteristics of tank 241-A-105 waste in order to select appropriate simulant materials for retrieval testing. PNNL is conducting development testing of the Hanford Waste End Effector (HWEE) to provide information for initial assessment of the HWEE for Hanford single-shell tank (SST) retrieval. PNNL will install the HWEE on a PNNL-designed robotic gantry system, apply instrumentation to measure reaction forces and process parameters, prepare and characterize simulant materials, and implement the retrieval test program. The tests will involve retrieval of sludge and hardpan simulants to determine pumping rate, dilution factors, and screen fouling rate. A primary goal of the HWEE is to minimize water usage during tank retrieval to minimize downstream impact on tank farm volume space.
- Served as the test authority in the evaluation of ultrasonic nondestructive examination (NDE) technology for Hanford under-tank inspection. PNNL is leveraging its 50-year NDE Reliability Test & Evaluation program to define and administer testing to establish the extent to which emerging and commercial ultrasonic NDE technologies can satisfy an under-tank inspection strategy for Hanford double-shell tanks (DSTs). The results of the evaluation will provide the technical basis necessary for purposeful selection of ultrasonic NDE technologies that will enable volumetric under-tank inspection. Flaw detection and measurement robustness testing is being performed at PNNL using full-scale mockups of primary tank swaths that contain representative DST plate geometries,

materials, and surface conditions; representative welds and weld patterns; and surrogate flaws to mimic flaw types having the potential to develop in DST plates and threaten leak integrity.

- Provided the technical underpinning for the Low-Activity Waste Pretreatment System (LAWPS). PNNL is using its expertise in simulant development; crossflow filtration; ion exchange; fluid dynamics; and hydrogen gas generation, retention, and release to develop the technical underpinning for the LAWPS. The data generated by this program will provide the basis for integrated testing of the system and technical defensibility of the hydrogen management strategy to enable maturation of the design, construction, and safe operations of the LAWPS. In addition, test data are being evaluated to recommend and support additional integrated testing that will establish a more robust performance envelope prior to facility construction.
- Defined the strategy and recommended processes for supporting the implementation of regular updates of the technical basis for the industrial hygiene program for tank vapors at the Hanford Site. The technical basis for this program is dependent on sound scientific and engineering understanding and analysis of tank contents, sampling and analysis, transport and dispersion, real-time measurement, and toxicology and health effects of tank vapors. PNNL is applying its technical expertise in chemistry, measurement, atmospheric sciences, biology/toxicology, chemical engineering, and fluid dynamics to develop, test, analyze, and recommend best practices for identifying, detecting, and monitoring chemicals of potential concern and establishing necessary exposure action levels to ensure worker protection. PNNL is also supporting the analysis of respirator cartridge testing on vapors from the Hanford waste tanks.
- Initiated development of a data visualization tool to enhance the accessibility and transparency of tank vapors sampling data. The Tank Vapors Data Access and Visualization application is being developed for WRPS and will significantly enhance the accessibility of sampling data for tank vapors. This application is presently available for limited internal use by WRPS staff but will eventually be available for public access. Data sets available through this application include headspace samples, samples from exhaust stacks and other emission points, and samples from outside the tanks where work could be performed. Limited data sets are also available from the pilot testing of real-time sensors that are part of the Vapor Monitoring and Detection System.
- Identified and developed underlying technical bases for the River Protection Project (RPP) Reference Integrated Flowsheet. PNNL is using its expertise in waste chemistry and physical properties, fluid dynamics and scaling, waste processing technology development, waste form development and testing, and applied engineering solutions to identify and resolve technical gaps and develop innovative solutions for the baseline integrated flowsheet. The technical work generated by this project closes flowsheet and operations gaps and realizes opportunities by providing technically defensible bases and tools used in establishing flowsheet strategies and modeling parameters to predict and plan the successful execution of the RPP waste cleanup mission.
- Addressed safety issues associated with isolation valves for double-valve isolation that have been installed in the Hanford Tank Farms Waste Transfer System for 10 or more years. Using PNNL's expertise in Hanford waste characterization and simulant development, a technically justifiable performance-based simulant was designed for extended abrasive wear testing at the Multi-Phase Transport Evaluation Loop Facility. Results from the simulant cycle tests provide WRPS with performance characteristics that can be used to verify compliance with the documented safety

analysis limits for valve seat leakage. Test results provide a technical basis for 3- and 2-in. (7.6- and 5-cm) valves installed at the Hanford Site to operate in an abrasive slurry environment for over 1500 and 5000 cycles, respectively. These results also provide a technical basis to define and plan maintenance and equipment replacement schedules. The test methodology and infrastructure established from testing valve models currently in service at the Hanford tank farms are now being used to evaluate and benchmark additional valve manufacturers and models against those involved in previous test campaigns to expand the number of qualified providers. Test results will be used to evaluate and potentially certify additional valve types as replacement valves for existing infrastructure or for incorporation into designs for future waste processing systems.

- Performed a structural integrity analysis of record to qualify the AN and AW DSTs for increased storage volume. Since 2003, PNNL has performed the structural integrity analyses of record for the DSTs and SSTs at the Hanford Site. These analyses dictate the maximum waste level allowed in the DSTs. In 2008, PNNL completed a structural analysis that demonstrated that the AP tanks could safely store an additional 38 in. (96.5 cm) of waste, representing 720,000 gal (2,725,496 L) of additional storage volume in the eight AP tanks. In 2017, WRPS requested that PNNL perform a similar analysis to qualify the AN and AW tanks for increased waste height. Similar conclusions to those of the AP analysis are expected, which could increase the storage capacity of the 13 AN and AW tanks by 1,170,000 gal (4,428,932 L).
- Enhanced the tank farm PHOENIX (PNNL Hanford Online Environmental Information Exchange) web application to provide online access to and visualization of important tank farm data. PNNL has added significant new functionality to the PHOENIX applications for the DOE Office of River Protection (ORP). This year, an application has been developed for exploring the best basis inventory estimates for tank waste, including the capability to view changes in those estimates over time. In addition, email alerts have been developed to notify staff when new data of interest become available.

In support of other projects at the Hanford Site, PNNL is contributing the following:

- Supported resolution and closure of S-1 Technical Issue 4 concerning the pulse-jet mixing (PJM) vessels in the WTP Pretreatment Facility. PNNL has been supporting design evaluations, full-scale standard high solids vessel test planning, development of simulants, and analysis of the new PJM controls systems. The testing project began controls testing in late 2016 and started the full-scale standard high solids vessel testing in June 2017. PNNL's support is also critical to the performance evaluations of the low solids PJM vessels that are located in the WTP Pretreatment Facility. Working alongside the Bechtel National, Inc. (BNI) engineering team and back at the laboratories at PNNL's Richland Campus, PNNL staff has been integral in supporting the resolution of the PJM technical concerns with the WTP.
- Developed enhanced glass formulations, key process control models, and tactical processing strategies to ensure safe and successful operations for the WTP high-level waste (HLW) and LAW vitrification facilities. Applying expertise in waste form development, melter processing, and waste form performance, PNNL has increased waste loading, troublesome component solubility limits, and melting rate; significantly increasing projections of waste throughput and decreases in glass volume. In late FY 2017, PNNL will issue updated process control models and algorithms for the LAW and HLW vitrification facilities, which provide the technical underpinning for implementation of

enhanced glasses. Development and implementation of enhanced glass property models and glass formulations will reduce the cost of Hanford tank waste management by reducing the schedule for tank waste treatment and reducing the amount of HLW and LAW glass for storage, transportation, and disposal. Enhanced glass formulations may also result in more cost effective direct vitrification of the HLW fraction without significant pretreatment. The advances in aluminum oxide and chromium(III) oxide solubility in borosilicate glasses should reduce or eliminate the need for caustic or oxidative leaching in pretreatment. The ability to target higher sodium oxide concentrations will translate into higher waste loadings and ultimately lower container counts for the LAW integrated flowsheet. The integration of increased waste loading, reduced leaching/washing requirements, and improved melting rates provides a system-wide approach to improve the effectiveness of the WTP process.

- Developed technologies to enhance technetium management strategies for LAW vitrification. The primary objective is to achieve high technetium retention in LAW glass without recycling the melter off-gas solution. Recycling the off-gas stream also increases the concentrations of other troublesome and volatile components in the melter feed, which decreases the loading of waste coming from the tank farms and thus increases the glass volume. Two major research areas include: 1) understanding the fundamental mechanism of technetium volatilization from and incorporation into glass melt and 2) incorporating technetium into various minerals directly from LAW or from off-gas solution, which can be used to increase the technetium retention in glass or can serve as a separate waste form.
- PNNL provided a fundamental understanding of technetium chemistry and translating that understanding into solutions for technetium management. PNNL is using cutting edge technologies to evaluate the nature of technetium present in Hanford tank waste. PNNL is using actual waste samples to evaluate the speciation and fate of technetium during waste processing. Using the information obtained from these samples, PNNL is able to develop new process flows for the treatment and disposition of technetium as well as the development of state-of-the-art sensors for identifying technetium speciation.
- Provided the fundamental understanding of radionuclide migration through concrete materials. PNNL developed and conducted diffusion experiments to measure the effect of concrete waste form properties (including iron content, carbonation, microcracking, and moisture content) on radionuclide release and migration in near-field environments representative of the arid environmental conditions at the Hanford Site. This knowledge provides the technical understanding necessary to assess the efficacy of the waste package in isolating the Category 3 low-level radioactive wastes from the hydrologic environment. Any failure of concrete encasement may result in water intrusion and consequent mobilization of radionuclides from the waste packages.

5.6.2 Nuclear Fuel and Material Management

In support of nuclear fuel and material management at the Hanford Site, PNNL is contributing the following:

- Lead actual waste testing to enable retrieval, storage, and treatment of K-Basin sludges. PNNL has partnered with Hanford contractors on characterization and management of suspect nuclear fuel and K-Basin sludge for 25 years. PNNL has performed all essential characterization and much of the data evaluation of K-Basin sludge, enabling retrieval and storage at Hanford's T-Plant. PNNL

maintains the inventory of well-characterized K-Basin sludge samples to allow for testing of future treatment options. Suspect nuclear fuel fragments from the K-Basin are expected to be added to this inventory in FY 2018. As part of this sample stewardship, sludge shear strength as a function of time was measured to better understand how the sludge currently stored in the large engineered containers may develop strength or otherwise change during interim storage. Increased sludge strength may adversely affect sludge transfer operations. PNNL also conducted essential characterization activities of the K-Basin water sand filter; the results are being used for proper waste designation and disposal. PNNL has supported alternatives analysis, engineering evaluations, and process development and process/unit operation validation tests, and will continue these functions as the overall project progresses toward final sludge treatment and disposition.

- Conducted accident thermal analyses to update the safety basis documentation for the K-Basin Sludge Transport System Transport Package. This package consists of a vessel carrying the sludge payload contained within a lead-lined shipping cask. This 11-ft-tall assembly sits upright on a flatbed trailer and is being used to transport sludge waste to the Hanford Central Plateau interim storage location at T-Plant. To recertify this package with an enhanced payload capacity for upcoming shipments, PNNL's Radioactive Packaging and Transportation team is modeling thermal transients for a hypothetical accident condition involving a pool fire. This is a standard requirement for transport of large quantities of nuclear materials.
- Provided source term estimates and atmospheric dispersion modeling in support of demolition of the Plutonium Finishing Plant (PFP) at Hanford. The release and dispersion modeling uses the facility design, measurements of residual radioactive contamination, plans for the demolition technologies and timing, and multiple years of meteorological information to estimate peak anticipated concentrations of contaminants in air and on nearby surfaces. The results have been used to modify the demolition techniques so that occupational and environmental standards may be met. The information has been shared with Hanford Site managers, decommissioning workers, and regulators so that all parties are cognizant of the potential hazards.
- Provided radiological characterization to Hanford Site contractors using nondestructive assay (NDA) methods and techniques. PNNL's NDA program uses gamma spectroscopy and neutron counting techniques to provide radiological characterization of waste containers and facility components (e.g., HEPA filters, pipes, glove boxes, ductwork) to support environmental remediation activities with waste classification/disposal, transportation, environmental reporting, safeguards and security, work planning, and facility safety basis development.
- PNNL provided high-range gamma and neutron radiological instrument calibrations to Hanford Site contractors. Working with the Hanford Site Support Services contractor, PNNL uses its unique gamma and neutron irradiators to calibrate radiation detection and survey instruments that cannot otherwise be calibrated. In addition to instrument calibrations, PNNL also troubleshoots and repairs radiological instruments and high-purity germanium detectors for the Hanford Site. Hanford contractors rely on these instruments and detectors to safely accomplish site remediation activities.

5.6.3 Environmental Remediation

In support of environmental remediation at the Hanford Site, PNNL is contributed the following:

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- Reduced the uncertainty associated with quantifying contaminant fluxes and providing a linkage to effective monitoring of vadose zone contaminant sites. Through development of a novel approach, geophysical monitoring is being integrated with predictive simulation to improve estimates of contaminant flux to groundwater. The flux assessment tool will be validated using a synthetic lifecycle simulation of vadose contamination within the BY Cribs area and will provide a method for monitoring contaminant flux to groundwater so that potential flux mitigation technologies can be implemented.
 - Provided the technical leadership for conducting CERCLA treatability studies of remediation technologies for the deep vadose zone in the Hanford Central Plateau. PNNL is finalizing the monitoring and field testing of soil desiccation and integrating this information into an evaluation that will support inclusion of desiccation in future feasibility studies for the Hanford Central Plateau. PNNL is also providing the technical basis for design and implementation of a field test using ammonia as a reactive gas to sequester uranium in the vadose zone. Treatability tests in the Central Plateau are important for demonstrating remedy feasibility, cost of implementation, and potential negative impacts prior to field-scale implementation. Field treatability testing of the PNNL-developed technology will be initiated in FY 2018.
 - Evaluated candidate remediation technologies for the Hanford Central Plateau vadose zone. PNNL is conducting laboratory studies of candidate vadose zone technologies for contaminants including uranium and technetium-99. The technology information will provide remedy options in FY 2018, when the site will determine what additional treatability tests will be conducted for the deep vadose zone in the Central Plateau.
 - Identified natural phases of technetium-99 in soil and groundwater and the potential conditions and attenuation mechanisms that immobilize technetium-99 in the subsurface. The total inventory of technetium-99 released to the environment at the Hanford Site is estimated at 700 curies, with ~100 curies released from SST leaks and the remainder disposed of in the cribs, trenches, and other waste sites at the Hanford Site. To date, the technetium-99 speciation in the deep vadose zone is unknown. If a significant amount of technetium-99 in the vadose zone is immobilized, this will provide critical knowledge to support the use of monitored natural attenuation as part of the remediation decision for long-term technetium-99 management.
 - Provided the technical knowledge necessary to understand the attenuation processes controlling the behavior and fate of contaminants within the 200-DV-1 Operable Unit on the Hanford Central Plateau. PNNL is advancing the development and utility of conventional site conceptual models to enable accurate quantification of current and predicted future flux of contaminants across multiple scales. Remediation of inorganic and radionuclide contaminants in vadose zone environments is foundational for protection of groundwater. The mass flux/discharge of contaminants through the vadose zone is a primary factor controlling vadose zone contaminants in groundwater. PNNL is quantifying attenuation processes, applying the mass-flux-based conceptual model framework that integrates this information, and conducting predictive analyses to understand and quantify moisture and contaminant flux in the vadose zone to provide the technical defensibility for groundwater remediation decisions and long-term predictions of contaminant fluxes to groundwater.
 - Conducted hydraulic and chemical analysis of a perched-water zone in the Hanford Central Plateau 200-DV-1 Operable Unit. PNNL is analyzing and interpreting hydraulic and chemical data to improve

the understanding of the perched-water zone in support of remedy operations and optimization. The perched-water zone is an important contaminant source for the underlying groundwater. The difficult hydrologic setting and complex contaminant conditions need to be quantified to enable effective remedy application and to provide the technical defensibility needed to transition from the active (pump-and-treat) remedy to remedies suitable for unsaturated conditions.

- Provided the scientific and technical understanding necessary to predict behavior of and remediate comingled contaminants in 200-UP-1 Operable Unit. PNNL is using a multiple lines-of-evidence approach to understand the effects of dynamic biogeochemical processes on the fate and transport of comingled contaminants (uranium, iodine, technetium, nitrate) in heterogeneous geological media. This work provides the technical underpinnings for identifying simultaneous or sequential remedies and long-term support for enhanced natural attenuation.
- Addressed conceptual site model data gaps to support 200-UP-1 Operable Unit iodine-129 technical evaluation. The conceptual site model is being updated with key data, most importantly biogeochemical drivers for iodine speciation that previously were not understood, to define the iodine cycle, interactions with co-contaminants, source terms, inventory, and speciation to provide a technical basis to support evaluation of remediation approaches for iodine-129 and complete the 200-UP-1 remedial investigation report. The updated conceptual model for iodine is not only required by the 200-UP-1 record of decision (ROD), but is also needed to adequately address known attenuation mechanisms that were not previously recognized or accounted for in assessments
- Evaluated candidate remediation technologies in support of the 200-UP-1 Operable Unit ROD-required iodine-129 remedy evaluation. While other contaminants in the 200-UP-1 Operable Unit could be addressed with a remedy, the iodine-129 contamination requires additional evaluation to select an appropriate remedy or determine if a technical impracticability waiver is appropriate. PNNL conducted a literature search to identify candidate technologies and is applying laboratory testing to determine if any of the candidates are suitable for treatability testing and subsequent consideration as an iodine-129 remedy. This level of technical rigor is needed to address the difficult nature of iodine-129 contamination and to provide defensibility for the associated iodine-129 remedy decision.
- Provided expert technical support to the development of the remedial investigation/feasibility study document for the 100-BC-5 Operable Unit. PNNL is providing technical expertise and input to CH2M Hill Plateau Remediation Company (CHPRC) for the 100-BC-5 remedial investigation/feasibility study. PNNL is providing input for modeling strategies and developing a systematic and holistic approach to support monitored natural attenuation evaluations at BC-5 and across all operable units at the site. PNNL's support is critical to developing and adapting national guidance for application at this site.
- Provided the technical underpinnings required to understand the interactions among co-contaminants in the 200-BP-5 Operable Unit. PNNL is applying a multiple lines of evidence approach to quantify and understand the impacts of geochemistry and microbiology to determine the mechanism(s) controlling attenuation of comingled plumes, in particular with cyanide, the perceived inhibitor of mechanisms of attenuation. This effort supports the long-term goal of providing the technical defensibility for monitored natural attenuation as a viable remedial alternative once pump-and-treat operations cease to be effective.

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- Provided the technical knowledge to design a sampling and analysis strategy that includes quantifying and interpreting attenuation processes for the 200-WA-1 Operable Unit in the Hanford Central Plateau. PNNL is synthesizing and interpreting national guidance for attenuation characterization to provide the site contractor with a technical basis for design of vadose zone characterization. These approaches will enable attenuation processes to be incorporated into mass-flux-based conceptual and numerical models. The level of complexity required to represent attenuation mechanisms is important for providing the technical defensibility for both remedy decisions and technical infeasibility waivers.
 - Provided advanced microbial techniques and expertise to support optimization of the 200-West pump-and-treat system for carbon tetrachloride and nitrate remediation to improve effectiveness. The 200-West pump-and-treat fluidized bed biofilm reactors (FBBRs) are composed of complex groundwater microbial consortia that under engineered conditions remove carbon tetrachloride, chromium, and nitrate from groundwater. PNNL is applying molecular tools (i.e., microbial fingerprinting and sequencing) to determine the spatiotemporal identity, composition, and function of the microbial community within the FBBR to support performance decisions and optimization of the pump-and-treat system.
 - Evaluated the fate of iodine-129 in the existing 200-West pump-and-treat system. In addition to providing information about pump-and-treat system operations to the site, this investigation of iodine-129 fate in ion exchange and biological treatment components of the pump-and-treat system is being used to support evaluation of potential ex situ treatment technologies for iodine-129 in the ROD-required iodine-129 remedy evaluation for the 200-UP-1 Operable Unit.
 - Provided hydraulic and geochemical analyses to address operational issues and provide optimization information for the 100 Area pump-and-treat systems. PNNL is conducting studies for the 100-K Area to quantify the effect of influent geochemistry on co-contaminants in the aquifer to determine whether changes are needed to aboveground operational conditions. PNNL is also conducting hydraulic analyses of the semi-confined portions of the 100-H Area to provide the hydrologic basis for optimizing pump-and-treat operations.
 - Conducted monitoring to support source area remedy implementation in the 300-FF-5 Operable Unit. PNNL is installing and operating electrical resistivity tomography (ERT) monitoring that enables the site contractor to have near-real-time feedback on amendment injection performance and provides an opportunity to optimize delivery. PNNL is also applying sediment testing to quantify the change in uranium mobility caused by the source treatment, which provides a metric for determining treatment success. In addition, PNNL is supporting the implementation of this PNNL-developed technology.
 - Developed a grout formulation that meets well construction requirements and improves the resolution of geophysical characterization and monitoring. Because standard well grouting materials are highly conductive, they interfere with geophysical techniques such as ERT. PNNL is developing and testing a revised grout formulation with lower electrical conductivity. This new grout directly supports new field applications of ERT in the Hanford 300-FF-5 Operable Unit and for deep vadose zone treatability tests that are being initiated in FY 2018. It also enables improved use of ERT for future applications as electrodes are emplaced during characterization and monitoring efforts in the

Hanford Central Plateau, which will provide direct measures of both active and passive remedy performance.

- Provided the environmental science and risk and decision expertise to develop the remedial investigation work plan for the Pre-Hanford Orchards Lands operable unit, enabling DOE to decide if pre-Hanford pesticides must be remediated. Farmstead communities existed adjacent to the Columbia River from 1880 to 1943. The Hanford River Corridor includes approximately 8,300 ac (3,359 ha) of historical farmsteads, of which approximately 5,000 ac (2,023 ha) are historical orchard lands. Based on what is known about the history of the site, and the current site conceptual model, the major contaminant for this operable unit is residual lead arsenate, which was used as a pesticide. PNNL characterized 133 decision units (4,996 ac [2,022 ha]). The project uniquely deployed handheld x-ray fluorescence analyzers in the field, significantly reducing schedule and cost. Current efforts are focused on completing the draft remedial investigation report.
- Completed the over 20-year Prototype Hanford Barrier performance assessment and is transitioning this barrier test site into long-term monitoring. Building on the 20 years of performance monitoring, PNNL is preparing the barrier site to transition into long-term monitoring following NQA-1 requirements for instrumentation and data collection. DOE has identified long-term surface barriers as a candidate remedy for contamination in the deep vadose zone to reduce contaminant flux into the groundwater. The Prototype Hanford Barrier over the 216-B-57 crib was completed in 1994 but past monitoring accounts for only about 2% of the design life.
- Lead the national, multi-institutional Deep Vadose Zone Applied Field Research Initiative to provide the scientific underpinnings and develop and demonstrate transformational remedial strategies. The initiative is providing the framework for a coordinated, integrated, and leveraged research and technology development strategy to target understanding and remediation of vadose zone environments. This approach integrates efforts from SC to enhance our understanding of vadose zone challenges and infuses investments from EM to develop cost-effective characterization and monitoring methods, and remedial strategies and design. The results provide a systems-based understanding of water, gas, and chemical exchange within this complex deep vadose zone to drive improved long-term predictions of contaminant behavior; flux to groundwater; and, ultimately, the risks to human health and the environment. The initiative is critical for providing the scientific and technical understanding to develop, demonstrate, and predict the near- and far-term impact of remedial strategies that prevent contamination from reaching groundwater.
- Improved the PHOENIX groundwater toolset by adding new capabilities requested by users. PNNL developed a Remediation Dashboard to visually represent the remediation progress of Hanford's groundwater treatment systems. This tool makes it easy for stakeholders, regulators, and others to understand the effectiveness of remedies and to see progress toward cleanup objectives. Another capability is being added to the groundwater toolset that will allow users to receive customized email alerts when data of interest are added (e.g., new sample results) and to save queries that will facilitate periodic analysis of areas of interest.
- PNNL developed a set of web-based analysis tools to meet DOE needs for groundwater data assessments. New tools use the data access capabilities from the PHOENIX system to enable users to compile water-level or contaminant data. The tools provide data filtering, statistical, and analysis capabilities so that users can evaluate the groundwater flow system and contaminant plume

dynamics. Tools were designed to provide technical defensibility for remedy performance, monitoring design, and interpretation, and will be freely available on the web.

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2017 Highlight

Effluent Releases

Nonradiological and radiological air effluent releases for calendar year 2017 were similar to calendar year 2016 releases and below permit limits and applicable standards.

Surveillance Program

Ambient air sampling was conducted at 96 stations either on the Hanford Site or at offsite locations. For the year, the operational availability for all stations was approximately 99% and approximately 99% of all scheduled samples were collected.

6.0 Air Monitoring

CJ Perkins, DL Dyekman

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 the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and/or Washington State Department of Health (WDOH) standards. This report presents 2017 measurement results.

6.1 Air Effluent Monitoring

DL Dyekman

DOE contractors monitor airborne pollutants from site facilities to quantify emissions, determine compliance with federal and state regulatory requirements, and to assess the effectiveness of emission control equipment. Most facility radioactive air emission point sources are actively ventilated stacks sampled prior to the point of release to the ambient environment. Airborne emissions with potential to contain radioactive materials are sampled for gross alpha, gross beta and radionuclides specified in the Hanford Site Air Operating Permit (AOP) [Ecology 2016]. Nonradioactive air pollutants are sampled or estimated based on material and chemical use.

Quantified emissions estimates are documented in annual reports available to the public. The DOE annually prepares and submit reports of Hanford Site radionuclide air emissions and non-radioactive chemical emissions as required per the Hanford Site AOP.

6.1.1 Radioactive Airborne Emissions

Small quantities of radionuclides are emitted to the environment through radioactive emission point sources (i.e., stacks and vents) during routine operations. The federal and state permit requirements contained in the AOP define which stacks require sampling, how often to collect the samples, and the isotopes to be measured. The commonly measured isotopes include: tritium (i.e., hydrogen-3), strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, and americium-241. Emission points are sampled and monitored continuously if they have the potential to emit radionuclides that exceeds 1% of the 40 CFR 61, Subpart H public dose limit of 10 mrem/yr or

100 microsievert (μSv)/yr. For other release points, periodic confirmatory measurements are made to verify low emissions.

Offsite radiological dose assessments related to stack releases are ideally based on direct measurements of radionuclide concentrations in specific environmental media such as air, water, and food measured at offsite locations. However, amounts of many radioactive materials released to the atmosphere from Hanford Site sources are too small to be measured in media after they are released from stacks and diluted through miles of dispersion in the environment. Radioactive air emissions from the Hanford Site are decreasing over time because the production and processing of nuclear materials ceased more than 30 years ago. For the radionuclides present in measurable amounts, it can be difficult to distinguish the small contribution of Hanford Site stacks from other contributions caused by fallout from historical nuclear weapons testing and naturally occurring radionuclides such as uranium and its decay products. As a result, the dose assessment process incorporates conservative assumptions to ensure that calculated doses are likely to be overestimated. In the air pathways calculations, gross alpha and gross beta radiation measurements in stack emissions are added to the measured emissions of plutonium-239/240 and cesium-137, respectively. The actual measured air releases of plutonium-239/240 and cesium-137 are a small fraction of assumed releases that include 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 contributions from any unmeasured radionuclides are added into the estimated doses. The dose to the Maximally Exposed Individual (MEI) calculated in 2017 from Hanford Site operations was 0.22 mrem ($1.2 \mu\text{Sv}$), which is 0.22% of the 100 mrem ($1,000 \mu\text{Sv}$) annual public dose limit specified in DOE O 458.1. Radon-219 and tritium emitted from the 325 Building stack contributed 99% of this offsite dose. For more information on doses due to radiological releases (Section 4.2).

Radioactive air emission points are located on the Hanford Site in the 100, 200, 300, and 400 Areas. Table 6-1 lists the 41 stacks that operated on the Hanford Site during CY 2017. Table 6-2 shows the curies released from these stacks in CY 2017.

Table 6-1. Hanford Site Stack Locations and Sample Analyses. (3 Pages)

Stack ID	Facility	EDP Codes	Individual Sample Analyses	Additional Sample Analyses
105-KW	KW Fuel Storage Basin	Y234, Y236	Alpha, Beta	137Cs, 90Sr, 239Pu, 238Pu, 241Pu, Am241
291-A-1	PUREX	A006, A007	Alpha, Beta	129I, 90Sr, 137Cs, 238Pu, 239Pu, 241Pu, Am241
296-A-18	241-AY-101 Annulus	E060	Alpha, Beta	None
296-A-19	241-AY-102 Annulus	E061	Alpha, Beta	137Cs
296-A-20	241-AZ Tank Farm Annuli	E197	Alpha, Beta	None
296-A-21A	242A Building Vent	E651	Alpha, Beta	None
296-A-22	242A Evaporator Vessel Vent	E643	Alpha, Beta	137Cs, 90Sr, 239Pu, 238Pu, Am241
296-A-28	241-AW Tank Farm Annuli	E272	Alpha, Beta	None
296-A-30	241-AN Tank Farm Annuli	E903	Alpha, Beta	None
296-A-41	241-AP Tank Farm Annuli	E015	Alpha, Beta	None

Table 6-1. Hanford Site Stack Locations and Sample Analyses. (3 Pages)

Stack ID	Facility	EDP Codes	Individual Sample Analyses	Additional Sample Analyses
296-A-42	241-AY/AZ Tank Farm	E147	Alpha, Beta	137Cs, 90Sr, Am241
296-A-43	702AZ Building Exhauster	E148	Alpha, Beta	None
296-A-44	241-AN Tank Farm	E920	Alpha, Beta	90Sr, 137Cs, 154Eu, 238Pu, 239Pu, 241Am, 241Pu
296-A-45	241-AN Tank Farm	E922	Alpha, Beta	90Sr, 137Cs, 154Eu, 238Pu, 239Pu, 241Am, 241Pu
296-A-46	241-AW Tank Farm	E924	Alpha, Beta	90Sr, 137Cs, 154Eu, 238Pu, 239Pu, 241Am, 241Pu
296-A-47	241-AW Tank Farm	E926	Alpha, Beta	90Sr, 137Cs, 154Eu, 238Pu, 239Pu, 241Am, 241Pu
296-A-48	241-AP Tank Farm	E986	Alpha, Beta	90Sr, 137Cs, 154Eu, 238Pu, 239Pu, 241Am, 241Pu
296-A-49	241-AP Tank Farm	E988	Alpha, Beta	90Sr, 137Cs, 154Eu, 238Pu, 239Pu, 241Am, 241Pu
296-B-1	B Plant	B001	Alpha, Beta	137Cs, 90Sr, 239Pu, 238Pu, Am241
296-B-10	WESF	B748	Alpha, Beta	137Cs, 90Sr, 239Pu, 238Pu, Am241
296-E-1	Effluent Treatment Facility	E001	Alpha, Beta	None
FFTF-CB-EX	FFTF	F011	None	Emissions estimated by calculation
437-MN&ST	FFTF MASF	F014	Alpha, Beta	None
437-1-61	FFTF MASF	F019	Alpha, Beta	None
296-H-212	CSB	C601	Alpha, Beta	137Cs
296-P-22	241-SY Tank Farm Annuli	W191	Alpha, Beta	None
296-P-23	241-SY Tank Farm	W190	Alpha, Beta	None
296-P-45	241-T-111 Tank Exhauster	E047	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
296-P-49	241-AX Tanks Exhauster	E100	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
296-P-50	241-AX Tanks Exhauster	E102	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
296-P-107	241-C Tanks Exhauster	E104	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
291-S-1	S Plant	S001	Alpha, Beta	None
296-S-16	219-S	S264	Alpha, Beta	None
296-S-21	222-S	S289	Alpha, Beta	137Cs, 90Sr, 239Pu, 238Pu, Am241
296-S-25	241-SY Tank Farm	W145	Alpha, Beta	None
291-T-1	T Plant	T785	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
296-T-7	2706T	T154	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
296-W-4	WRAP	W123	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
291-Z-1	Plutonium Finishing Plant	Z810	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Pu, 241Am
EP-324-01-S	324 Building	F025	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
EP-325-01-S	325 Building	N/A	Alpha, Beta	Tritium, Radon, numerous additional isotopes

Table 6-1. Hanford Site Stack Locations and Sample Analyses. (3 Pages)

Stack ID	Facility	EDP Codes	Individual Sample Analyses	Additional Sample Analyses
EP-331-01-S	331 Building	N/A	Alpha, Beta	90Sr, 137Cs, 238Pu, 239Pu, 241Am
EP-331-01-09-S	331 Building	N/A	Alpha, Beta	14C
CSB = Canister Storage Building FFTF = Fast Flux Test Facility MASF = Material and Storage Facility N/A = Not Applicable PUREX = Plutonium Uranium Extraction Facility WESF = Waste Encapsulation and Storage WRAP = Waste Receiving and Processing				

The quantity of radionuclide air emissions reported in 2017 were similar in magnitude to those reported in 2017. Table 6-2 summarizes Hanford Site radioactive airborne emissions in 2017.

Table 6-2. Hanford Site Radioactive Airborne Emissions in Calendar Year 2017. (2 Pages)

Radionuclide	100 Area (Ci)	200-East Area (Ci)	200-West Area (Ci)	300 Area (Ci)	400 Area (Ci)	Totals (Ci)
Actinium-227	ND	ND	ND	3.1E-10	NA	3.1E-10
Alpha (gross)	8.2E-06	4.2E-07	2.1E-05	4.6E-06	2.9E-07	3.5E-05
Americium-241	3.9E-06	5.7E-08	2.1E-06	1.6E-08	NA	6.1E-06
Americium-243	ND	ND	ND	4.3E-08	NA	4.3E-08
Beta (gross)	1.5E-05	1.3E-05	6.4E-06	1.4E-05	1.9E-06	5.0E-05
Carbon-14	NA	NA	NA	1.2E-04	NA	1.2E-04
Cesium-137	4.6E-06	1.9E-06	3.9E-07	2.3E-08	1.1E-11	6.9E-06
Cobalt-60	ND	ND	ND	7.7E-08	NA	7.7E-08
Europium-152	ND	ND	ND	2.2E-09	NA	2.2E-09
Europium-154	ND	ND	ND	1.1E-08	NA	1.1E-08
Gadolinium-153	ND	ND	ND	9.0E-11	NA	9.0E-11
Iodine-129	NA	9.3E-04	NA	NA	NA	9.3E-04
Krypton-85	NA	NA	NA	5.2E-07	NA	5.2E-07
Neptunium-237	ND	ND	ND	1.4E-08	NA	1.4E-08
Plutonium-238	4.1E-07	ND	1.8E-07	3.6E-08	NA	6.3E-07
Plutonium-239	3.1E-06	ND	9.6E-06	5.7E-09	2.3E-13	1.3E-05
Plutonium-241	1.4E-05	ND	3.3E-06	2.5E-08	NA	1.7E-05
Radium-226	NA	NA	NA	3.7E-10	NA	3.7E-10
Radon-219	NA	NA	NA	3.6E+03	NA	3.6E+03
Radon-220	NA	NA	NA	8.9E+02	NA	8.9E+02
Radon-222	NA	NA	NA	3.6E-05	NA	3.6E-05

Table 6-2. Hanford Site Radioactive Airborne Emissions in Calendar Year 2017. (2 Pages)

Radionuclide	100 Area (Ci)	200-East Area (Ci)	200-West Area (Ci)	300 Area (Ci)	400 Area (Ci)	Totals (Ci)
Ruthenium-106	ND	ND	ND	1.3E-09	NA	1.3E-09
Sodium-22	NA	NA	NA	NA	2.1E-10	2.1E-10
Strontium-90	5.5E-06	4.7E-06	1.2E-06	1.9E-07	NA	1.2E-05
Technicium-99	ND	ND	ND	4.1E-06	NA	4.1E-06
Tritium (elemental)	NA	NA	NA	1.6E+01	NA	1.6E+01
Tritium (tritiated water vapor)	NA	NA	NA	1.6E+02	NA	1.6E+02
Uranium-232	NA	NA	NA	8.6E-09	NA	8.6E-09
Uranium-233	NA	NA	NA	2.3E-08	NA	2.3E-08

Ci = curies

NA = Not applicable

ND = Not detected

6.1.2 Non-Radioactive Air Pollutants

Non-radioactive air pollutants are emitted from Hanford facility operations and fossil fuel combustion. The non-radioactive air emissions fall under two general categories of pollutants: criteria pollutants and hazardous or toxic air pollutants. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, volatile organic compounds, particulate matter, and sulfur dioxide. These criteria pollutants are named after EPA regulations that establish national ambient air quality standards (NAAQS) criteria that define allowable concentrations of the compounds in air. Hazardous and toxic air pollutants are defined in federal and state regulations and are known or suspected to cause cancer or other serious health effects. The federal *Clean Air Act Amendment of 1990* included a list of 187 hazardous air pollutants (HAPs) that are considered dangerous to human health and the environment. In addition to the federal HAP list, the Washington Administrative Code (WAC) lists toxic air pollutants (TAPs) that include the federal list of 187 HAPs and adds approximately 200 more substances and compounds.

The Hanford Site AOP and WAC 173-400-105 require the DOE to prepare an annual Air Emissions Inventory (AEI) [DOE 2018] report for submittal to Ecology. The AEI report includes measured and estimated emissions of the criteria and toxic air pollutants for permitted emission units listed in the AOP. The most significant source of emissions is from combustion of the fossil fuels diesel, gasoline, natural gas, and propane. Fossil fuels are burned during routine operations to produce steam and provide a local source of light and electricity. The emission estimates are calculated using published EPA formulas ([Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources](#) [EPA 1995]). The fossil fuel combustion sources accounts for nearly 100% of carbon monoxide, oxides of nitrogen, particulate matter, and sulfur dioxide emissions reported annually. Other sources exhibiting a large fraction of total emissions are the tank farm exhausters producing roughly 88% of reported ammonia and 98% of the TAPs, and fuel dispensing stations (i.e. vehicle gas refueling stations) emitting greater than 70% VOCs due to evaporation. Table 6-3 summarizes the Hanford Site emissions of nonradioactive criteria and toxic air pollutants discharged to the atmosphere in CY 2017.

Table 6-3. Calendar Year 2017 Hanford Site Criteria and Toxic Air Pollutant Emissions.

Constituent	2017 Releases		
	Ton	lb	Kg
Criteria Pollutants			
Particulate matter	1.8	3,547	1,609
Lead	0	0	0
Nitrogen oxides	22.4	46,776	21,213
Sulfur oxides	1.3	2,554	1,158
Carbon monoxide	10.4	20,843	9,453
Volatile organic compounds	4.8	9,550	4,331
Ammonia	2.0	4,003	1,815
Toxic Air Pollutants	0.5	522	237

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, offsite 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 the [Hanford Site 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 59 locations across the Hanford Site was used during 2017 to monitor radioactive airborne materials in air near Hanford Site facilities and operations (Table 6-4). 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 2017 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 onsite facility environment.

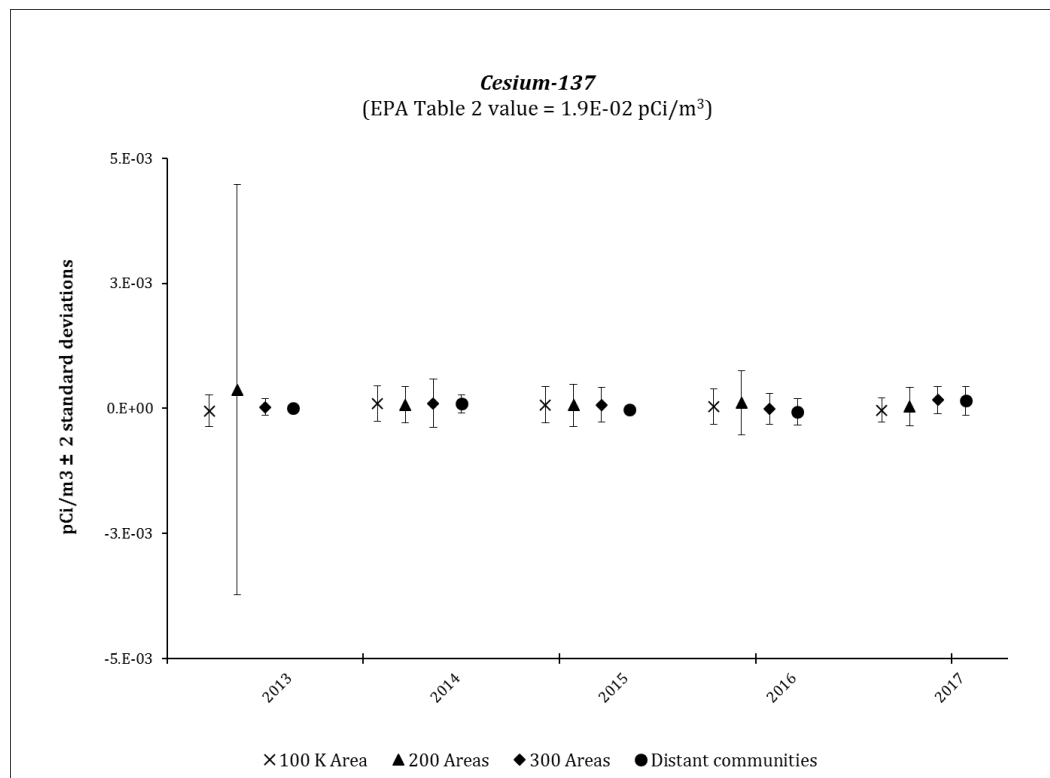
**Table 6-4. Hanford Site Monitoring Locations and Analyses
for Ambient Air Monitoring Samples.**

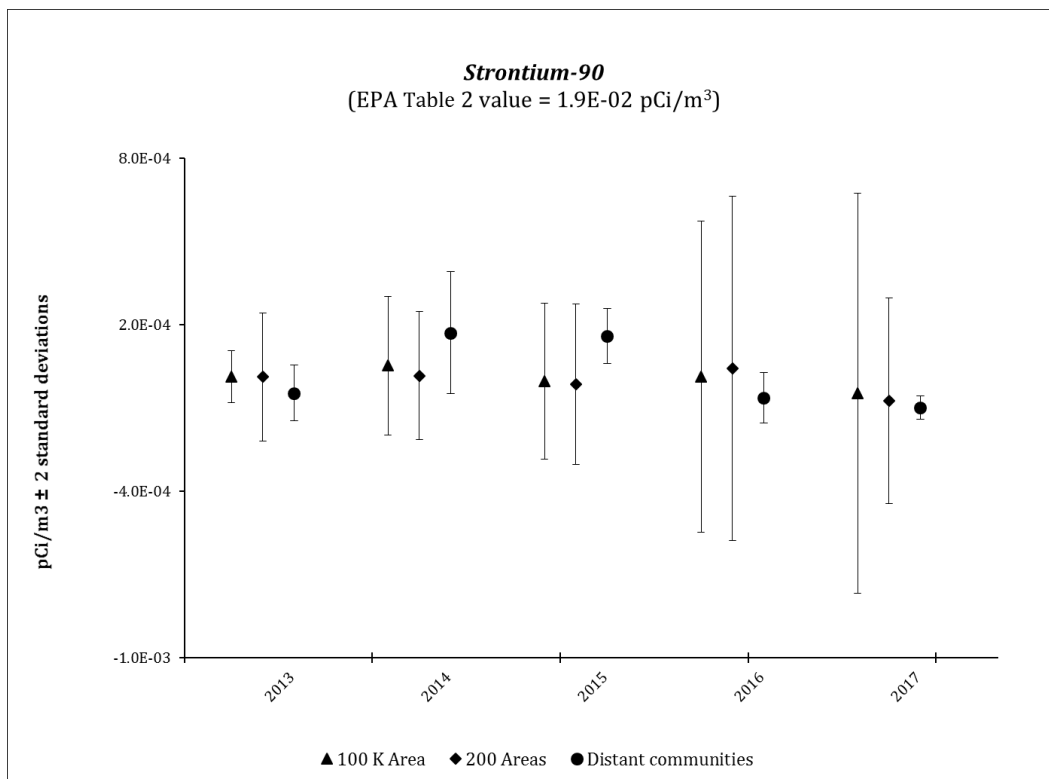
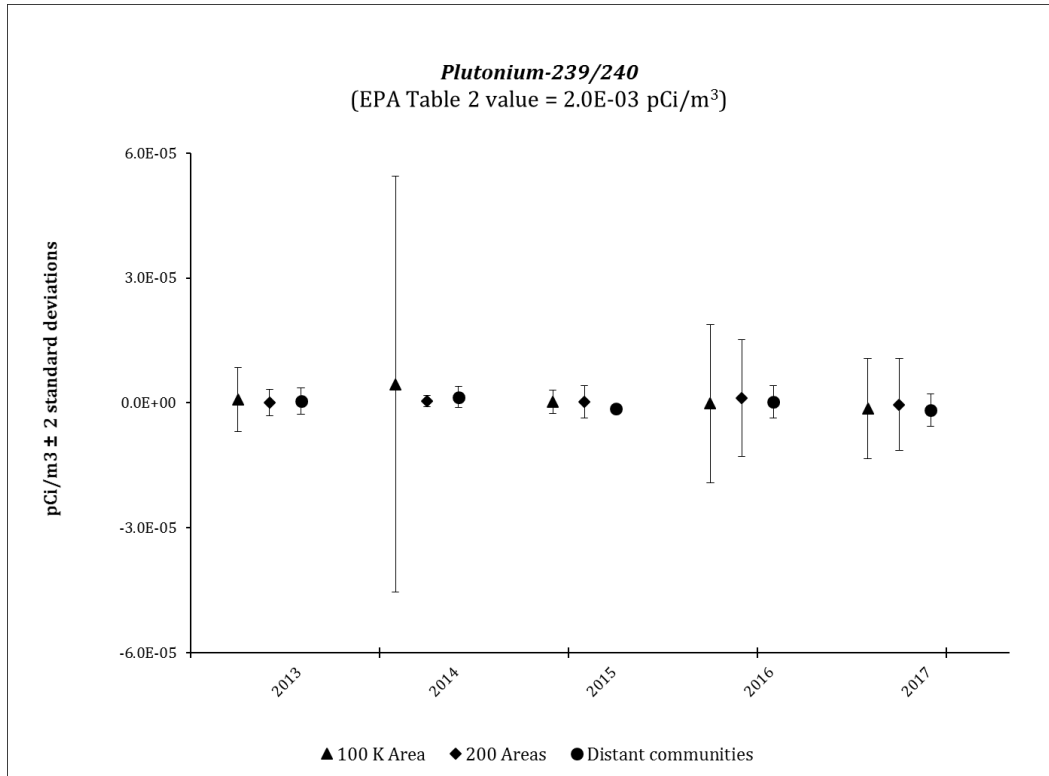
Air Monitoring Locations	Number of Samplers	Analyses			
		EDP Codes	Bi-Weekly	Monthly	Semi-Annual Composite
100-K Area	6	N476, N534, N535, N575, N576 ^a , N578	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA
200-East Area	18	N019, N158, N498, N499 ^a , N582, N957, N967, N968, N969, N970, N972, N973, N976, N977, N978, N984, N985, N999	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
Canister Storage Building (200-East)	2	N480, N481	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA
Integrated Disposal Facility (200-East)	2	N532, N559	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
200-West Area	15	N161, N168, , N304, N441, N442, N449, N456, N457, N956, N963, N965, N966, N974, N987, N994	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
Plutonium Finishing Plant (200-West Area)	7	N155, N165 ^a , N433, N554 ^a , N555 ^a , N964, N975 ^a	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, ²⁴¹ Pu, ²⁴¹ Am, GEA
300 Area	1	N130	Alpha, Beta	Tritium	⁹⁰ Sr, Pu-iso, U-iso, GEA
618-10 Burial Ground	4	N548 ^a , N549, N579, N580	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
Environmental Restoration Disposal Facility	3	N482 ^a , N517, N518	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
Wye Barricade	1	N981 ^a	Alpha, Beta		⁹⁰ Sr, Pu-iso, U-iso, GEA
^a Collocated sampling location with WDOH EDP Code = environmental data point code = sampler location code. GEA = Gamma Energy Analysis WDOH = Washington State Department of Health					

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 6-4) 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 (40 CFR 61, Appendix E, Table 2) are dose-based reference values that would result in a dose of 10 mrem (100 μ Sv)/yr under conditions of continuous exposure. The 2017 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 offsite. Data also show that concentrations of certain radionuclides were higher and widely variable within different Hanford Site operational areas. Appendix C, Table C-4 shows the annual average and maximum concentrations of radionuclides in air samples collected near Hanford Site facilities and operations during 2017.





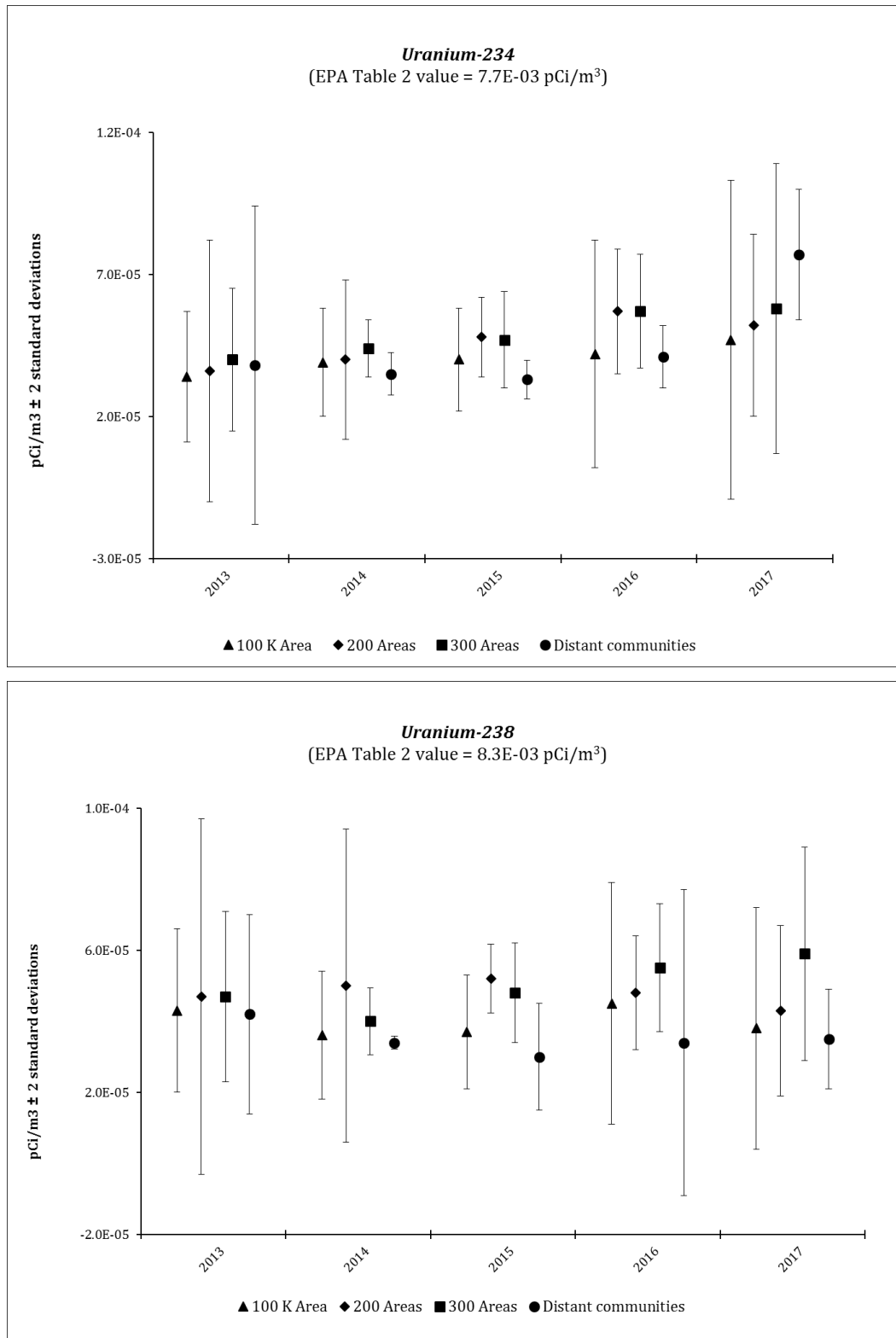


Figure 6-1. Hanford Site Average Radionuclide Concentrations in Ambient Air Samples Compared to Distant Community Samples.
NOTE: Because of figure scale, some uncertainties (error bars) are concealed by the point symbol

6.2.1.1 Monitoring Results

Wildfires 2017 – Smoke/Particulate. During August thru Early September statistical anomalies were observed at up to ~80% of the onsite and offsite monitoring stations and were attributable to smoke/particulate build-up on the filters as a result of extremely smoky air from regional wildfires and a persistent ridge of high pressure through early September.

100-K Area. Ambient air was monitored in 2017 at six locations in the 100-K Area, and analytical results showed radionuclide concentrations at or below typical Hanford Site levels. Uranium-234 was detected in approximately 42% of the samples, and tritium was detected in approximately 15% of the samples. All other radionuclides of concern were below analytical detection limits.

200-East Area. Air sampling was conducted at 21 locations in the 200-East Area during 2017. Generally, radionuclide levels measured in the 2017 air composite samples were similar to those measured in previous years. Uranium-234 was detected in approximately 24% of the samples.

PUREX Tunnel (200-East Area). On May 9, 2017, a portion of the PUREX Tunnel 1 wood timber roof structure was observed to have collapsed into the tunnel resulting in a hole approximately 19 ft (5.79 m) wide by 17 ft (5.18 m) long. The actual time of the collapse and cause of the failure has not been determined. Immediate and follow-up ambient air sampling showed the following:

- Ambient air samples collected on May 8 had slightly elevated gross alpha and gross beta concentrations at stations located in the vicinity of PUREX and detectable levels of cesium-137 at low concentrations at two stations located south of PUREX.
- Ambient air samples collected on May 11 had no detectable levels of cesium-137.
- Ambient air samples subsequently collected on May 22 had normal gross alpha and gross beta concentrations.
- Stations in the vicinity of PUREX did not detect isotopes in concentrations that exceeded the reporting threshold pursuant to Section 5.1.5.1 of the *Hanford Site Radioactive Air Emissions License #FF-01* (FF-01) (10% of the value of 40 CFR 61, Appendix E, Table 2).

200-West Area. Air sampling was conducted at 22 locations in the 200-West Area during 2017. Radionuclide levels measured were, in general, similar to results for previous years. Uranium-234 and uranium-238 were detected in approximately 23% and 11% of the samples, respectively. Plutonium-239/240 was detected in approximately 45% of the samples and americium-241 was detected in approximately 39% of the samples.

Plutonium Finishing Plant (200-West Area) Demolition. Open-air demolition of the Plutonium Finishing Plant (PFP) complex continued in 2017. Significant events and associated air sampling information during the year included:

242-Z Demolition. Bi-weekly air samples collected during the period March 27 through April 10 showed statistically elevated gross alpha results at two stations: N555 (S) and N964 (NW)

Other stations in the vicinity of PFP showed typical low gross alpha results. Semi-annual (January 3, 2017 through July 6, 2017) composite air samples showed the americium-241 concentration at station N964 in excess of 10% of EPA's concentration values (40 CFR 61, Appendix E, Table 2). As required by the FF-01 license (Section 5.1.5.1), this elevated air sample result was reported to the Washington State Department of Health.

CAM Alarm/Take Cover. A Continuous Air Monitoring (CAM) alarm was sounded the morning of June 8 while crews were removing one of the gallery glove boxes on the Plutonium Reclamation Facility (PRF). This CAM alarm was in the demolition area, an area where contamination is expected. Crews immediately stopped demolition; applied fixative to the area; and employees took cover while a recovery team entered the area, conducted additional surveys, and applied additional fixative to mitigate any further contamination spread.

Bi-weekly air samples collected during the period June 5 through 19 showed statistically elevated gross alpha results at two stations:

- N975 (E) and N956 (SSE) (Figure 6.2)
- Other stations in the vicinity of PFP showed typical low gross alpha results.

Demolition of the PFP Main Stack. Demolition of the PFP main stack occurred on July 15. Ambient air samples collected in the vicinity afterwards showed normal gross alpha and gross beta concentrations.

November D&D. Demolition of PRF resumed over the weekend of November 11 and 12.

Bi-weekly air samples collected during the period November 6 through 20 showed statistically elevated gross alpha results at five stations: N155 (SSE), N165 (SE), N554 (NE), N555 (S), and N975 (E).

Bi-weekly air samples collected during the period November 20 through December 4 showed statistically elevated gross alpha results at three stations: N155 (SSE), N165 (SE), and N555 (S).

December D&D. Between December 14 and 18 contaminations were detected outside of the Contamination Area (CA) at the PFP demolition zone, including around the PFP offices and on multiple vehicles located outside the radiological boundary. Demolition work was suspended on Sunday, December 17, and remains on hold. Several ambient air monitoring stations showed elevated gross alpha results during this period (Figure 6.2)

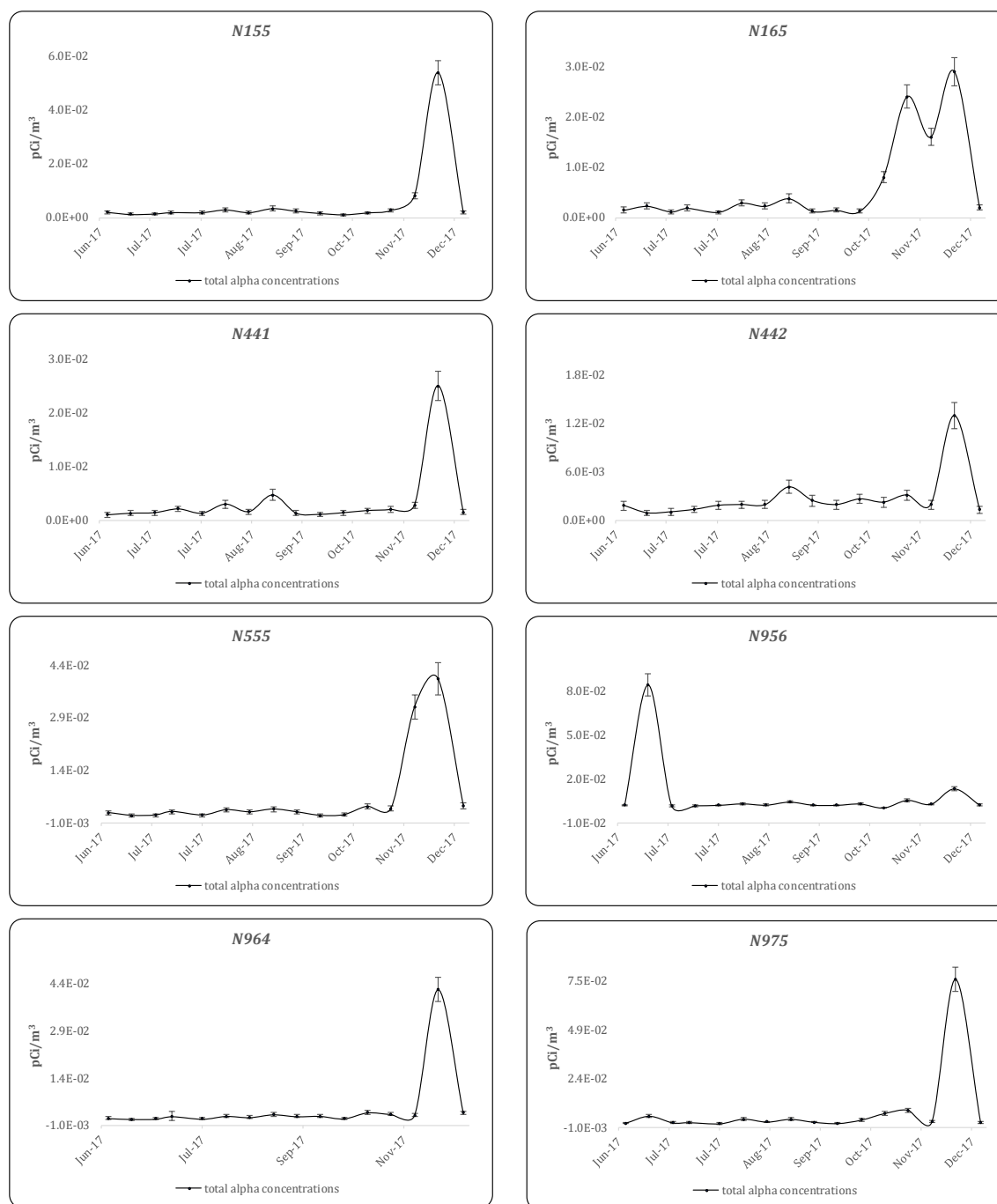


Figure 6-2. Total Alpha Concentrations (pCi/m³) at Selected 200-West Area Ambient Air Sampling Stations in the Vicinity of the Plutonium Finishing Plant.

Bi-weekly air samples collected during the period December 6 thru 18 at the following nine stations showed statistically elevated sample results, as well as positive [alpha] counts after radon decay:

- N155 (SSE): total alpha & total beta
- N165 (SE): total alpha
- N168 (ESE): total alpha & total beta
- N433 (N): total alpha
- N441 (SE): total alpha & total beta
- N442 (SE): total alpha & total beta
- N554 (NE): total alpha & total beta
- N956 (SSE): total alpha & total beta
- N975 (E): total alpha & total beta.

Bi-weekly air samples collected during the period sample results for the period December 18, 2017, through January 2, 2018, for these same nine stations showed no statistically elevated results.

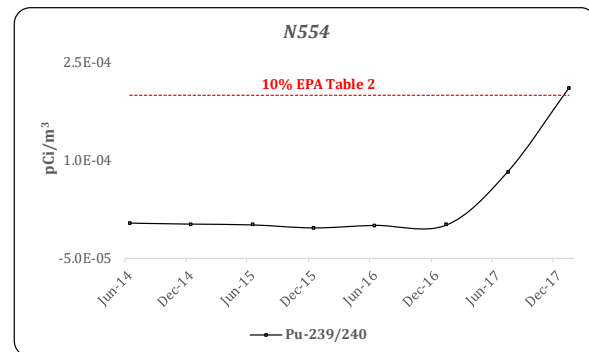
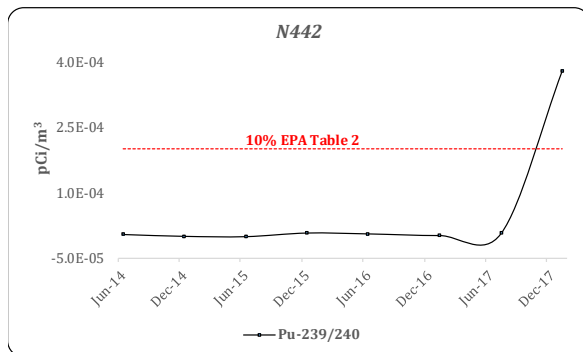
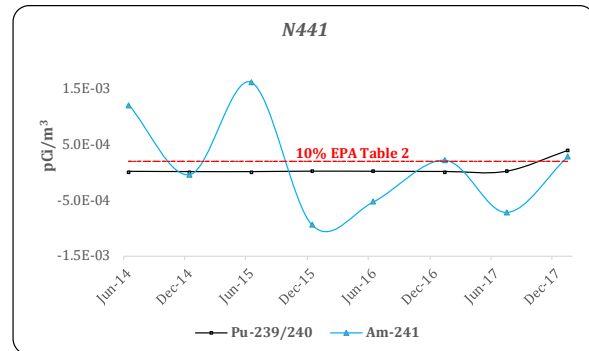
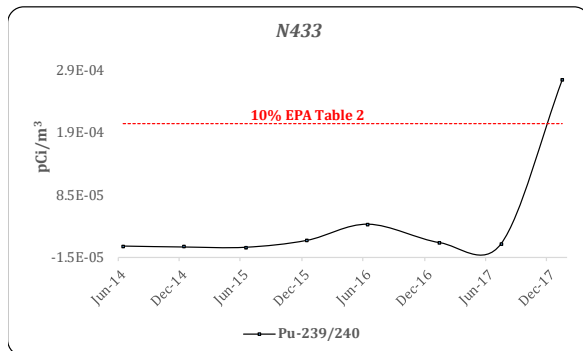
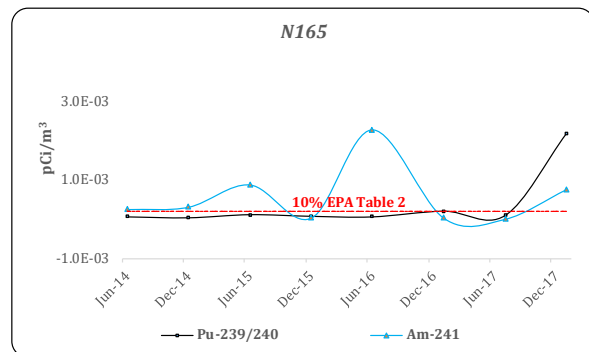
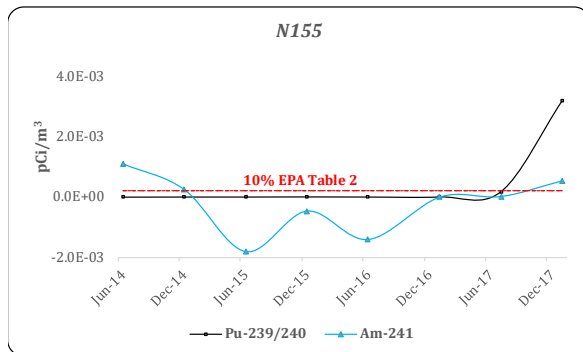
Semi-annual (July 3, 2017, through January 2, 2018) composite air samples showed there were 16 isotopic results (Figure 6.3) from the following 10 air sampling stations near PFP in excess of 10% of EPA's concentration values (40 CFR 61, Appendix E, Table 2). As required by the FF-01 license (Section 5.1.5.1), these elevated air sample results were reported to the Washington State Department of Health:

- N155 (SSE): plutonium-239/240 and americium-241
- N165 (SE): plutonium-239/240 and americium-241
- N433 (N): plutonium-239/240
- N441 (SE): plutonium-239/240 and americium-241
- N442 (SE): plutonium-239/240
- N554 (NE): plutonium-239/240
- N555 (S): plutonium-239/240 and americium-241
- N956 (SSE): plutonium-239/240
- N964 (NW): plutonium-239/240 and americium-241
- N975 (E): plutonium-239/240 and americium-241.

300 Area. At the 300 Treatment Effluent Disposal Facility station, air sample results were similar to those measured in previous years with tritium detected in only approximately 15% of the samples at concentrations slightly lower than those seen in stations located in/near the 300 Area.

Environmental Restoration Disposal Facility (ERDF). Air sampling in support of ERDF operations was conducted at five locations at ERDF (200-West Area). Radionuclide levels measured at this site were comparable to previous years. Uranium-234 and -238 were detected in approximately 30% and 40% of the samples, respectively. Plutonium-239/240 was detected in approximately 40% of the samples.

618-10 Burial Ground Remediation. Air monitoring was conducted at four locations at the 618-10 Burial Ground Project north of the 300 Area. Remediation activities were completed and air sampling was concluded at this site in December. Radionuclide levels measured at this site were comparable to previous years. Uranium-234 and -238 were detected in approximately 38% and 50% of the samples, respectively. Americium-241 was detected in approximately 25% of the samples.



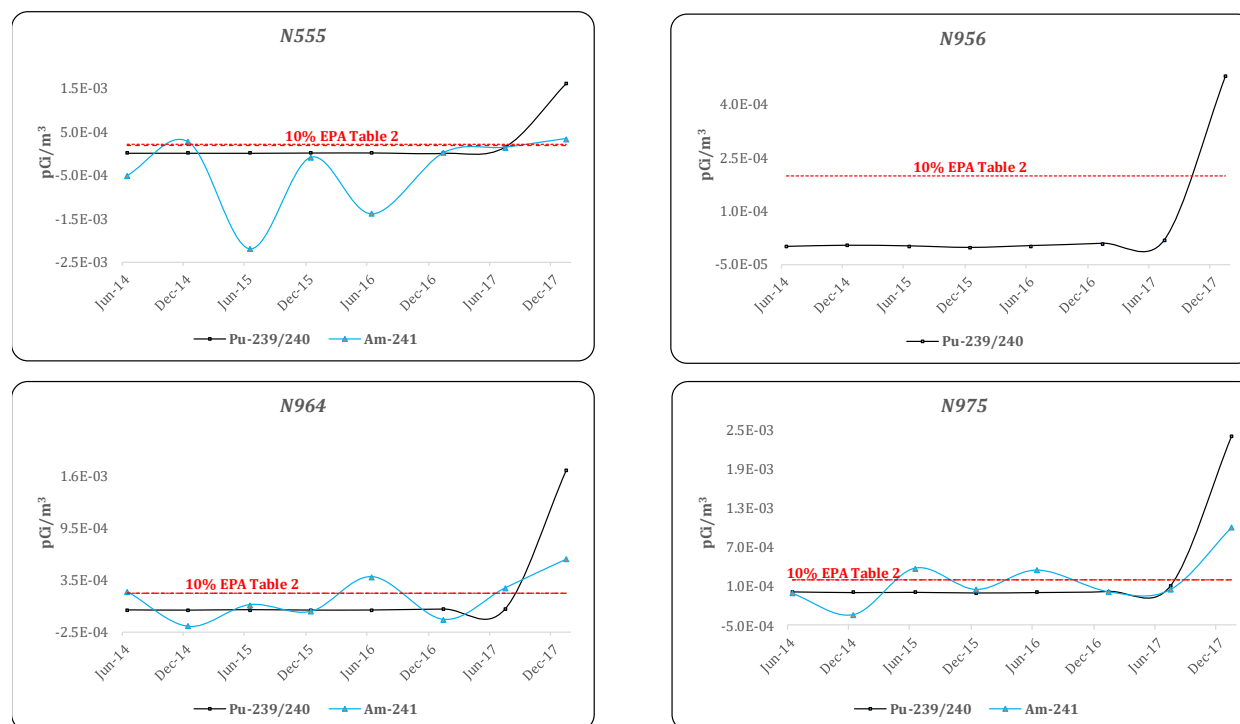


Figure 6-3. Isotopic Concentrations (pCi/m³) at Selected 200-West Area Ambient Air Sampling Stations in the Vicinity of the Plutonium Finishing Plant.

6.2.2 Hanford Site and Offsite Ambient Air Monitoring

Airborne radionuclide samples were collected in 2017 by 37 continuously operating samplers at or in the vicinity of the Hanford Site. The stations were grouped into four location categories: Hanford Site (18 stations), perimeter (11 stations), nearby Hanford Site communities (7 stations), and distant community (1 station; Figure 6-4; Appendix C, Table C-4). 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, Washington, provided data for the nearest population centers. A sampler in Yakima, Washington, provided background data from a community essentially unaffected by Hanford Site operations.

6.2.2.1 Sampling and Analyses. Samples were collected and analyzed according to a schedule established prior to the monitoring year for offsite samples ([DOE/RL-2013-53, Rev. 3, Hanford Site Environmental Surveillance Master Sampling Schedule Calendar Year 2017](#)). 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 hours, 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. Bi-weekly 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 as shown in Table 6-5.

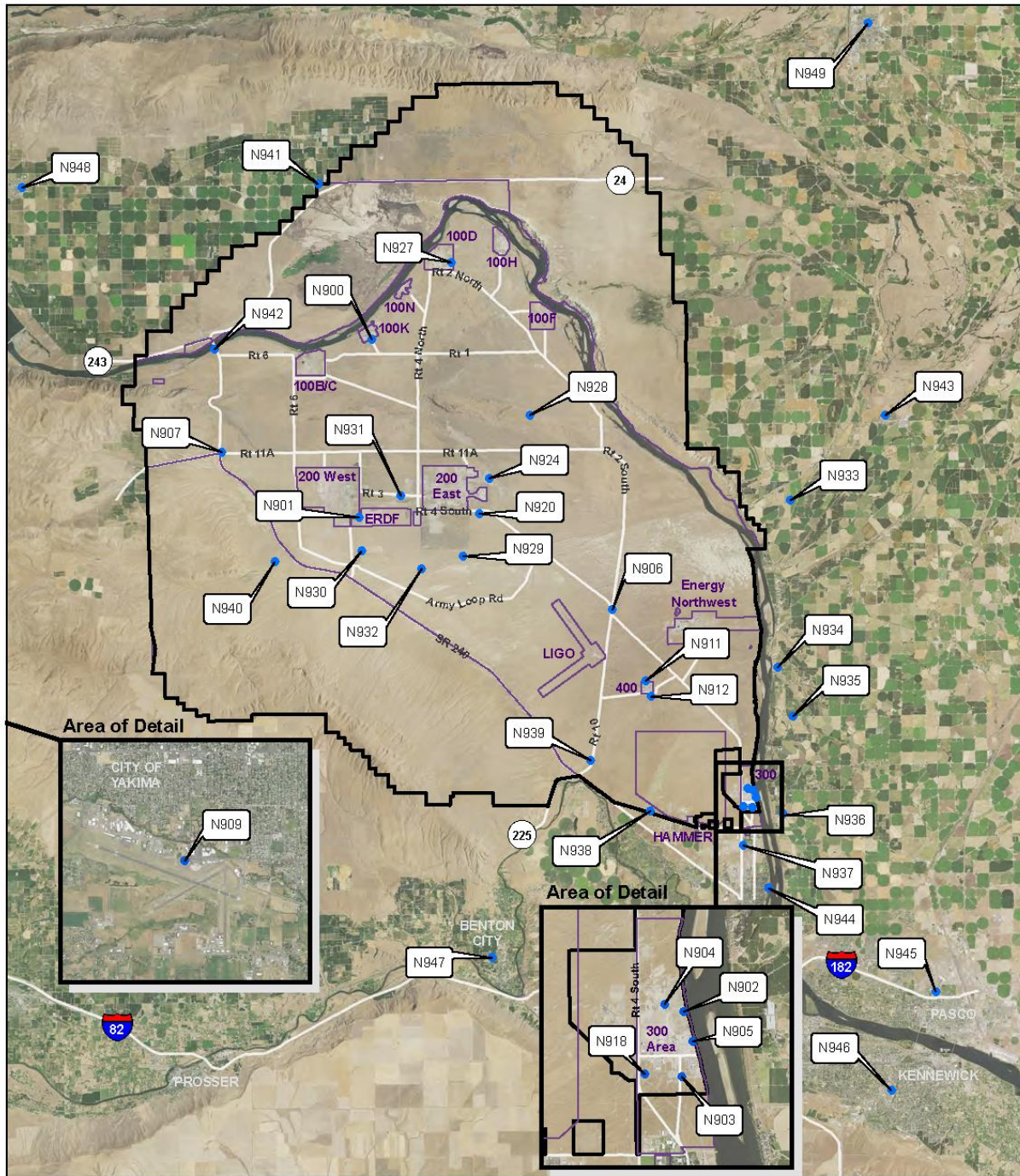
Atmospheric water vapor was collected for tritium analysis at 20 locations in 2017 by continuously drawing air through multi-column samplers containing adsorbent silica gel. The water-vapor samplers were exchanged every 4 weeks to prevent sample loss as a result of breakthrough (i.e., oversaturation). 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 et al. 1997). The collected water was distilled from the silica gel and analyzed for its tritium content.

Table 6-5. Hanford Site and Offsite Ambient Air Sampling Locations and Analytes. (2 Pages)

EDP Code ^a	Location	Analyses		
		Bi-Weekly	Monthly ^b	Composite
Hanford Site				
N900	100-K Area	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
N928	Gable Mountain	Alpha, Beta		GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238
N920	200-East SE	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238
N929	S of 200-East	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-West SE	Alpha, Beta		GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238
N905	300 Water Intake ^{c, d}	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238
N903	300 South Gate ^{e, f}	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238
N918	300 South West ^e	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238
N904	300 Trench ^e	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238
N902	300-NE ^e	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 ^{c, f}	Alpha, Beta		GEA, strontium-90, plutonium-238, 239/240, uranium-234,235,238

Table 6-5. Hanford Site and Offsite Ambient Air Sampling Locations and Analytes. (2 Pages)

EDP Code ^a	Location	Analyses		
		Bi-Weekly	Monthly ^b	Composite
Hanford Site Perimeter				
N933	Ringold Met Tower	Alpha, Beta	Tritium	GEA, plutonium-238, 239/240
N934	W End of Fir Road ^{c, d}	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 ^{c, d}	Alpha, Beta	Tritium	GEA, uranium-234,235,238
N938	Horn Rapids Substa.	Alpha, Beta		GEA, strontium-90, plutonium-238, 239/240
N939	Prosser Barricade ^{c, d}	Alpha, Beta	Tritium	GEA, strontium-90, plutonium-238, 239/240
N907	Yakima Barricade ^c	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
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
^a EDP code=environmental data point code = sampler location code; refer to Figure 6-4. ^b Atmospheric water vapor samples for tritium analysis are collected every 4 weeks using silica gel columns. ^c WDOH particulate air sampler also at this location. ^d WDOH tritium air sampler also at this location. ^e Two tritium samples are collected from this location, one as a Quality Assurance duplicate sample. ^f Quality assurance duplicate sample collected at this location. GEA = gamma energy analysis WDOH = Washington State Department of Health				



Legend

- Far Field Air Sampling Location
- Operational Areas
- Hanford Site Boundary

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Figure 6-4. Far Field Air Sampling Locations for Fiscal Year 2017.

6.2.2.2 Monitoring Results. Sample results in 2017 showed very low radiological concentrations in air. With the exceptions of the two sample results discussed immediately below, radionuclide concentrations 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 μ Sv)/yr from airborne radiological material.

Miscellaneous Regulatory Notifications

1st-half of 2017 Reportable to WDOH: Cobalt-60 at 300 Area station N905 (300 Water Intake). This station is not associated with any Hanford-specific facility or project and the cobalt-60 is likely attributable to non-Hanford Site air emissions operation emissions.

2nd-half of 2017 Reportable to DOH: During the period from November 1, 2017, through November 29, 2017: tritium at station N944 (aka “Leslie Groves” – Richland). Per conversation with WDOH, the likely source of elevated tritium levels was from non-Hanford Site air emissions. This facility is located in north Richland, north of Leslie Groves Park and south of the Battelle Sports Complex. The facility was known by WDOH to be engaged in radioactive materials handling/packaging activities during November. Tritium concentrations during the same time period at the following stations also were statistically elevated: N937 (Battelle Complex), N902 (300 NE), N903 (300 South Gate), N904 (300 Trench), and N130 (300 TEDF).

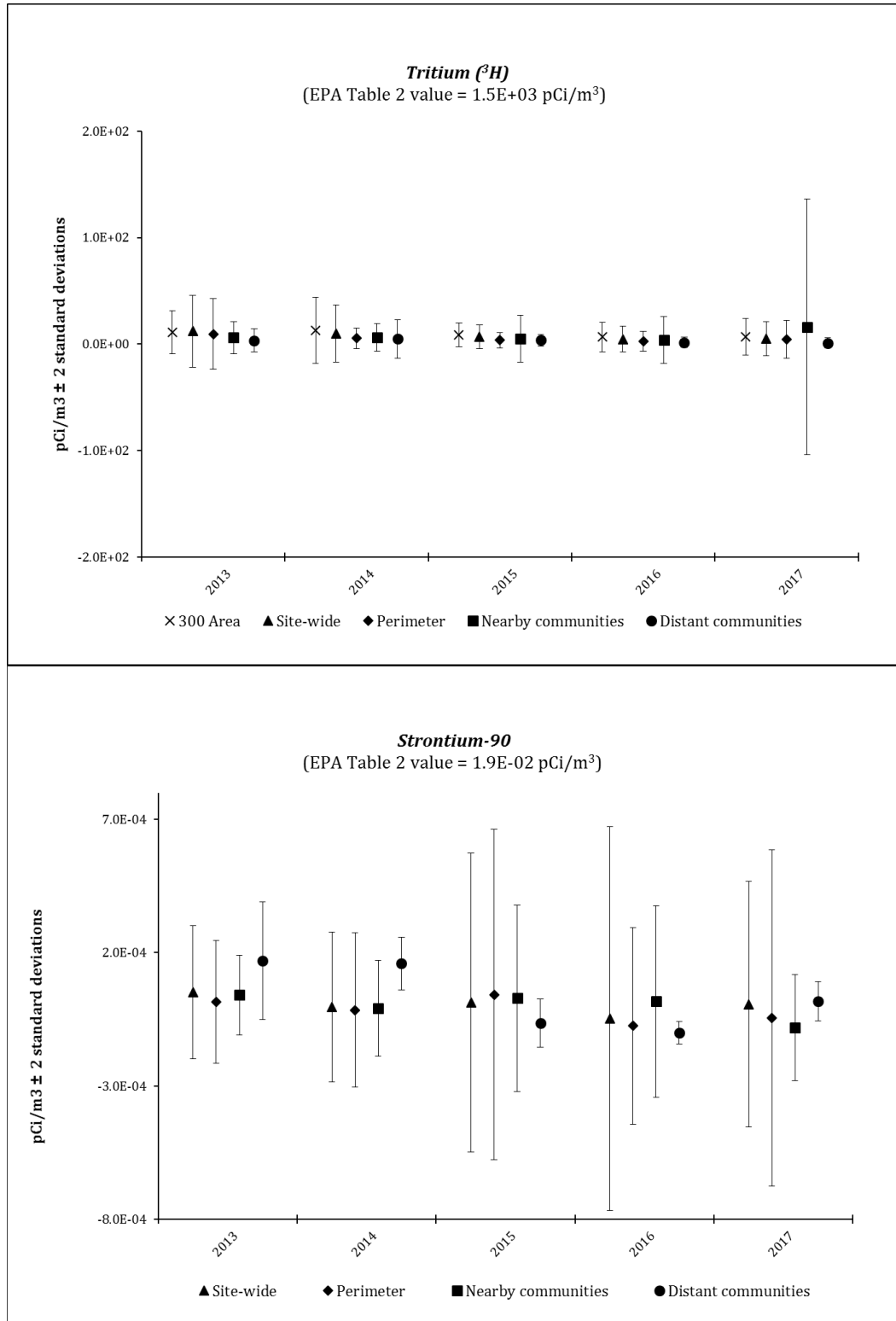
Gross alpha and gross beta concentrations in the air samples collected in 2017 from Hanford Site, perimeter, and nearby Hanford Site communities were comparable to each other and slightly higher than samples from the distant community. Concentrations in 2017 were comparable to concentrations seen in 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.

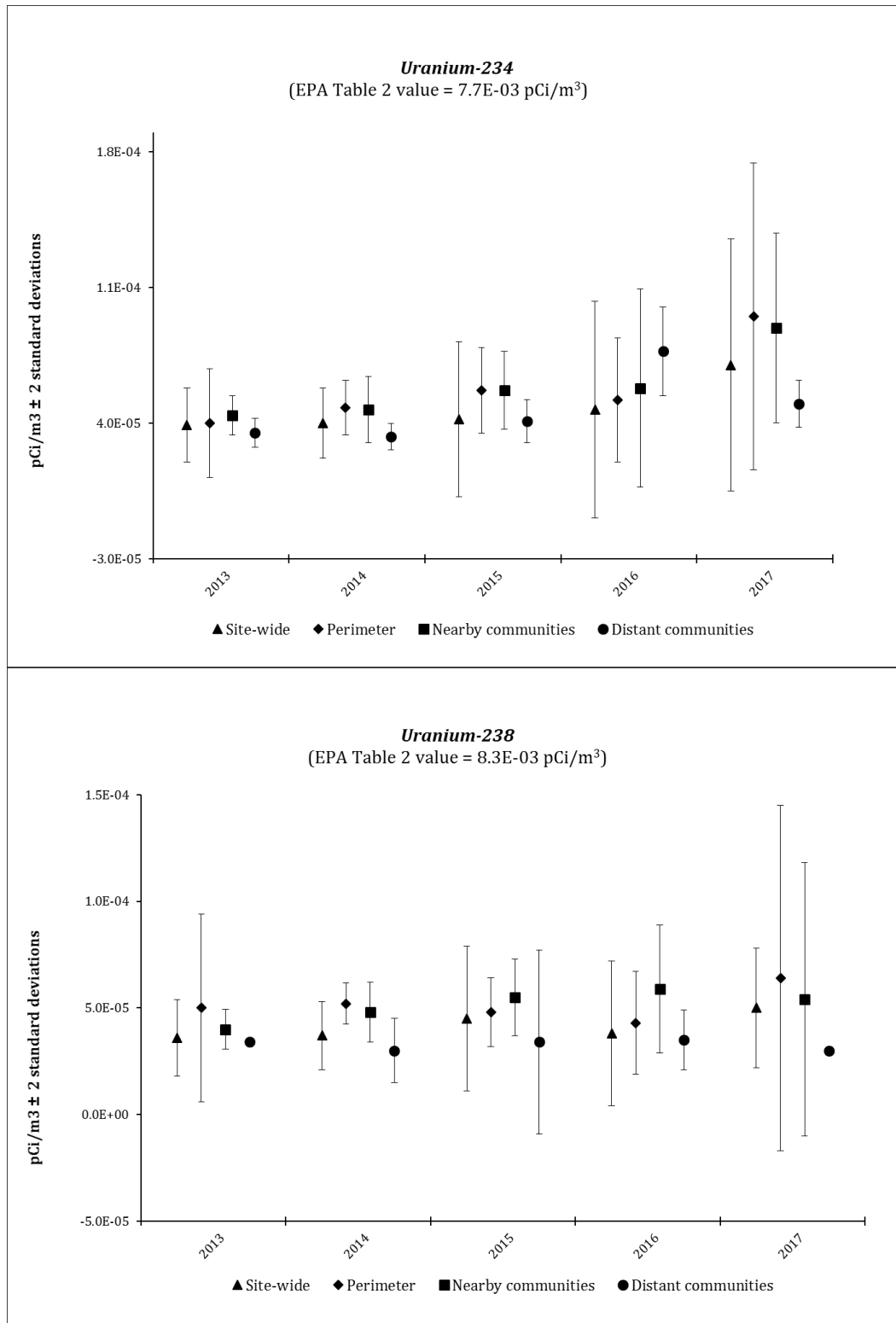
Plutonium-239/240 was detected at a low concentration in one air sample at 100-K Area. Figure 6-4 shows plutonium-239/240 concentrations in the air samples collected in 2017 and in previous years.

Uranium-234 and -238 were both detected in approximately 50% of the air samples collected in 2017 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.

Tritium was detected in approximately 21% of the samples collected in 2017. Approximately 80% of the samples with detectable tritium concentrations were collected from stations located near the 300 Area.

Cesium-137 and strontium-90 were not detected in any of the samples collected during 2017.





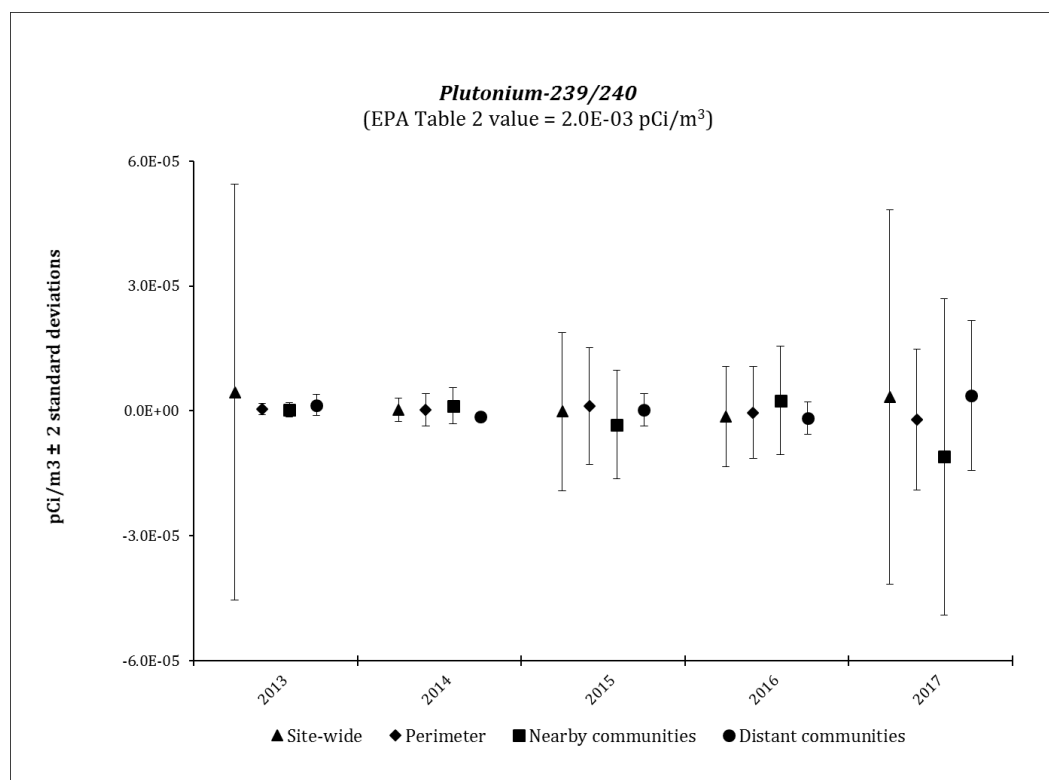


Figure 6-5. Radionuclide Concentrations in Ambient Air Samples (1 pCi = 0.037 Bq).

6.3 References

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2017 Highlight

Effluent Releases

Liquid effluent releases were below permit limits and applicable standards.

Onsite Drinking Water

Routine radiological, chemical, physical, and microbiological monitoring of Hanford Site drinking water is performed regularly as mandated by the U.S. Environmental Protection Agency's Community Water System requirements. With the exception of the 300 Area water system, all of the U.S. Department of Energy-owned Hanford Site systems were in compliance with drinking water standards for 2017. The 400 Area source of supply was groundwater provided from one of three wells. The primary 400 Area well suffered an equipment malfunction in October 2016; therefore, a backup well became the water supply to 400 Area consumers during 2017.

The 300 Area water system experienced a maximum contaminant level exceedance for disinfection by-products monitoring in the third and fourth quarters of 2017. Transition of the 300 Area operations and responsibilities from Mission Support Alliance to Pacific Northwest National Laboratory occurred on October 1, 2017.

7.0 Water Monitoring

7.1 Drinking Water Systems

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Eight U.S. Department of Energy (DOE)-owned, contractor-operated public water systems supply drinking water to DOE facilities on the Hanford Site (Table 7-1). MSA operates five of the public water systems, CH2M Plateau Remediation Contractor (CHPRC) operates two systems, and PNNL operates one system. The City of Richland supplies water to the 300 Area, Richland North Area, and Hazardous Materials Management and Emergency Response facility.

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)	PNNL ^a
400 Area	400 Area Groundwater Wells	CHPRC
609 Fire Station	Trucked Water from Water Treatment Plant 283-W	MSA
^a As of October 2017, PNNL began 300 Area utility responsibility; MSA continued operations via an inter-contractor agreement. CHPRC = CH2M Plateau Remediation Contractor PNNL = Pacific Northwest National Laboratory MSA = Mission Support Alliance		

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 Columbia River was the source of supply water for the 100-K Area and 200-West Area facilities. 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) encountered an equipment malfunction in October 2016; therefore, backup well 499-SO-07 (P-15) was the source of drinking water for 2017. Emergency backup well 499-SO-8 (P-14) did not supply water to 400 Area consumers during the reporting period.

7.1.2 Monitoring

Samples at the 100-K, 200-West, and 400 Areas drinking water treatment facilities were collected monthly and analyzed quarterly or annually for radiological contaminants (Table 7-2). 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 C. 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=7520>.

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, "Group A Public Water Supplies," requires that all drinking water analytical results be reported routinely to the Washington State Department of Health. Radiological results for Hanford Site drinking water samples are reported to the state through this annual environmental report. The contractor responsible for operating the water system provides process-monitoring reports directly to the state. 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.

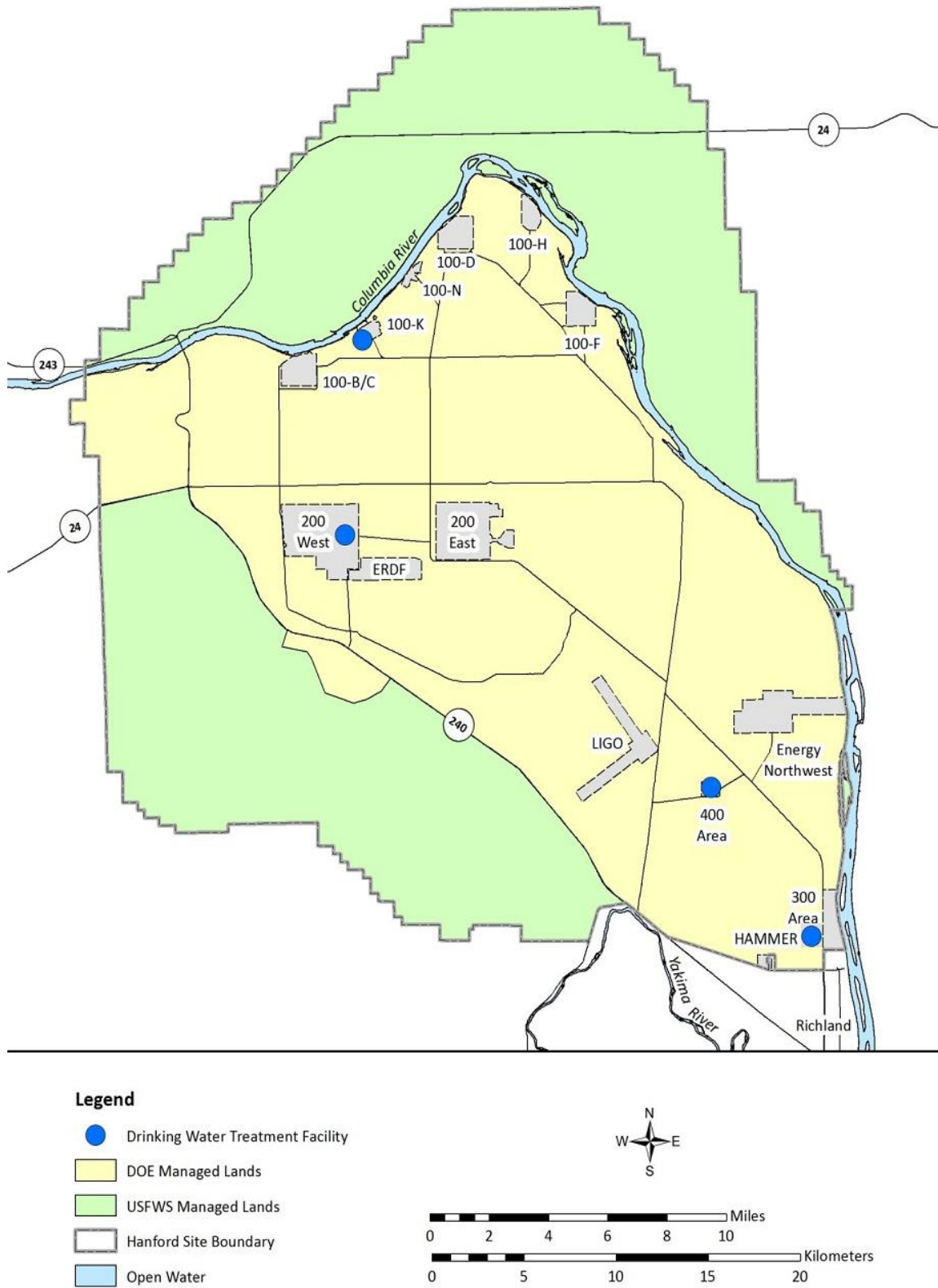


Figure 7-1. Drinking Water Treatment Facilities.

With the exception of the 300 Area water system, all of the DOE-owned Hanford Site drinking water systems were in compliance with drinking water standards for radiological, chemical, physical, and microbiological contaminant levels during 2017. Contaminant concentrations measured during the year were similar to those observed in recent years as described in the annual Hanford Site environmental reports for 2015 (DOE/RL-2016-33) and 2016 (DOE/RL-2017-24).

The 300 Area water system experienced a maximum contaminant level exceedance for total trihalomethanes disinfection by-products monitoring in the third and fourth quarters of 2017. Transition of the 300 Area operations and responsibilities from MSA to PNNL occurred on October 1, 2017. MSA assisted the PNNL Water Purveyor with the exceedance response, operational updates, and public notifications. MSA's Water & Sewer Utilities continued to operate the water system under an inter-contractor work order agreement with PNNL for the remainder of calendar year (CY) 2017.

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 the U.S. Environmental Protection Agency (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 millisievert [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 2017 were below state and federal maximum allowable contaminant levels (Table 7-2). The gross alpha, 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), as was gross beta results for seven of the eight water samples analyzed. The 400 Area source of drinking water was backup well 499-S0-7 (P-15). Gross beta and tritium were found in all 400 Area water samples with tritium annual averages being slightly elevated when compared to historical data where only the 400 Area primary well was sampled but were still below the maximum allowable contaminant level. Gross alpha and strontium-90 were not detected in 400 Area water samples.

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). In 2017, 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 ($6,710 \pm 1,390$ pCi/L), and fell below the 20,000-pCi/L (740-Bq/L) federal and state annual average drinking water standards. CHPRC Soil and Groundwater Remediation Project personnel collected and analyzed raw (untreated) water samples from two of the three 400 Area drinking water wells. The primary well suffered a malfunction in October 2016 and the two backup wells were sampled and analyzed for tritium (Figure 7-2; Table 7-3).

**Table 7-2. Drinking Water Annual Average Concentrations
of Selected Radiological Constituents.**

Constituent	System	Frequency	Sample From	Samples Analyzed at Each Location	Annual Average (pCi/L) ^{a, b}			Standard
Gross alpha	100-K Area	Quarterly	Tap	4 ^c	-0.29	±	1.06	15 ^{d, e}
	200-West Area	Quarterly	Tap	4 ^c	0.16	±	2.54	
	400 Area	Quarterly	Tap	4 ^c	0.83	±	0.91	
	400 Area Well P-14	Quarterly	Well	4	2.31	±	3.16	
Gross beta	100-K Area	Q Comp ^f	Tap	4 ^c	0.83	±	2.41	50 ^e
	200-West Area	Q Comp ^f	Tap	4	2.46	±	6.15	
	400 Area	Q Comp ^f	Tap	4	7.56	±	2.38	
	400 Area Well P-14	Q Comp ^f	Well	4	14.69	±	19.68	
Tritium	100-K Area	A Comp ^g	Tap	1 ^c	-161	±	324	20,000 ^e
	200-West Area	A Comp ^g	Tap	1 ^c	-432	±	295	
	400 Area	Quarterly	Tap	4	6688	±	898	
	400 Area Well P-14	A Comp ^g	Well	1	6710	±	1390	
Strontium-90	100-K Area	A Comp ^g	Tap	1 ^c	-0.44	±	0.36	8 ^{d, e}
	200-West Area	A Comp ^g	Tap	1 ^c	0.12	±	0.39	
	400 Area	A Comp ^g	Tap	1 ^c	-0.96	±	0.63	
	400 Area Well P-14	A Comp ^g	Well	1 ^c	0.01	±	0.75	

^a 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.

^b Multiply pCi/L by 0.037 to convert to Bq/L.

^c Analytical results are below the minimum detectable concentration.

^d WAC 246-290.

^e 40 CFR 141.

^f Samples were collected monthly and composited quarterly for analyses.

^g Samples were collected quarterly and composited annually for analyses.

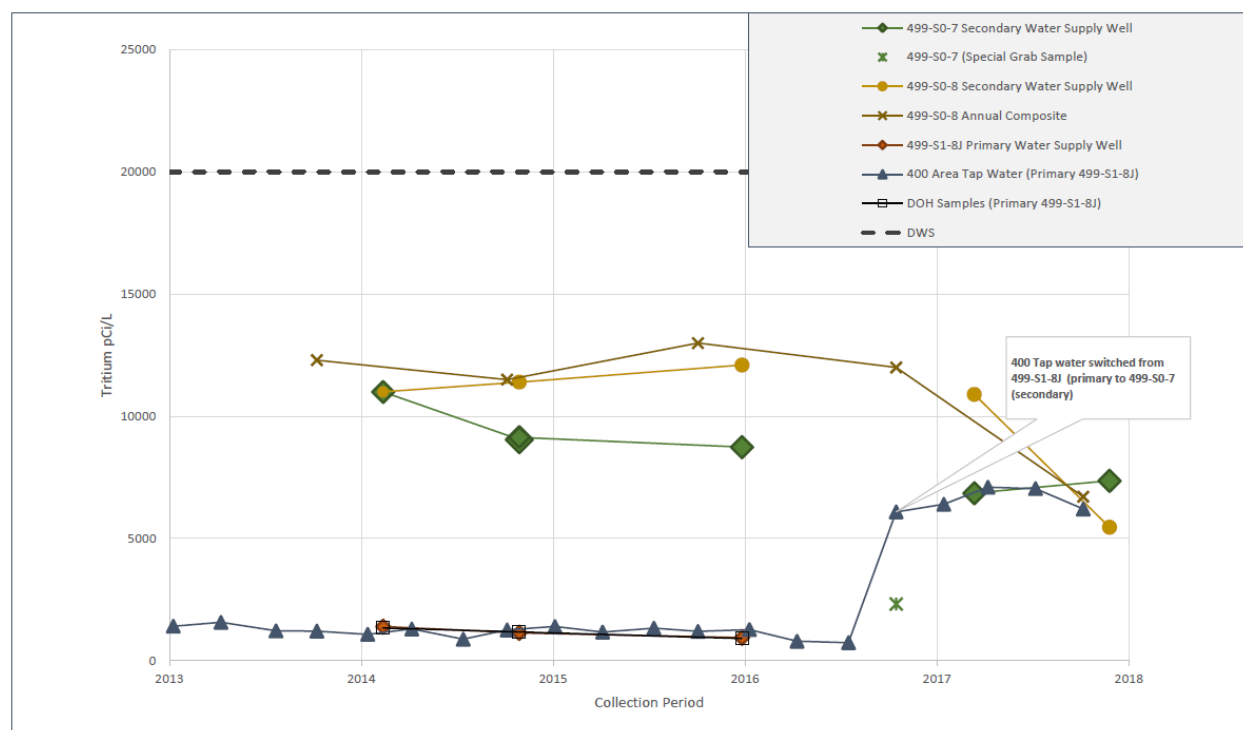


Figure 7-2. 400 Area Tritium Concentrations in Drinking Water (2013-2017)
(multiply pCi/L by 0.037 to convert to Bq/L).

Table 7-3. Tritium Concentrations in Hanford Site 400 Area Drinking Water Wells^a.

Sampling Date	Primary Drinking Water Well 499-S1-8J (P-16; pCi/L)	Backup Drinking Water Well 499-S0-8 (P-14; pCi/L) ^b	Backup Drinking Water Well 499-S0-7 (P-15; pCi/L) ^b
March 16, 2017	No Sample	10,900 ± 2,180	6,860 ± 560
November 29, 2017	No Sample	5,460 ± 1,130	7,360 ± 924

^a Reported concentration ± 2 total propagated analytical error.
^b Multiply pCi/L by 0.037 to convert to Bq/L.

7.2 Columbia River Surface Water

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Samples of Columbia River surface water were collected upstream and downstream of the Hanford Site as well as from locations along the Hanford Reach. Tables 7-4 and 7-5 summarize the sampling locations, types, frequencies, and sample analyses included in surface water monitoring.

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. River water is also used for irrigation purposes downstream of the

Hanford Site, as well as a variety of recreational activities. Water removed from the river immediately downstream of the Hanford Site is used to irrigate a small portion of agricultural crops in Benton and Franklin counties. The majority of irrigation water utilized by Franklin County residents originates at Grand Coulee Dam and is provided through its extensive water delivery systems (i.e., canals). Likewise, Benton County relies heavily on the Yakima River for irrigation purposes. Originating in the Rocky Mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of approximately 260,000 mi² (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, near the City of Richland. 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 2017. The annual average flow of the Columbia River downstream of Priest Rapids Dam was approximately 137,271 ft³ (3,888 m³)/sec, slightly above the most recent 10-year average annual flow rate of 115,831 ft³ (3,280 m³)/sec ([USGS 2013](#)). The highest monthly average flow rate occurred during May (250,533 ft³ [7,095 m³]/sec; Figure 7.4). The lowest monthly average flow rate occurred during October (62,042 ft³ [1,757 m³]/sec) based on mean daily flows. Daily average flow rates varied from 40,195 to 290,469 ft³ (1,138 to 8,226 m³)/sec in 2017. 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 Area 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.

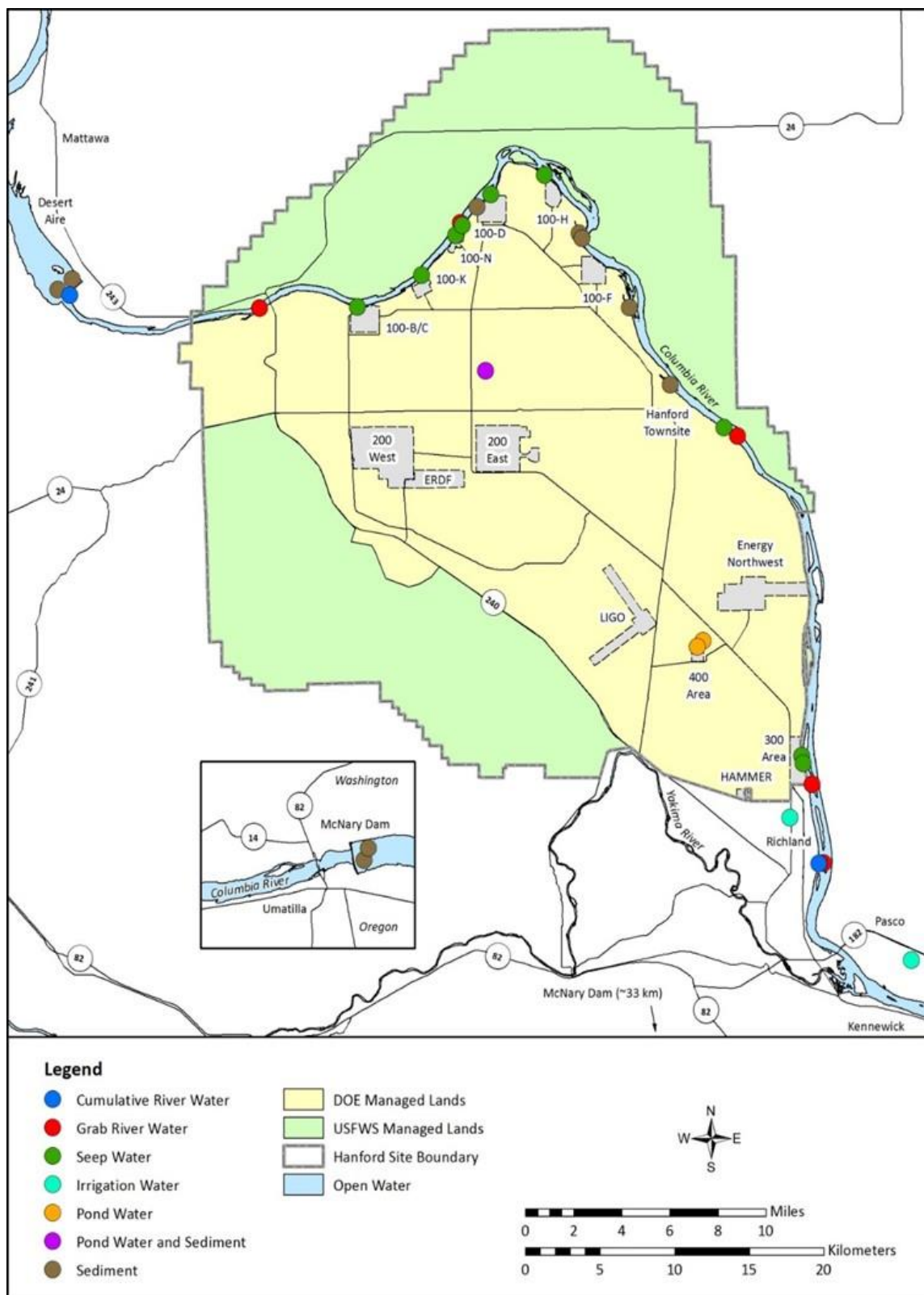


Figure 7-3. Surface water and Sediment Sampling Locations.

Table 7-4. Surface Water Surveillance. (2 Pages)

Location	Sample Type	Frequency	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland Pump House	Cumulative	M Comp ^(a)	Low tritium ^(b) , strontium-90, technetium-99, isotopic uranium ^(c)
	Particulate (filter)	M Cont ^(d)	Gamma energy analyses, isotopic plutonium ^(e)
	Soluble (resin)	M Cont ^(d)	Gamma energy analyses, isotopic plutonium ^(e)
Vernita Bridge	Grab (transects)	Semi-annual	Gamma energy analyses, low tritium ^(b) , strontium-90, isotopic uranium ^(c) , isotopic plutonium ^(e) , technetium-99
Richland	Grab (transects)	Semi-annual	Gamma energy analyses, low tritium ^(b) , strontium-90, isotopic uranium ^(c) , isotopic plutonium ^(e) , technetium-99
100-H, 100-N, 300 Areas and Hanford Townsite (HTS)	Grab (transects)	Annually	Gamma energy analyses, low tritium ^(b) , strontium-90, isotopic uranium ^(c) , uranium-236 (300 Areas only)
Columbia River - Inorganics and Organics			
Vernita Bridge	Grab (transects)	Semi-annual	Anions, mercury, metals (filtered and unfiltered), hexavalent chromium (filtered and unfiltered)
	Grab (transects)	Semi-annual	Volatile organic compounds
Richland	Grab (transects)	Semi-annual	Anions, mercury, metals (filtered and unfiltered), hexavalent chromium (filtered and unfiltered)
	Grab (transects)	Semi-annual	Volatile organic compounds
100-H, 100-N, 300 Areas and Hanford Townsite (HTS)	Grab (transects)	Annually	Anions, metals (filtered and unfiltered), hexavalent chromium (filtered and unfiltered)
Onsite Ponds			
West Lake Seep	Grab	March	Tritium, technetium-99, isotopic uranium ^(c)
West Lake Water	Grab	May	Tritium, technetium-99, isotopic uranium ^(c)
Offsite Irrigation Water			
Riverview Irrigation Canal	Grab	3/year	Alpha, beta, low tritium ^(b) , strontium-90, gamma energy analyses

Table 7-4. Surface Water Surveillance. (2 Pages)

Location	Sample Type	Frequency	Analyses
Horn Rapids Battelle Sports Complex Irrigation Valve	Grab	3/year	Alpha, beta, lowtritium ^(b) , strontium-90, gamma energy analyses
Sagemoor Irrigation Canal	Grab	3/year	Alpha, beta, lowtritium ^(b) , strontium-90, gamma energy analyses
^a M Comp indicates river water was collected at set intervals and composited monthly for analyses. ^b Low tritium = Low-level tritium analysis (10-pCi/L detection limit). ^c Includes uranium-234, uranium-235, and uranium-238. ^d M Cont = River water was sampled for 2 weeks by continuous flow through a filter and resin column. Samples were composited monthly for analyses. ^e Includes plutonium-238 and plutonium-239/240. Comp = Composite Cont = Continuous M = Monthly			

Table 7-5. Columbia River Sediment.

Location ^a	Frequency	Analyses
McNary Dam (Two locations near the dam)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium(b), isotopic plutonium(c), metals, mercury, strontium-90, and total organic carbon
Hanford Reach ^d	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium(b), isotopic plutonium(c), metals, mercury, strontium-90, and total organic carbon
Priest Rapids Dam (Two locations near the dam)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium(b), isotopic plutonium(c), metals, mercury, strontium-90, and total organic carbon
Contiguous Hanford Reach Islands (Adjacent to Locke and Savage)	Annually	Anions, Cr+6, gamma energy analyses, isotopic uranium(b), isotopic plutonium(c), metals, mercury, and strontium-90
^a Refer to Figure 7-3. ^b Uranium-234, uranium-235, and uranium-238. ^c Plutonium-238 and plutonium-239/240. ^d Hanford Reach consists of sediment collected in the following areas: 100D Spring 102-1, 100K Spring 63-1, 100-H Spring 145-1, 100F Slough, Hanford Slough, White Bluffs Slough, and 300 Area Spring DR 42-2.		

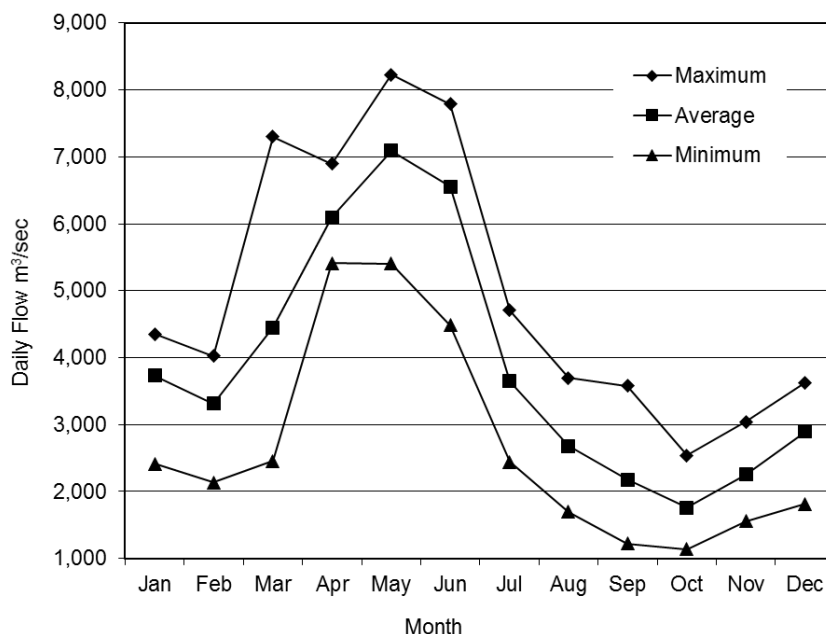


Figure 7-4. Columbia River Flow Rates at Priest Rapids Dam (multiply m³/sec by 35.31 to obtain ft³/sec).

7.2.1 Monitoring

In 2017, 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 transect samples near Vernita Bridge, 100-N Area, 100-H Area, Hanford Townsite, 300 Area, and the City of Richland were also collected and 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, Hanford Site Environmental Monitoring Plan](#).

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 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 guideline standards were used to compare concentrations of contaminants of concern at upstream (Vernita) and downstream (Richland Pumphouse) locations for 2017. At both locations, concentrations were similar and lower than the guideline standards. Drinking water supplied by the City of Richland travels through their water treatment plant 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 Pumphouse*). 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 were 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 2017, the Richland Pumphouse and Vernita Bridge transects were collected twice (spring/late summer). The 100-N Area, 100-H Area, Hanford Townsite, and 300 Area locations were all sampled once in 2017 during late summer when river flows were low. Low river flows provide the highest probability of detecting Hanford Site contaminants carried by groundwater to the Columbia River. Transect stations at the Richland Pumphouse, 300 Area, Hanford Townsite, 100-H Area, and 100-N Areas were comprised of five locations. The Vernita Bridge station is made up of four locations due to safety concerns associated with an inability to anchor at the midstream location because of the smooth riverbed and high flow rates.

Columbia River transect water samples collected during 2017 were analyzed for radiological, inorganic, and organic contaminants (Table 7.4). The contaminants of concern (specifically hexavalent chromium [filtered and unfiltered], metals, and anions that were selected for analyses) were based upon previous

studies of groundwater plume migration, reviews of existing surface water and groundwater upwelling/discharge data, various remedial investigation/feasibility study 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](#)). Hexavalent Chromium, and metals analyses included both unfiltered (recoverable) and filtered (dissolved) samples.

7.2.2 Radiological Results

7.2.2.1 Fixed-location Samples. Individual radiological contaminant concentrations measured in Columbia River water during 2017 were well below the DOE-derived concentration standards. The DOE-derived concentrations are based on a 100 mrem/yr (1 mSv/yr) standard; dividing by 25 allows for more direct comparison to the 4 mrem/yr (0.04 mSv/yr) drinking water standards and Washington State ambient surface water quality criteria (40 CFR 141; WAC 173-201A;). Results of radiological analyses of Columbia River water samples collected at Priest Rapids Dam and the City of Richland raw water intake facility in 2017, and for the previous 5 years, are summarized in Appendix C, Tables C-9 and C-10.

Due to operational issues with the Richland Pumphouse sampling system during the second half of CY 2017, grab samples were obtained from the Columbia River directly adjacent to the pumphouse structure every 2 weeks to maintain sample scheduling and analyses.

Radionuclide concentrations in Columbia River water were low throughout 2017. Tritium, uranium-234, and uranium-238 were consistently detected. Uranium-234 and uranium-238 results were measured at less than 5% of their respective DOE-derived concentration standards. One down-gradient sample from the Richland Pumphouse and another up-gradient sample from Priest Rapids had detectable plutonium-239/240 results. All other radionuclides were below minimum detectable concentrations.

The 2017 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in recent years (Figure 7-5). Tritium concentrations in river water samples at the City of Richland raw water intake facility were slightly higher than in samples from Priest Rapids Dam. The maximum concentration detected at the Richland Pumphouse was 52.0 pCi/L (1.9 Bq/L), while Priest Rapids Dam had a maximum concentration of 26.7 pCi/L (1 Bq/L). Average tritium concentrations in Columbia River water samples collected at the City of Richland raw water intake facility were well below the Washington State ambient surface water quality criterion of 20,000 Ci/L (740 Bq/L).

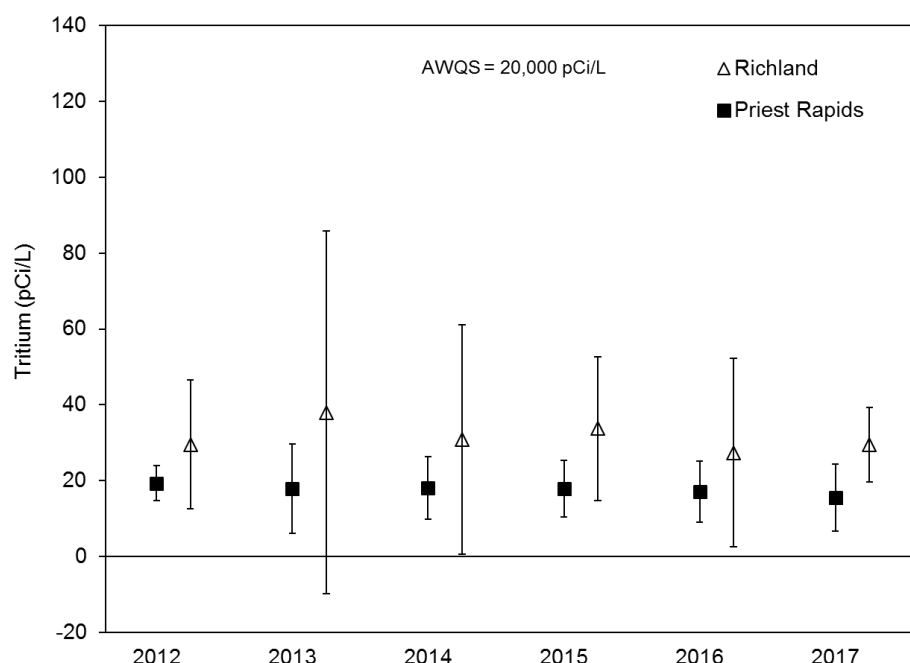


Figure 7-5. Tritium Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (\pm X standard deviations, AWQS=ambient water quality standard; Washington State AWQS for tritium is 20,000 pCi/L [740 Bq/L]).

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 tritium 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 and at shoreline seep locations during 2017 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 2017, 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. Strontium-90 concentrations at Priest Rapids Dam and the City of Richland were below minimum detection limits (0.06 pCi/L). Priest Rapids Dam had a maximum concentration of 0.04 pCi/L (0.0015 Bq/L), and the City of Richland intake had a maximum concentration of 0.038 pCi/L (0.0014 Bq/L). Low concentrations are likely attributable

to a permeable reactive barrier within the groundwater that was put into place by DOE that locks up most of the groundwater strontium entering the Columbia River.

Annual average uranium-234 and uranium-238 concentrations measured in water samples collected upstream and downstream of the Hanford Site in 2017 were similar to those observed during recent years (Figure 7-7). Average monthly uranium concentrations measured at Priest Rapids Dam (0.52 pCi/L total uranium) in 2017 were slightly lower than those averages measured at the City of Richland (0.61 pCi/L total uranium). Uranium is present in the groundwater beneath the 300 Area as a result of past Hanford Site operations, it has also been previously 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 2017 were well below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]).

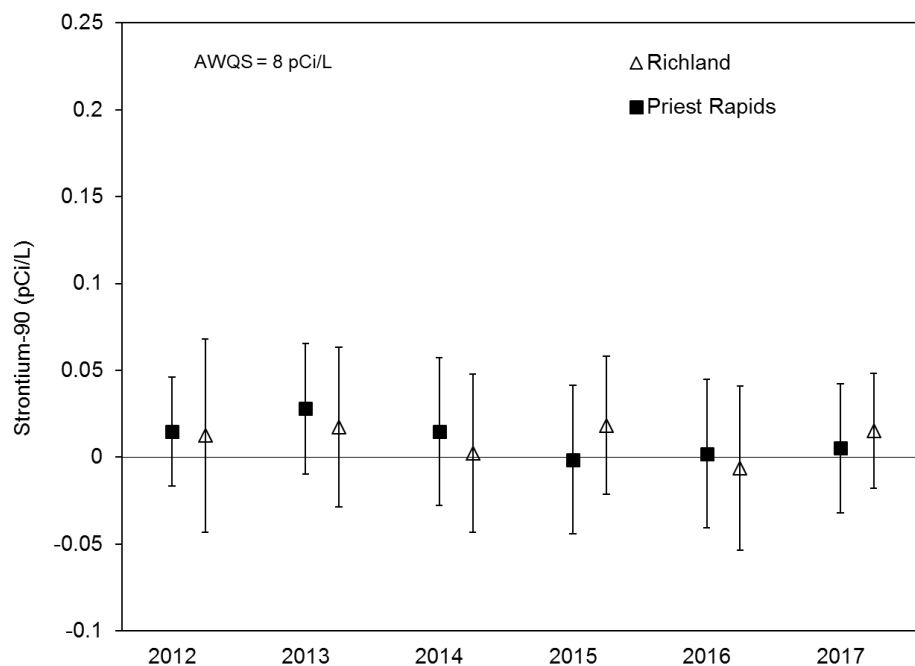


Figure 7-6. Strontium-90 Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (± 2 standard deviations, AWQS = ambient water quality standard).

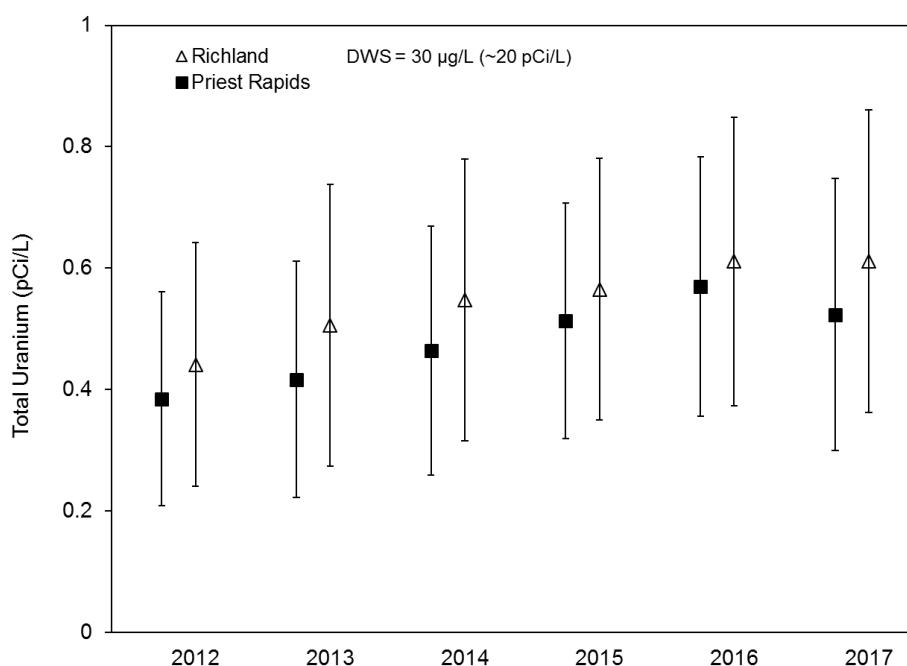


Figure 7-7. Uranium Annual Average Concentrations in Columbia River Water Upstream and Downstream of the Hanford Site (± 2 standard deviations; DWS = drinking water standard).

Plutonium-238 and plutonium-239/240 concentrations in river water samples collected at the City of Richland in 2017 were below analytical detection limits. One sample collected upstream at Priest Rapids Dam did show plutonium-239/240 at an extremely low concentration.

7.2.2.2 Columbia River Transect Samples. Radiological results from samples collected along Columbia River transects near Vernita Bridge, 100-N Area, 100-H Area, Hanford Townsite, 300 Area, and the City of Richland are presented in Appendix C, Table C-11. Station 1 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 detected included tritium, uranium-234, and uranium-238. 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, 100-H Area, Hanford Townsite, 300 Area, and the City of Richland during 2017 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. Incomplete mixing of river water and groundwater is likely a result of differing water temperatures as well. All of these factors affect the tritium concentration in this area.

Concentrations of tritium in a sample collected from the City of Richland fixed station were comparable to levels observed in the Benton County shoreline transect sample (Richland Pumphouse Hanford River Mile [HRM] 46.4 station-1). The highest tritium concentration measured in a cross-river transect water was at the Hanford Townsite at a concentration approximately 1% of the Washington State Drinking Water Quality Standard of 20,000 pCi/L.

Strontium-90 concentrations in Hanford Reach transect samples collected in 2017 were similar to upstream reference concentrations for most locations. The maximum strontium-90 concentration was from a sample collected along the 100-N transect. Average strontium-90 concentrations at the Priest Rapids Dam fixed-location monitoring station were less than those measured at the Richland Pumphouse and in all Richland Pumphouse HRM 46.4 transect samples.

Uranium concentrations in all transect samples collected during 2017 were below the EPA drinking water standard of 30 µg/L (approximately 20 pCi/L [0.74 Bq/L]). The highest uranium-234 concentration was measured in the sample collected near the Benton County shoreline (300 Area–1 HRM 43.1). Uranium-236 concentrations were below analytical detection limits.

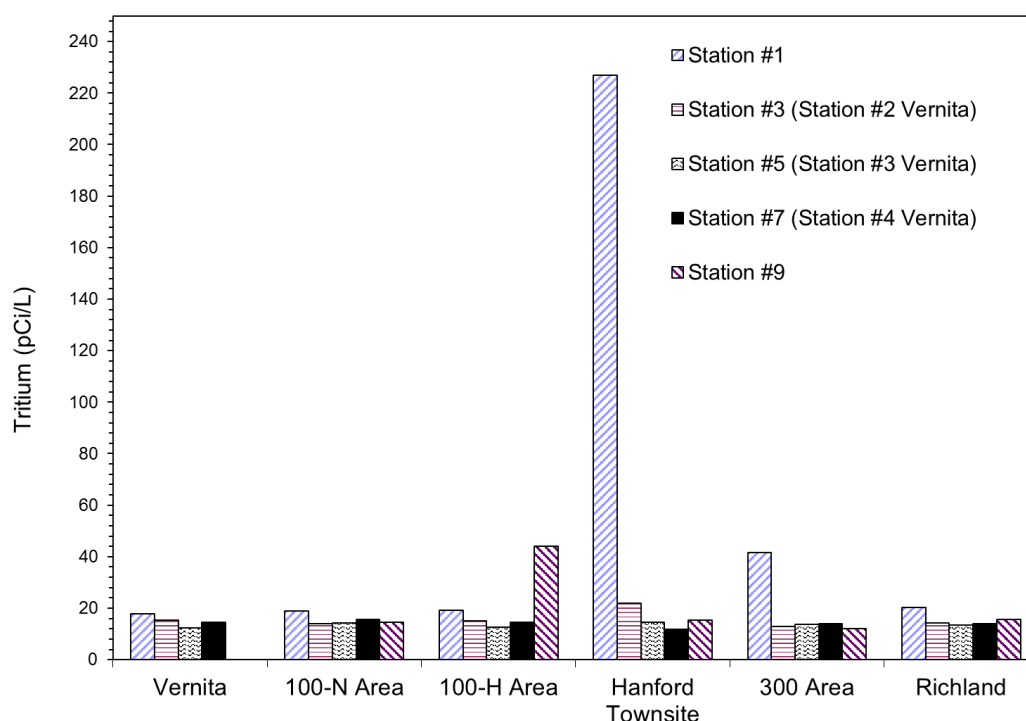


Figure 7-8. Tritium Concentrations in Cross-River Transect Water Samples (Hanford Reach, Columbia River).

7.2.3 Inorganic and Organic Chemical Results

Inorganic and organic water quality data were compiled in 2017 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. Analytical results showed detections of copper, uranium, and zinc. There were also detections of aluminum, arsenic, cadmium, iron, lead, and nickel in a few 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-12).

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 in recent years based on U.S. Geological Survey monitoring of Columbia River water near Vernita Bridge (USGS 2007) and the City of Richland.

The 300 Area HRM 43.1 station-1 (Benton County shoreline) had nitrate concentrations approximately two times the concentration of the next highest transect result found at the Hanford Townsite. All other samples collected throughout the Hanford Reach, Richland, and Vernita Bridge were typically three times less than the 300 Area HRM 43.1 station-1 location. Concentrations of chloride and sulfate were slightly elevated at Richland Pumphouse HRM 46.4 station-9 and 300 Area HRM 43.1 station-1 when compared to other transect locations (Figure 7-9) found throughout the Hanford Reach. In some cases, the highest anion concentrations were found in samples collected along the Grant-Franklin County shoreline. These elevated results are likely attributable to 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 10 mg/L, the EPA maximum contaminant level measured as nitrate nitrogen (40 CFR 141; USGS 1998).

Average annual upstream and downstream concentrations of chloride measured at the City of Richland and Vernita Bridge transects were similar. The highest concentrations of nitrates were measured at the 300 Area HRM 43.1 transect and the Richland Pumphouse, 300 Area, Hanford Townsite, 100-H, 100-N, and Vernita Bridge transects had detectable levels of nitrates. Anion analysis of Columbia River transect samples showed detectable levels of fluoride at very low concentrations in all samples. The overall average concentration of fluoride in transect samples has dropped from 109 µg/L in 2010 to 96 µg/L in 2017.

Concentrations of chromium (Appendix C, Table C-12) 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 filtered river water samples for 2017 had chromium concentrations below the minimum detectable concentration.

Results from organic analyses of water samples are voluminous and not all results are included in this report. A complete listing may be found in the Hanford Environmental Information System (HEIS)

database. The two major organic contaminants monitored in 2017 were trichloroethene and dichloroethene, compounds used during past reactor fuel fabrication in the 300 Area. These contaminants were measured in transect and shoreline seep water collected upstream and downstream of the Hanford Site and in the vicinity of the 300 Area. Analytical results for these samples showed concentrations below their respective EPA Drinking Water Standards (Appendix C, Table C-13).

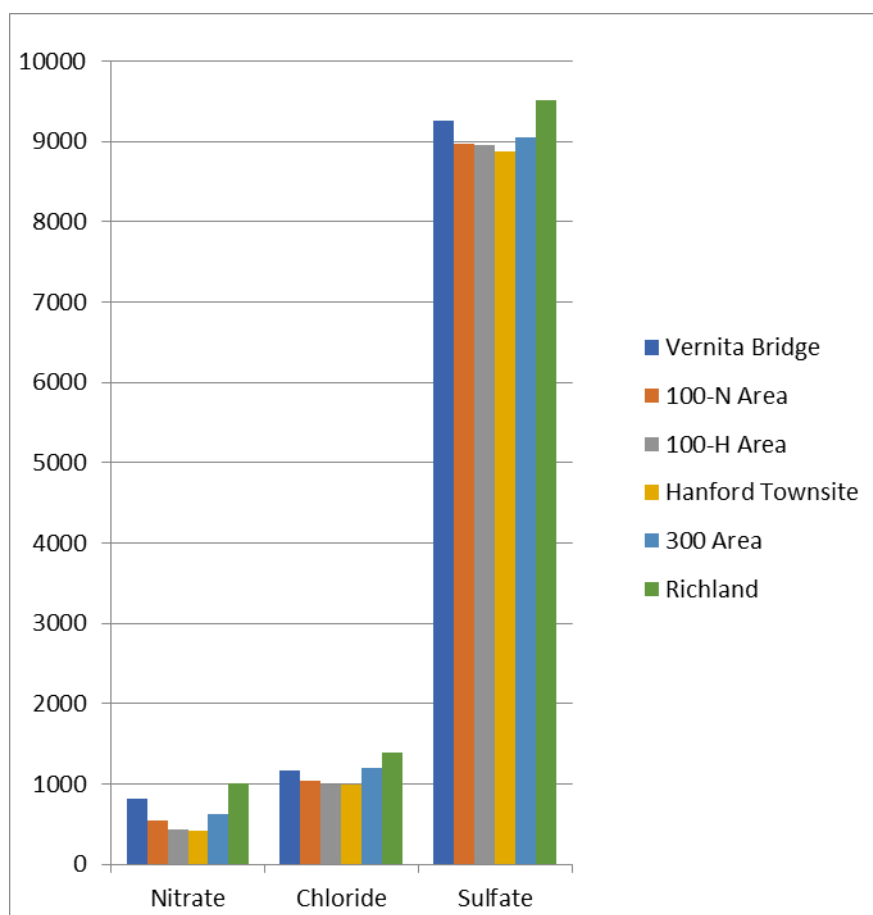


Figure 7-9. Selected Anion Concentrations in Columbia River Transect Samples (micrograms/liter).

7.3 Columbia River Sediment

During peak operating years at the Hanford Site, large volumes 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 13 river locations that were predominantly submerged (some Hanford Reach sampling locations may not be submerged during an extremely low-river stage). Surface sediment was collected using a clamshell-style sediment dredge sampler (Petite Ponar), capturing several years-worth of sediment deposits. Estimated average sediment deposition rates are 0.28 in. (0.723 cm)/yr for Priest Rapids Dam and 0.89 in. (2.25 cm)/yr for McNary Dam (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 Hanford 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, 100-H Spring 145-1, Hanford Slough, 100-K Spring 63-1, 300 Area DR 42-2, White Bluffs Slough, and locations adjacent to Locke and Savage Islands. These sites

are located along the Hanford Reach of the Columbia River in 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.

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. 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 2017 included cesium-137, uranium-234, uranium-235, uranium-238, 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, are present in many agricultural fertilizers, and have been present in past releases of Hanford Site effluent. Analytical results for 2017 showed similar concentrations of cesium-137 at Priest Rapids and McNary Dam 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: both Figures 7-10 and 7-11 have upper and lower bars that represent maximum and minimum values, which may be similar to the average and may not be visible.

Uranium-234 concentrations were slightly elevated in the Adjacent to Locke Island location compared to other sediment samples collected from the Hanford Reach, McNary Dam, and Priest Rapids Dam samples in 2017. Other radionuclide concentrations in river sediment were similar to those reported for previous years, and there were no obvious differences between locations.

Total Uranium averaged 1.9 pCi/g for the Hanford Reach, while Priest Rapids and McNary Dam concentrations averaged 2.8 pCi/g and 2.9 pCi/g, respectively (Figure 7-12). Note: upper and lower bars represent maximum and minimum values, which may be similar to the average and may not be visible.

The values for cesium-137 in the White Bluffs Slough location of the Hanford Reach were slightly elevated (0.29 pCi/g maximum concentration) compared to other Hanford Reach sample locations (0.11 pCi/g average concentration). McNary Dam had a slightly lower cesium-137 concentration compared to Priest Rapids Dam sediment results (0.22 pCi/g and 0.28 pCi/g, respectively). The average, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (2012 to 2017) are presented in Figures 7-10, 7-11, and 7-12.

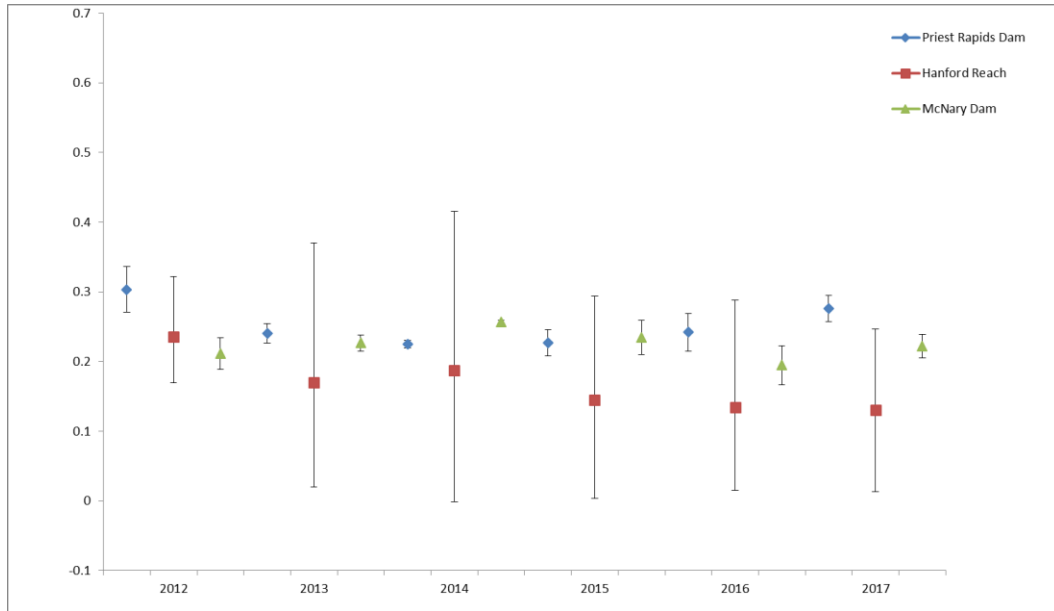


Figure 7-10. Cesium-137 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment.

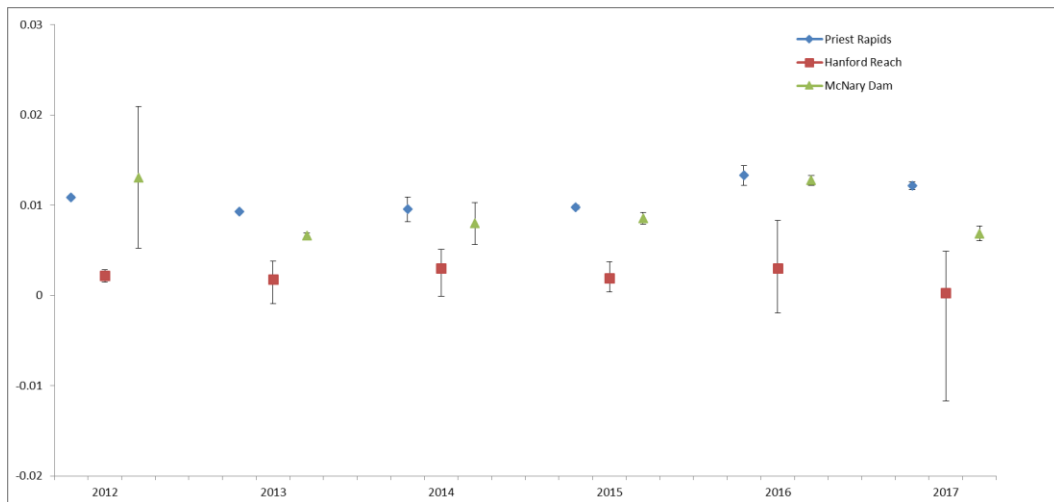


Figure 7-11. Plutonium-239/240 Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment.

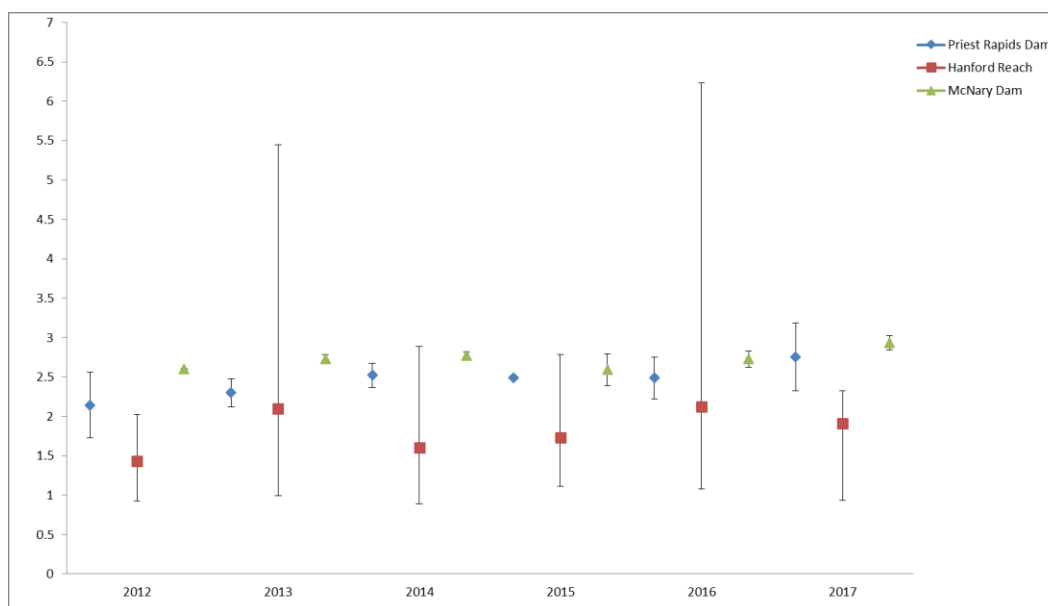


Figure 7-12. Uranium Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment.

7.3.3 Chemical Results

Detectable amounts of most metals were found in all river sediment samples (Figure 7-13). Note: upper and lower bars represent maximum and minimum values, which may be similar to the average and may not be visible. Average concentrations of beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, 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. Maximum concentrations of arsenic, chromium, lead, and thallium were higher for sediment collected in the Hanford Reach than in sediment collected at Priest Rapids and McNary Dam. Lead concentrations were detected at higher rates in the 100-H Spring 145-1 shoreline 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 100-H.

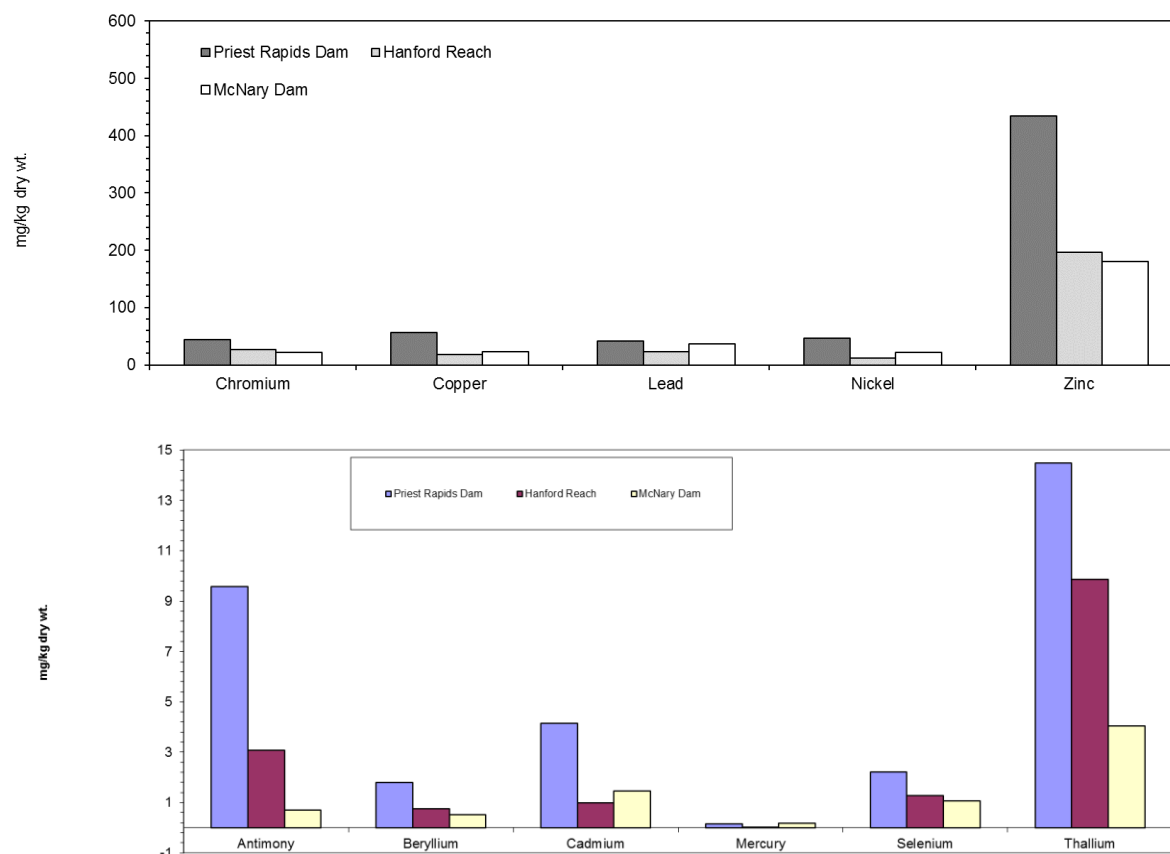


Figure 7-13. Selected Metals Average, Maximum, and Minimum Concentrations Measured in Columbia River Sediment (Washington and Oregon), 2017.

7.4 Columbia River Seep Water

In 2017, samples of Columbia River seep water and three associated shoreline sediment samples were collected along the Hanford Reach (Figure 7-3). These samples were analyzed to determine the potential impact of radiological, inorganic, and organic contaminants from the Hanford Site on the public, aquatic, and riparian environment. Various radiological analyses were performed on selected seeps following reviews of existing surface water and groundwater data, multiple remedial investigation/feasibility study 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 in tables in Appendix C.

Table 7-6. Columbia River Seep Monitoring.

Location ^a	Sample Type	Sampling Frequency	Analyses
100-B Area	Grab	Annually	Alkalinity, anions, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), strontium-90, tritium, VOA
100-D Area	Grab	Annually	Alkalinity, alpha, anions, beta, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), strontium-90, technetium-99, tritium, isotopic uranium ^b
100-F Area	Grab	Annually	Alkalinity, anions, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), strontium-90, tritium, VOA
100-K Area	Grab	Annually	Alkalinity, alpha, anions, beta, carbon-14, hexavalent chromium (filtered/unfiltered), metals (filtered/unfiltered), strontium-90, technetium-99, tritium, VOA
100-N Area	Grab	Annually	Alpha, anions, beta, hexavalent chromium (filtered/unfiltered), metals (filtered and unfiltered), strontium-90, TPH, tritium
300 Area	Grab	Annually	Alkalinity, alpha, anions, beta, hexavalent chromium (filtered/unfiltered), tritium, isotopic uranium ^b , uranium-236, VOA
Hanford Townsite	Grab	Annually	Alkalinity, alpha, anions, beta, hexavalent chromium (filtered/unfiltered), iodine-129, metals (filtered/unfiltered), strontium-90, technetium-99, tritium, VOA

^a Refer to Figure 7-3; Locations may contain multiple shoreline seeps with differing analyses.

^b Uranium-234, uranium-235, and uranium-238

TPH = total petroleum hydrocarbon

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. It is also a regional groundwater discharge zone that includes discharge from confined basalt aquifers. 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.

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 along the Hanford Reach. Water table elevations are declining as a result of decreased artificial groundwater mounding from the discharge of millions of gallons of effluent from the 1950s through the early 1980s. As the groundwater mound declines, the water levels will reach pre-Hanford water level equilibrium, which result in the gradual disappearance of groundwater seeps.

Columbia River seeps also vary with river stage (riverwater surface elevation). The water table near the Hanford Reach is influenced strongly 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 accurately estimate 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. It is suspected that some seep samples collected may be a blend of groundwater and Columbia River 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, 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 2017. This section describes the monitoring efforts and summarizes results for these aquatic and riparian 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.

In 2017, 13 of 14 seeps were successfully sampled. The lone seep that was not successfully collected has been removed from future sampling due to a lack of available seep/spring water. All samples collected were analyzed for tritium. Some samples from selected seeps were analyzed for alpha, anions, beta, carbon-14, hexavalent chromium, metals, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, and volatile organic compounds. Unfiltered samples were analyzed, except for hexavalent chromium and 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 2017 in water from riverbank seeps entering the Columbia River along the Hanford Site. A listing of the 2017 sampling results is provided in Appendix C, Table C-14.

Tritium concentrations varied widely with location. The highest tritium concentration measured in riverbank seeps was at the Hanford Townsite 28-2 riverbank seep ($15,900 \text{ pCi/L} \pm 3,100 \text{ pCi/L}$ [$588 \pm 115 \text{ Bq/L}$]), which was slightly below the Washington State ambient surface water quality criterion of $20,000 \text{ pCi/L}$ (740 Bq/L). No tritium results exceeded the Biota Concentration Guide (DOE/EH-0676) level to the Riparian Animal receptor ($265,000,000 \text{ pCi/L}$). Tritium concentrations in riverbank seep water samples were higher compared to maximum concentrations in 2017 Columbia River fixed-station location samples at Priest Rapids Dam and the City of Richland, as well as Columbia River transect samples. Overall, results in 2017 were comparable to the previous 5 years of concentrations reported in riverbank seeps.

A water sample from a riverbank seep in the Hanford Townsite area was collected in 2017 and submitted to a laboratory for iodine-129 analysis using an ultra-trace analytical method. Laboratory results showed the concentration to be below analytical detection limits.

All water samples from riverbank seeps were analyzed for strontium-90 and the highest concentration was in the 100-N Area, at approximately 2% of the DOE-derived concentration standard. Historically, groundwater in the 100-N Area has had the highest strontium-90 levels measured at Hanford. This 2017 result was less than half of the 2016 concentration.

Uranium isotopes' concentrations measured in the 300 Area riverbank seep water samples were higher than those at the 300 Area HRM 43.1 transect location as well as at all other transect locations. 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.

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 seep water collected at the 300 DR 42-2 riverbank seep site. This location is down gradient from the retired 300 Area process trenches. The uranium concentrations in this seep water sample were slightly higher ($27 \text{ pCi/L} \pm 6.5 \text{ pCi/L}$ uranium-234) than the EPA drinking water standard limit of $30 \text{ } \mu\text{g/L}$ (approximately

20 pCi/L [0.74 Bq/L]). The 2017 concentrations of uranium-234, uranium-235, and uranium-238 were lower than those measured during 2012 through 2016.

During 2017 riverbank seep collections, three detections of gross alpha were recorded. The 300 Area DR 42-2 riverbank seep had two of the three detections (34 pCi/L \pm 6.2 pCi/L and 32 pCi/L \pm 5.1), both of which exceeded Washington State Ambient Water Quality criteria (15 pCi/L; DOE O 458.1). The other detection was at Hanford Spring 28-2 (4.2 pCi/L \pm 2.6 pCi/L), which was below the Washington State criteria.

Gross beta detections occurred in 100-D, 100-K, 100-N, Hanford Townsite 25-4, Hanford Spring 28-2, and 300 Area seeps during 2017. 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 (1.7 pCi/L \pm 1.6 pCi/L) and Riverview (2.1 pCi/L \pm 1.1 pCi/L) collection locations. The highest gross beta concentration was measured in the Hanford Townsite 28-2 riverbank seep (36 pCi/L \pm 4.0 pCi/L [1.3 \pm 0.15 Bq/L]), which was 72% of the Washington State ambient surface water quality criterion of 50 pCi/L (1.85 Bq/L; WAC 173-201A and 40 CFR 141).

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.

For most locations, the 2017 sample results were similar to those previously reported (PNNL-19455). Nitrate concentrations were highest in seep water samples from the 300 Area. Dissolved chromium concentrations were highest in the 100-B Area. Hexavalent chromium concentrations were highest in the 100-B Spring 39-2 Area. Appendix C, Table C-15 presents concentration ranges of selected metals and anions measured in riverbank seep water during 2012 through 2017.

Concentrations of most metals measured in water collected from seeps along the Hanford Site shoreline during 2012 through 2017 were below the Washington State ambient surface water chronic toxicity levels (WAC 173-201A). All 2017 riverbank seep nitrate concentrations exceeded the Washington State drinking water standard of 10 μ g/L (WAC 246-290). However, it is extremely unlikely that members of the public would ever consume riverbank seep water.

Results from organic analyses of water samples are voluminous and not all results are included in this report. A complete listing may be found in the Hanford Environmental Information System (HEIS) database. The two major organic contaminants monitored in 2017 were trichloroethene and dichloroethene, compounds used during past reactor fuel fabrication in the 300 Area. These contaminants were measured in transect and shoreline seep water collected upstream and downstream of the Hanford Site and in the vicinity of the 300 Area. Analytical results for these samples showed concentrations below their respective EPA Drinking Water Standards (see Appendix C, Table C-16).

7.4.3 Sediment Monitoring

Beginning in the 1990s, periodic studies were conducted to collect and analyze sediments at riverbank seeps in the 100 and 300 Areas (DOE/RL-92-12; WHC-EP-0609; WHC-SD-EN-TI-125; WHC-SD-EN-TI-198).

Routine sediment sampling began in 1993 at the Hanford Townsite and the 300 Area. Sampling in the 100-B, 100-K, and 100-F Areas began during 1995 and the 100-H Area was added in 2004.

Over the years, as a result of fluctuating groundwater shoreline discharge patterns, sediment collection locations have been moved, added, and/or abandoned. In 2017, sediment samples were collected from riverbank seep locations in the 100-D, 100-H, 100-K, and 300 Areas. (Table 7-7).

Table 7-7. Sediment Samples from Riverbank Seep Locations.

Location ^a	Sampling Frequency	Analyses
100-D Area	Annually	Anions, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
100-H Area	Annually	Anions, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
100-K Area	Annually	Anions, carbon-14, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, and total organic carbon
300 Area	Annually	Anions, Cr+6, gamma energy analysis, isotopic uranium ^b , isotopic plutonium ^c , metals, mercury, strontium-90, total organic carbon, and uranium-236
^a Refer to Figure 7-8		
^b Uranium-234, uranium-235, and uranium-238		
^c Plutonium-289, and plutonium-239/240		

7.4.3.1 Radiological Results. Radiological results for the 2017 shoreline seep sediment samples were similar to those measured in Columbia River sediment samples collected at Priest Rapids and McNary Dams. Cesium-137, plutonium-238, plutonium-239/240, and uranium isotopes were consistently detected at low levels at all sediment sample locations. Table C-17 in Appendix C shows radionuclide concentrations in Columbia River and shoreline seep location sediment samples from 2012 through 2017.

7.4.3.2 Metals Results. Concentrations of metals in shoreline seep sediment samples collected in 2017 were similar to concentrations in Columbia River sediment samples with the exception of antimony, arsenic, chromium, selenium, and thallium. Shoreline sediment collected from 100-D Spring 102-1 had higher levels of antimony and thallium than those measured in Columbia River sediment samples. The 100-K 63-1 site had the highest chromium concentrations of all sediment collected while the highest levels of arsenic were found at 100-H Spring 145-1. The 300-Area DR 42-2 seep had the highest levels of selenium in comparison to all other sediment collection locations (see Appendix C, Table C-18). Currently, there are no Washington State freshwater sediment quality criteria to compare against the measured values.

7.4.3.3 Hexavalent Chromium Results. The 100-D Spring 102-1 and 100-B Spring 39-2 Areas had the highest levels of hexavalent chromium. The 100-D Area has two separate hexavalent chromium plumes that have been recorded, and surrounding soil and water sampling have shown elevated concentrations (see Appendix C Table C-19).

7.4.3.4 Total Organic Carbon Results. All Columbia River sediment samples collected in 2017 had detections of Total Organic Carbon. Results were similar to those observed in previous years from the same locations. The highest result was found in a 2017 Priest Rapids Dam sample which mirrored historical observations (Appendix C, Table C-20).

7.5 Pond Water and Sediment

West Lake water (Figure 7.3) sampling was conducted biannually (during early spring/late spring) during 2017. West Lake is accessible to migratory waterfowl, deer, and other wildlife, creating a potential biological pathway for the dispersion of contaminants.

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 Water

Water monitoring continued at West Lake in 2017 with sampling conducted twice (early and late spring). Surface water samples collected from West Lake were analyzed for tritium, uranium-234, uranium-235, and uranium-238. Tritium concentrations were below the laboratory detection limits and were well below applicable DOE-Biota Concentration Guide levels (DOE/EH-0676) for Aquatic Animal receptors. Radionuclide concentrations from surface water samples collected during 2017 and in the previous 2 years are shown in Appendix C, Table C-2.

Isotopes of uranium were detected in all samples at varied concentrations, all within the historic range of sample results for this location.

7.5.2 West Lake Sediment

Biannual sediment samples were collected from West Lake during 2017. The sediment sample was collected from upper-layer material near the pond shoreline.

The West Lake sediment samples were 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 2017 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 2017 and a summary of those collected during the previous 5 years are shown in Appendix C, Table C-1.

7.6 Offsite Irrigation Water

Water removed from the Columbia River immediately downstream of the Hanford Site is used to irrigate agricultural areas in Benton and Franklin counties. The majority of irrigation water utilized in Franklin County originates at Grand Coulee Dam and is provided through its extensive water delivery systems (i.e., canals). Similarly, Benton County relies heavily on the Yakima River for irrigation.

Sampling of irrigation water is conducted to monitor for the presence radionuclides. The consumption of food products (Section 10.1, Agricultural Monitoring) irrigated with Columbia River water downstream of the site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical maximally exposed individual and any other member of the public (Section 4.2.1).

7.6.1 Offsite Irrigation Water Monitoring.

Irrigation water samples were collected in 2017 from a canal located on the east side (left bank) of the Columbia River downstream of the Hanford Site at Riverview (Road 68, Pasco), and from another irrigation line located on the west side (right bank) of the Columbia River just downstream of the 300 Area (Horn Rapids, Richland). Samples from the Horn Rapids irrigation pumping station (Figure 7-3) were collected at the Battelle sporting complex. Each location was sampled three times during the irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, strontium-90, and tritium.

7.6.2 Sample Results.

Radionuclide concentrations measured in irrigation water samples collected during 2017 were comparable to levels detected in Columbia River transect water samples collected upstream of the Hanford Site. Tritium was the only radionuclide detected in any of the samples collected during 2017. At the Horn Rapids location the tritium concentrations were slightly higher than the Riverview irrigation system samples. Radionuclide concentrations from irrigation water samples collected during 2017 and in the previous 5 years are shown in Appendix C Table C-21.

7.7 Liquid Effluent

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During peak operating and production years at the Hanford Site from the 1940s through the 1990s, billions of gallons of effluent waste containing millions of metric tons of pollutants from reactor operations and chemical fuel processing were discharged to the Columbia River and soil column. Most of the discharges occurred in the 100 Reactor Areas along the river, 200-East Area, 200-West Area, and the 300 Area. As the mission of the Hanford Site shifted from production of nuclear materials to environmental cleanup, all discharges to the Columbia River were ceased. The last permitted discharges to the Columbia River stopped operating in March 2011. In CY 2017, two permitted point sources discharged effluents to the ground and several permitted nonpoint sources also operated.

7.7.1 Point Source Discharges

The U.S. Environmental Protection Agency (EPA) describes a point source of pollution as a single identifiable source from which all pollutants are discharged (e.g., a pipe, factory, or facility). Two liquid effluent point sources discharging liquids to the ground operated in CY 2017 on the Hanford Site: the Effluent Treatment Facility and Treated Effluent Disposal Facility.

7.7.1.1 200 Area Effluent Treatment Facility. Hanford's Effluent Treatment Facility (ETF) located in the 200 East Area treats liquid waste and has been in operation since 1995. The ETF influent consists of individual waste streams from multiple Hanford facilities. Source streams received for treatment include process condensate from the 242-A Evaporator, and leachate from land waste disposal sites. Most liquid waste streams to be treated at ETF are initially stored at the Liquid Effluent Retention Basin (LERF), located near the ETF. The ETF waste treatment system removes toxic metals, radionuclides, and ammonia in addition to destroying organic compounds. The ETF waste treatment system does not remove tritium, a radioactive isotope of hydrogen, which cannot be easily removed. After the liquid is treated, it is stored in tanks, sampled and analyzed, and then discharged to the ground at the State-Approved Land Disposal Site (SALDS). The SALDS is located north of the 200-West Area (Figure 7-16). The ETF is the only Hanford facility permitted to discharge radioactive effluents to the ground. Table 7-7 contains the volume of liquid discharged and curies of tritium released during CY 2017. See Section 5.3.4 for more information on ETF.

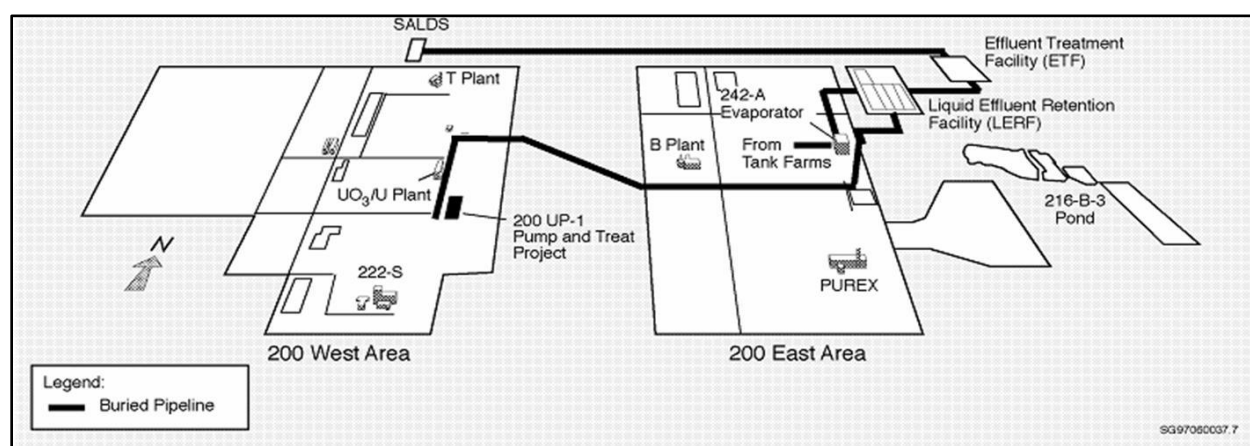


Figure 7-16 Location of Effluent Treatment Facility and State-Approved Land Disposal Site.

**Table 7-8. Calendar Year 2017 Tritium Discharges to SALDS^a.
(2 Pages)**

Month	Effluent Discharge (gal)	Tritium Released (Ci)	Comment
January	576,201	0.21	Actual discharge
February	290,437	0.10	Actual discharge
March	1,183,552	0.41	Actual discharge
April	568,556	0.18	Actual discharge
May	0	0.0	Actual discharge
June	0	0.0	Actual discharge
July	0	0.0	Actual discharge
August	583,991	0.20	Actual discharge
September	503,786	0.16	Actual discharge
October	1,000,000	2.87	Forecast
November	0	0.0	Forecast
December	500,000	0.73	Forecast

Table 7-8. Calendar Year 2017 Tritium Discharges to SALDS^a.
(2 Pages)

Month	Effluent Discharge (gal)	Tritium Released (Ci)	Comment
TOTAL	5,206,523	4.86	
^a Information from RPP-CALC-61950			
Ci = curies			
SALDS = State-Approved Land Disposal Site			

7.7.1.2 200 Area Treated Effluent Disposal Facility. The Treated Effluent Disposal Facility (TEDF) provides a collection, conveyance, and disposal system for treated effluent from buildings in the 200 Areas (Figure 7-17). It is located in the 200-East Area and consists of an 11-mi (17.7-km)-long pipeline and two adjacent 5-ac (2-ha) infiltration ponds. The TEDF is a piped collection system that does not have any treatment or retention capacity. Wastewater generating processes include: cooling water, steam condensate, dryer condensate, air conditioning condensate, reverse osmosis unit brine, potable water, raw water, rainwater, miscellaneous effluents, water softener regenerant, filter backwash, boiler blowdown, and cooling tower blowdown. The water from individual waste streams must be treated prior to transfer to TEDF. State Waste Discharge Permit Number ST0004502 (Ecology 2012a) provides the terms and conditions that regulate the discharge of this wastewater to the ground and ensures the discharges meet state standards in WAC 173-200 "Water Quality Standards." See Section 5.3.4 for more information on TEDF.

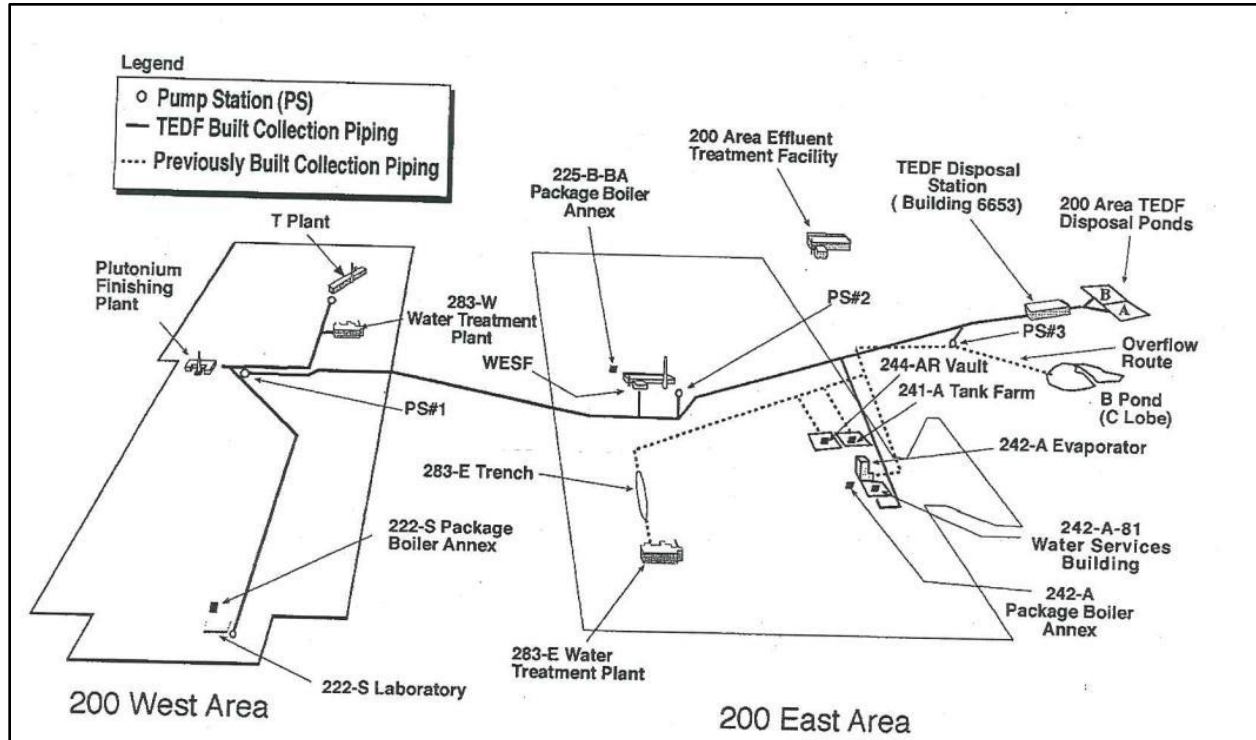


Figure 7-17 Location of the Treated Effluent Disposal Facility.

7.7.1.3 300 Area Discharges to the City of Richland Sewer. The City of Richland regulates industrial wastewater discharges to its sewer collection system. DOE holds Permit No. CR-IU010, which allows discharges from contractor-operated facilities in the 300 Area.

7.7.2 Nonpoint Source Discharges

Nonpoint source discharges are effluents that are also described as diffuse, which occur over an area and are not easily attributed to a single point source. An example of a nonpoint source discharge is rain water or snowmelt runoff. Several nonpoint discharges were permitted in CY 2017 on the Hanford Site.

7.7.2.1 Miscellaneous Wastewater Discharges. The routine operations conducted at various locations on the Hanford Site periodically generate discharges of liquid waste streams. These types of miscellaneous wastewater discharges include hydrotesting water, construction, and maintenance wastewater; the discharge of cooling water and condensate; and the collection and the discharge of industrial stormwater. The terms and conditions regulating these wastewater discharges are included in a categorical State Waste Discharge Permit number ST0004511 (Ecology 2013).

7.7.2.2 Waste Treatment Plant. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) operates two state permitted sand and gravel locations. The concrete batch plant facility supports the construction of the WTP with the primary function of making concrete. The Pit 30 quarry also supports the construction of the WTP with the primary function of making gravel. The types of discharges include process water, storm water, and activities associated with sand and gravel operations and rock quarries. Permit conditions require the permit holder to provide environmental protection through best management practices (BMP) and wastewater treatment.

7.7.2.3 200-West Area Evaporative Sewage Lagoon. The 200-West Area Evaporative Sewage Lagoon is a domestic wastewater treatment facility located northeast of the 200-West Area of the Hanford Site (Figure 7-18). The facility consists of double-lined evaporative lagoons and is designed and operated to have zero liquid discharge to the ground. The system provides domestic wastewater treatment for domestic wastewater transported from other locations within the Hanford Site. The DOE constructed the 200-West Area Evaporative Sewage Lagoon to replace the previously existing 100-N Sewage Lagoon, which was near the end of its service life. The majority of future Hanford Site cleanup activities are anticipated to be located in the vicinity of the 200 Areas and the siting of this treatment facility near 200-West better serves the cleanup mission over time. Although this facility is not permitted to discharge, except in the case of emergencies, State Waste Discharge Permit Number ST0045514 (Ecology 2012b) governs the operation and maintenance of this facility.

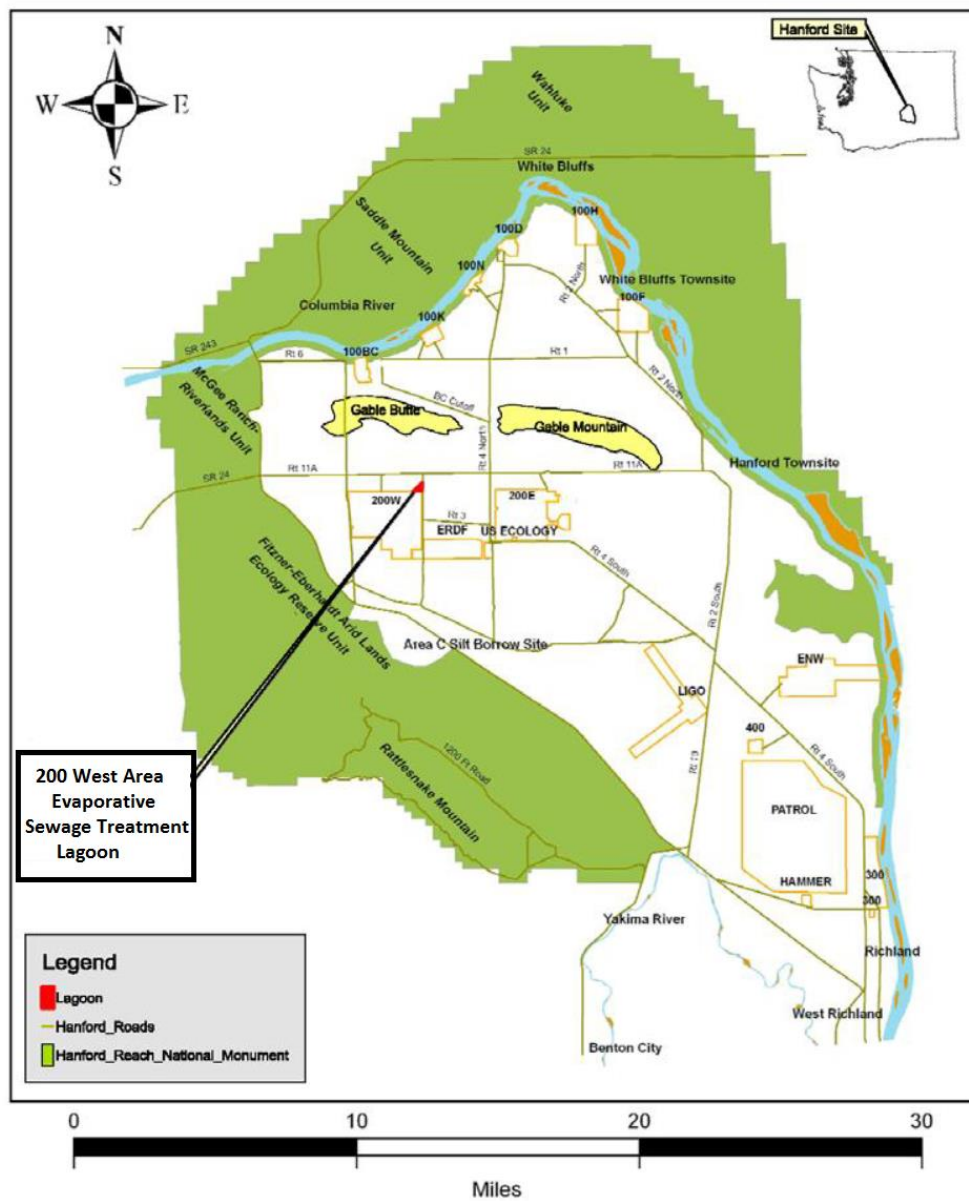


Figure 7-18. Location of the Evaporative Sewage Treatment Lagoon

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2017 Highlight

Contaminant Plume Areas

The estimated area of Hanford Site groundwater contaminant plumes above regulatory standards in 2017 was 65 mi² (169 km²), slightly more than in 2016. The combined plume area has declined since 2000 as a result of remediation and natural attenuation.

Groundwater Remediation

- Pump and treat systems in the 100 Areas removed 93 kg of Hexavalent chromium in 2017, and 3,364 kg in their lifetimes.
- Pump and treat systems in the 200-West Area removed 1,906 kg of carbon tetrachloride in 2017, and 26,802 kg since 1994. Other groundwater contaminants removed by pump-and-treat systems in the 200 Areas include nitrate, technetium-99, and uranium.
- DOE continued to make progress on other groundwater remedial actions in 2017, including a permeable reactive barrier in 100-N Area, enhanced attenuation in the 300 Area, hydraulic control in the 200 Area, and monitored natural attenuation of selected plumes in the 100, 200, and 300 Areas.

Well installation: In 2017 DOE drilled 107 wells and boreholes for monitoring, groundwater remediation, and characterization.

8.0 Groundwater Monitoring

MJ Hartman

This section summarizes results of Hanford Site groundwater monitoring for 2017. The *Hanford Site Groundwater Monitoring Report for 2017* (DOE/RL-2017-66) contains detailed information and is accessible through the Internet at <http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports>. DOE provides groundwater data to the public via the Internet at <https://ehs.hanford.gov/eda>.

Chemical and radioactive wastes contaminated the soil and groundwater beneath portions of the Hanford Site. The majority of the contamination is found in the 200-East Area, 200-West Area, 300 Area, and 100 Area (Figure 8-1).

DOE operates an extensive groundwater monitoring program on the Hanford Site. Groundwater is monitored for [Resource Conservation and Recovery Act of 1976](#) (RCRA) units; for [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (CERCLA) groundwater operable units; for other Washington State-required programs; and for the [Atomic Energy Act of 1954](#) (AEA), as required by DOE Orders. Tritium, iodine-129, and nitrate comprise the largest contaminant plumes in Hanford Site groundwater. Figure 8-1 shows the extent of these plumes in 2017, and Figure 8-2 shows how the sizes of these three plumes have changed over the years.

8.1 River Corridor

The 100 and 300 Areas comprise the River Corridor of the Hanford Site. About 94% of the waste sites in this region have been remediated or were determined not to require remediation, reducing the possibility of continued contaminant migration to groundwater. Remedial action decisions for the remaining 6% of the waste sites are in progress. Groundwater in this region migrates slowly through the aquifer and into the Columbia River. Figure 8-3 illustrates River Corridor contaminant plumes in 2017, and Table 8-1 compares the maximum concentration measured in 2017 and 2016 for the contaminants in each of the River Corridor groundwater interest areas.

River Corridor groundwater is being remediated under various CERCLA decision documents (Table 8-2). The size of the hexavalent chromium and nitrate plumes have decreased markedly since 2002 due to groundwater remediation and natural attenuation (Figure 8-4). Other contaminants are attenuating naturally or as a result of influences from pump-and-treat systems. Decreases in the sizes of the tritium and trichloroethene (TCE) plumes are evident in Figure 8-4, whereas the uranium and strontium-90 plumes are attenuating more slowly.

Maximum concentrations of hexavalent chromium, nitrate, and TCE in the River Corridor have decreased over time (Figure 8-5). The detected maximum concentrations of some other contaminants increased in recent years because new wells were intentionally installed in areas near suspected contaminant sources. Data from these characterization wells are used to develop and select alternatives for remediation.

DOE has established derived concentration standards for use in conducting radiological environmental protection programs. The standards represent the concentration of a given radionuclide in water or air that would result in a person receiving a 100 mrem total effective dose following continuous exposure for 1 year. Figure 8-6 illustrates the total effective dose that would occur if a person consumed River Corridor groundwater for 1 year. The dose in wells with values greater than 100 mrem/yr is primarily from strontium-90 in the 100-K and 100-N Areas.

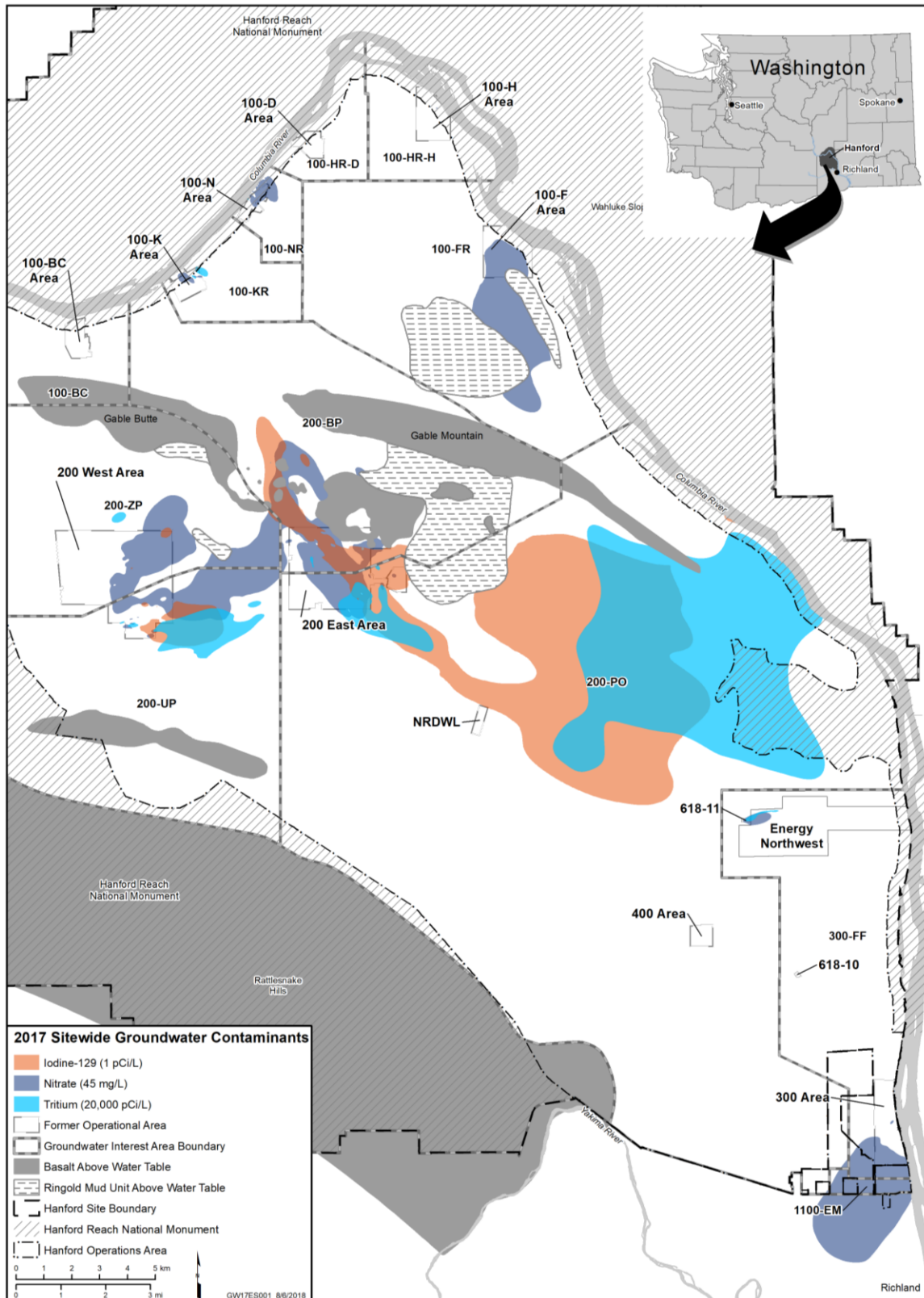


Figure 8-1. Major Groundwater Contaminant Plumes and Regions of the Hanford Site.

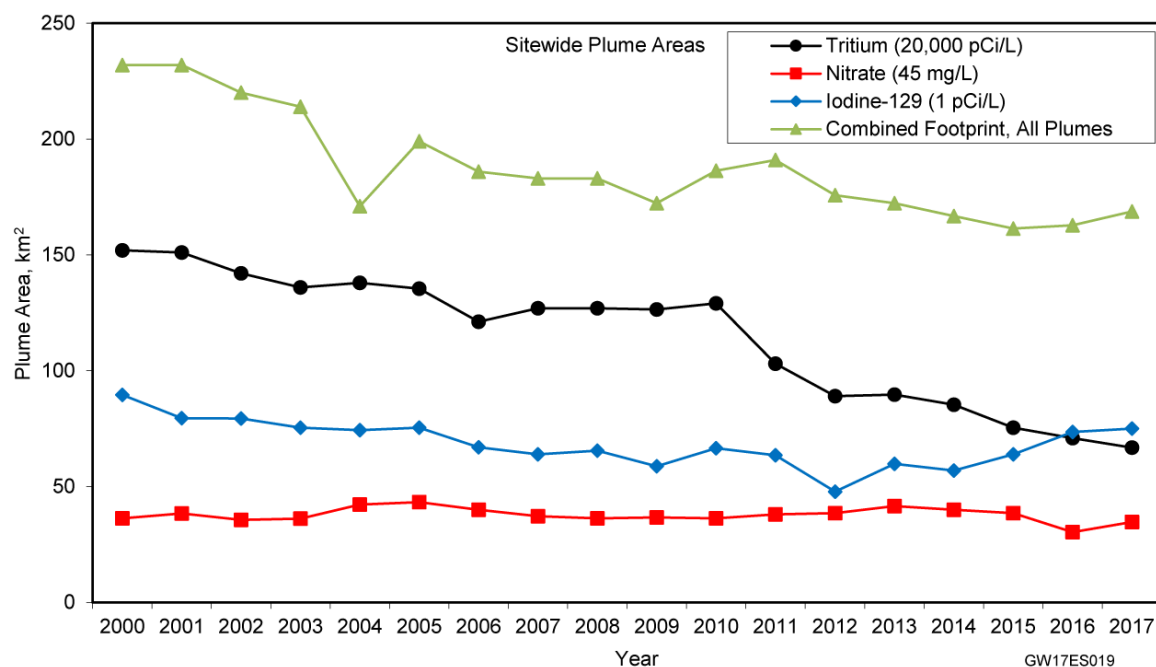


Figure 8-2. Hanford Site Plume Areas.

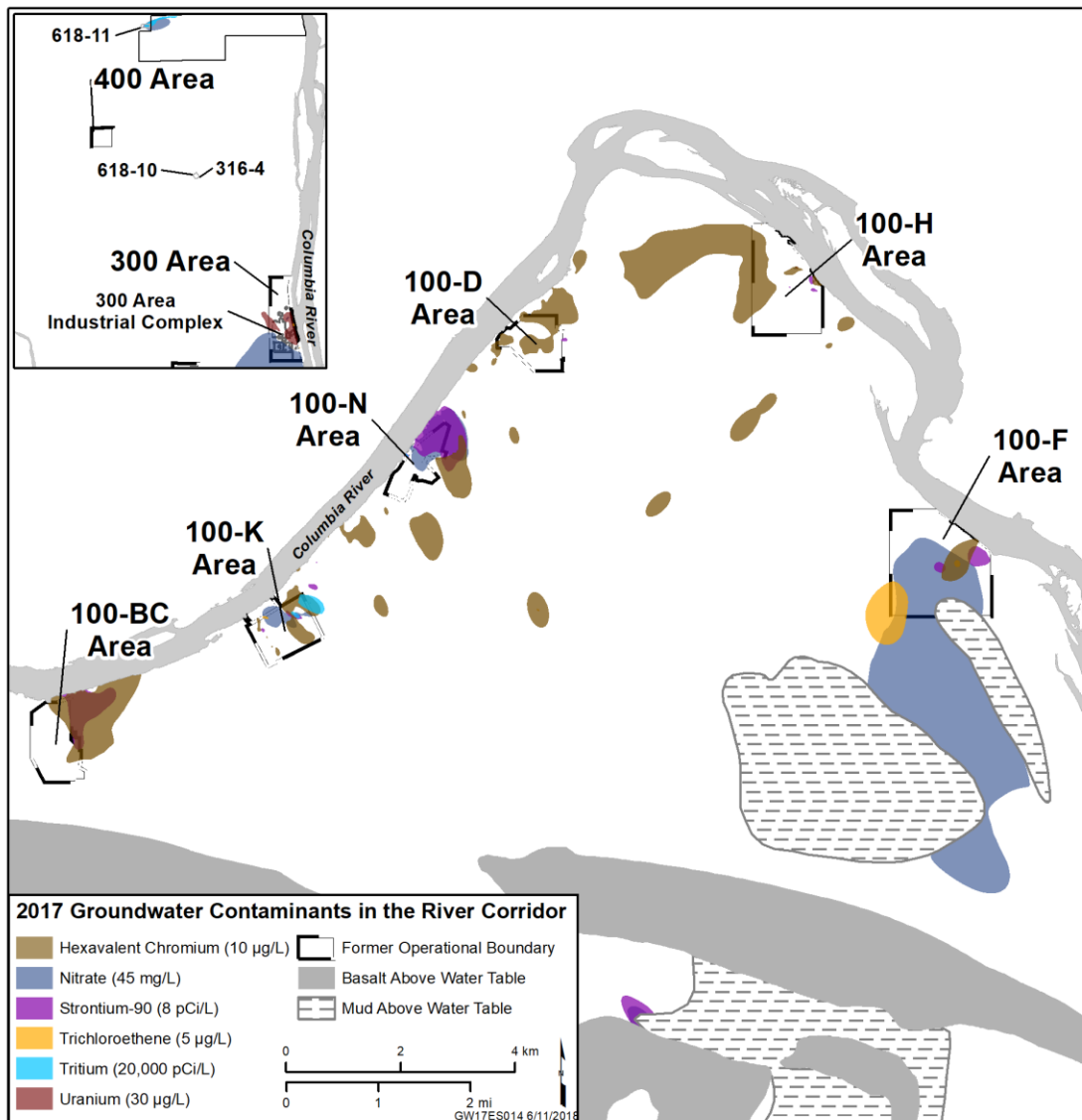


Figure 8-3. Groundwater Contaminant Plumes in the River Corridor.

Table 8-1. River Corridor Groundwater Contaminants, 2016 and 2017.

Ground-water Interest Area	Maximum Concentrations							
	Year	C-14 (pCi/L)	Cr(VI) (µg/L)	Nitrate (mg/L)	Sr-90 (pCi/L)	TCE (µg/L)	Tritium (pCi/L)	Uranium (µg/L)
100-BC	2017	N	50	21.9	43.6	5.49	11,900	5.4
	2016	N	58	19.9	49.7	6.69	15,600	5.5
100-FR	2017	N	42	342	120	13	3030	14
	2016	N	70	124	126	15	3,300	12.5
100-HR	2017	N	730	217	27.8	N	9440	142
	2016	N	640	66.4	30.1	N	10,600	50
100-KR	2017	28,500	840	115	15,600	8.1	3,810,000	13.8
	2016	40,100	360	75.3	164	9.48	730,000	27
100-NR	2017	325	130	319	14,200	0.3	282,000	8.9
	2016	357	117	443	12,600	0.18	373,000	9.45
300-FF	2017	N	10	186	N	1.99	570,000	5,460
	2016	N	12.5	181	N	2.09	799,000	1,180
1100-EM	2017	N	N	150 ^a	N	N	N	34.5 ^a
	2016	N	N	155 ^a	N	0.47	N	40.9 ^a
Standard ^b		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		High	High to moderate	High	Slight	Moderate	High	Moderate
Colors and listed values indicate maximum concentration, as follows:								
<div></div>		≥Standard and <10 × standard						
<div></div>		≥10 × standard and <100 × standard						
<div></div>		≥100 × standard and <1,000 × standard						
<div></div>		≥1,000 × standard						
a. Originate from offsite sources.								
b. Drinking water standards for all but hexavalent chromium (aquatic standard).								
Cr(VI) = hexavalent chromium								
MNA = monitored natural attenuation								
N = not detected or not analyzed								
N/A = not applicable								
TCE = trichloroethene								

Table 8-2. Summary of CERCLA Groundwater Remediation in the River Corridor.

Groundwater Operable Unit	CERCLA Decision Status	Groundwater Contaminants of (Potential) Concern ^a	Current Groundwater Remediation	Mass Removed
100-BC-5	Draft A RI/FS report and proposed plan released 2017	hexavalent chromium, strontium-90, TCE, tritium	No interim action required; final action pending	Not applicable
100-FR-3	ROD for final action signed 2014	hexavalent chromium, nitrate strontium-90, TCE	Monitored natural attenuation	Not applicable
100-HR-3	Interim ROD; RI/FS and proposed plan completed. ROD in progress.	hexavalent chromium, total chromium, nitrate, strontium-90, tritium	Interim action pump-and-treat for hexavalent chromium 1997-2017; interim action permeable reactive barrier emplaced but no longer maintained	2017: 56.3 kg Total: 2,460 kg
100-KR-4	Interim ROD; Draft A RI/FS report in revision	hexavalent chromium, total chromium, carbon-14, nitrate, strontium-90, TCE, tritium	Interim action pump-and-treat for hexavalent chromium 1997-2017	2017: 36.7 kg Total: 904 kg
100-NR-2	Draft B RI/FS report in progress	Strontium-90, TPH-D, nitrate, hexavalent chromium, total chromium, tritium	Interim action permeable reactive barrier for strontium-90; removal of TPH-D	Strontium-90: not applicable TPH-D: 1.5 kg in 2017; 17 kg total
300-FF-5	ROD for final action signed 2013	Uranium, gross alpha, <i>cis</i> -1,2-dichloroethene, TCE, nitrate, tritium	Enhanced attenuation for uranium; monitored natural attenuation for others	Not applicable
1100-EM-1	ROD signed 1993	TCE	No longer required; remedial action objectives achieved	Not applicable

^a Contaminants of concern are listed for operable units with RODs for final action. The primary contaminants of potential concern are listed for the other operable units.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

RI/FS = remedial investigation/feasibility study

ROD = Record of Decision

TCE = trichloroethene

TPH-D = total petroleum hydrocarbons-diesel range

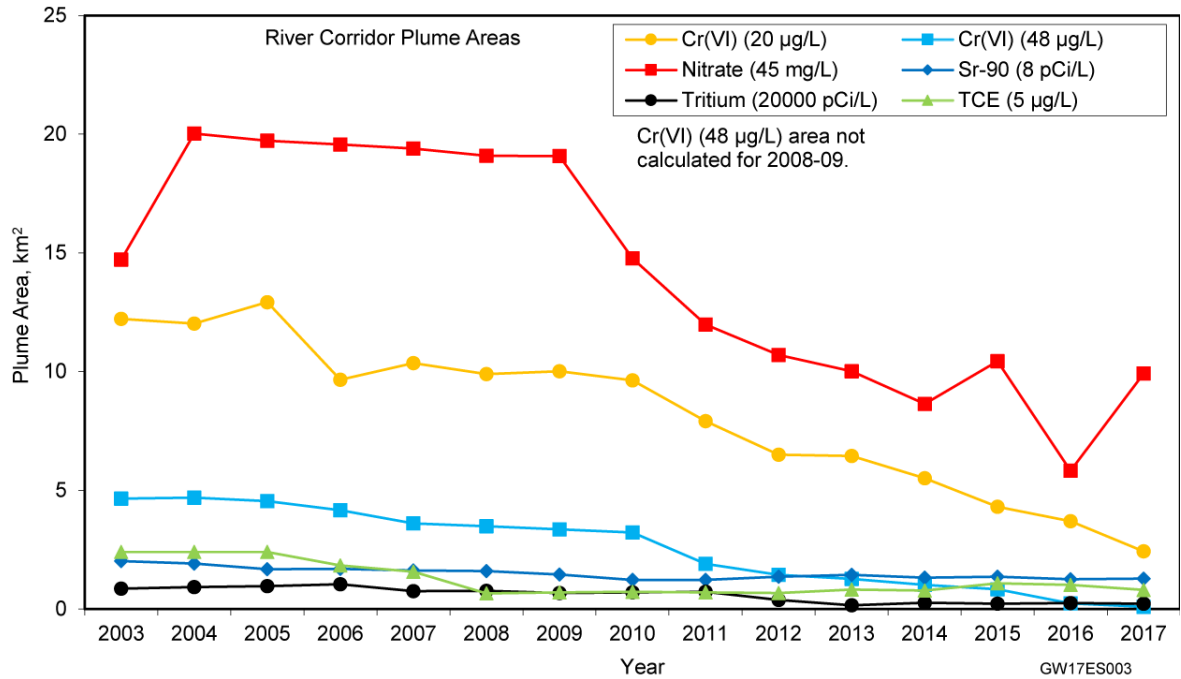


Figure 8-4. River Corridor Plume Areas.

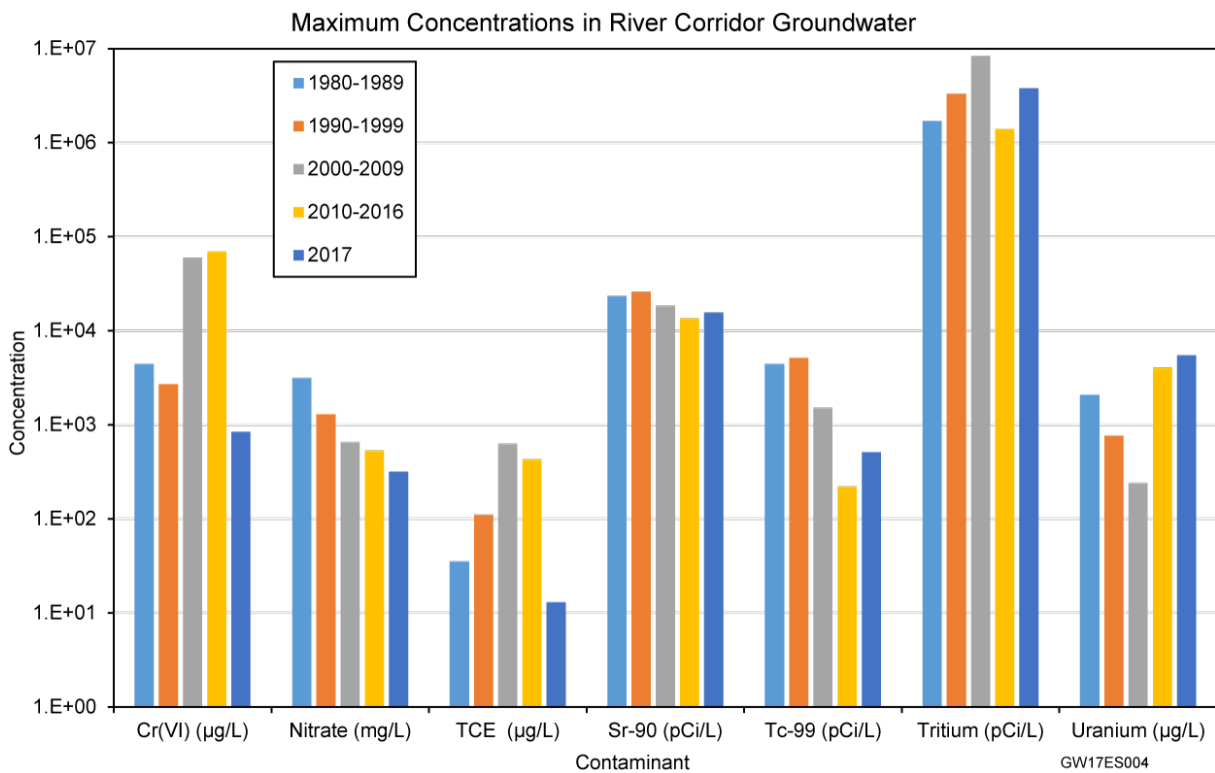


Figure 8-5. Maximum Concentrations of River Corridor Contaminants over Time.

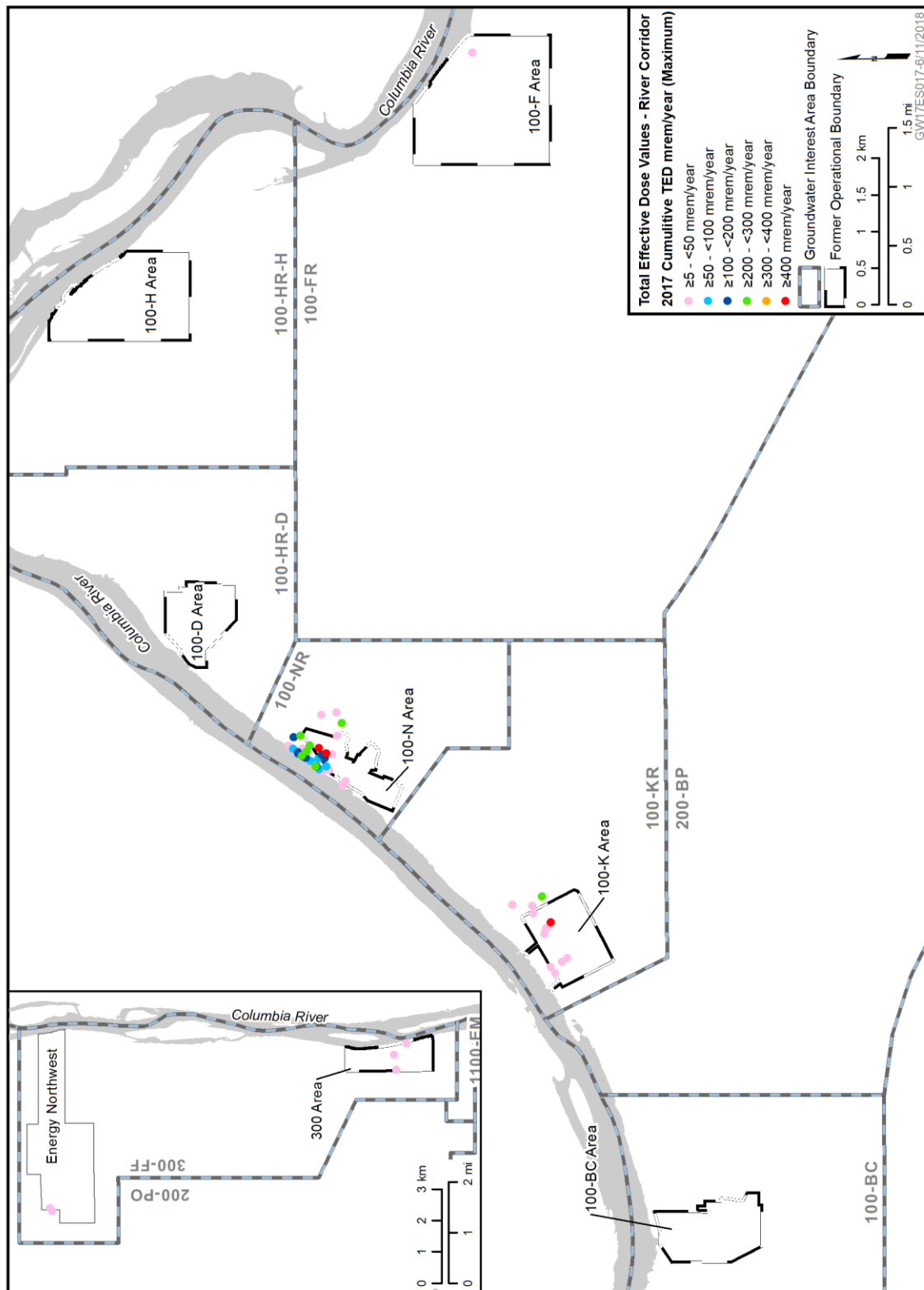


Figure 8-6. Groundwater Dose Calculation for the River Corridor.

The following activities or changes occurred in the River Corridor in 2017:

- **100-BC**
 - Hexavalent chromium concentrations continued to decline, and the 2017 plume area was smaller than 2016, particularly at concentrations above 20 µg/L.
- **100-FR**
 - Nitrate concentrations increased to 342 mg/L in a well in the central 100-F Area, which is the highest ever observed in 100-FR groundwater. Nitrate concentrations also increased in two wells in the southern part of the interest area, causing the plume interpretation to change. The causes of the increases are not yet known. The concentrations of other contaminants declined in 2017.
- **100-HR**
 - The hexavalent chromium plumes in the 100-D Area continued to shrink in 2017 due to groundwater remediation, and concentrations declined. Concentrations of hexavalent chromium and uranium increased temporarily in a small region in 100-H Area wells during a period of high water levels in 2017.
 - In the 100-H Area, DOE installed three extraction wells screened in the unconfined aquifer and three wells to characterize and remediate the Ringold Formation upper mud unit semiconfined aquifer. Hydraulic testing concluded that the aquifer and the overlying unconfined aquifer are connected through a leaky confining layer, and there is some connection to the Columbia River. High levels of hexavalent chromium, technetium-99, and nitrate were identified in one of the new Ringold upper mud unit wells.
- **100-KR**
 - DOE installed four new wells for monitoring and potential groundwater extraction. One depth-discrete groundwater characterization sample from one of the wells had a tritium concentration of 3.8 million pCi/L, much higher than other results in recent years. Concentrations were much lower in other characterization samples and in samples from the completed well.
 - In 2017, DOE completed a 1-year rebound study at the K-West pump-and-treat. During the rebound period, concentrations of hexavalent chromium and other contaminants increased in wells near the former contaminant sources, indicating residual contamination in the vadose zone. The pump-and-treat restarted in April 2017, and concentrations in groundwater declined.
- **100-NR**
 - Concentrations of strontium-90 and total petroleum hydrocarbons increased temporarily in some wells during a period of high river stage in 2017. Plume areas did not change significantly between 2016 and 2017.
- **300-FF**
 - DOE installed 48 injection wells and 19 monitoring wells to support Stage B of the uranium sequestration remedy, which is planned for 2018.

- Uranium concentrations increased in some 300 Area wells, and the interpreted plume area increased between 2016 and 2017.
- **RCRA**
 - Ecology approved modifications to the Hanford RCRA Permit (WA7890008967), adding a clean closure option for the 1301-N and 1325-N Liquid Waste Disposal Facilities (100-NR), and revising groundwater monitoring requirements for the 183-H Solar Evaporation Basins (100-HR) and the 300 Area Process Trenches (300-FF).
- **New wells**
 - Table 8-3 lists wells installed or decommissioned in the River Corridor in 2017.

Table 8-3. Summary of River Corridor Wells or Boreholes Drilled or Decommissioned in 2017.

Groundwater Interest Area	Wells or Instrument Boreholes Completed	Wells or Boreholes Decommissioned	Comment
100-BC	0	0	
100-FR	0	0	
100-HR	6	0	Pump-and-treat extraction wells.
100-KR	4	1	Dual-purpose monitoring and extraction wells installed.
100-NR	0	0	
300-FF	67	0	Uranium sequestration injection and monitoring wells.
1100-EM	0	0	
Total	77	1	

8.2 Central Plateau

The Central Plateau, located in the middle of the Hanford Site, includes the 200-West and 200-East Areas. Ponds, cribs, and ditches used for liquid waste disposal were primary sources of groundwater contamination. There are also seven single-shell tank waste management areas in the 200 Areas. Contamination is still present at some locations in the thick Central Plateau vadose zone and may continue to migrate into the groundwater. DOE is beginning to characterize and remediate these sites.

Figure 8-7 shows the Central Plateau groundwater contaminant plumes in 2017, and Table 8-4 compares the maximum contaminant concentrations measured in 2017 and 2016 in the Central Plateau groundwater interest areas.

Groundwater beneath portions of the Central Plateau is being remediated under CERCLA decision documents. Table 8-5 summarizes the status of CERCLA remediation for Central Plateau groundwater

and deep vadose zone operable units. Pump-and-treat systems continued to remove carbon tetrachloride, nitrate, technetium-99, uranium, and other contaminants from groundwater in 2017.

The size of the Central Plateau tritium plume continued to decline in 2017 due to natural attenuation, which includes radioactive decay (Figure 8-8). The size of the carbon tetrachloride plume appears to have increased in recent years, partly due to better characterization (new wells) and partly due to migration of the distal lobes of the plume, which the pump-and-treat remedy is not designed to capture. The estimated extent of hexavalent chromium contamination increased in 2017 because new wells were installed to characterize and monitor contamination in the southeastern part of the 200-UP interest area. The area of other Central Plateau plumes remained about the same in 2017.

Maximum concentrations of most Central Plateau groundwater contaminants have decreased over time (Figure 8-9) due to remediation, migration, dispersion, and, in some cases, radioactive decay.

Figure 8-10 illustrates the total effective dose from hypothetical exposure of members of the public by drinking Central Plateau groundwater. Radionuclides contributing to doses greater than 100 mrem/yr include iodine-129, strontium-90, technetium-99, tritium, and uranium.

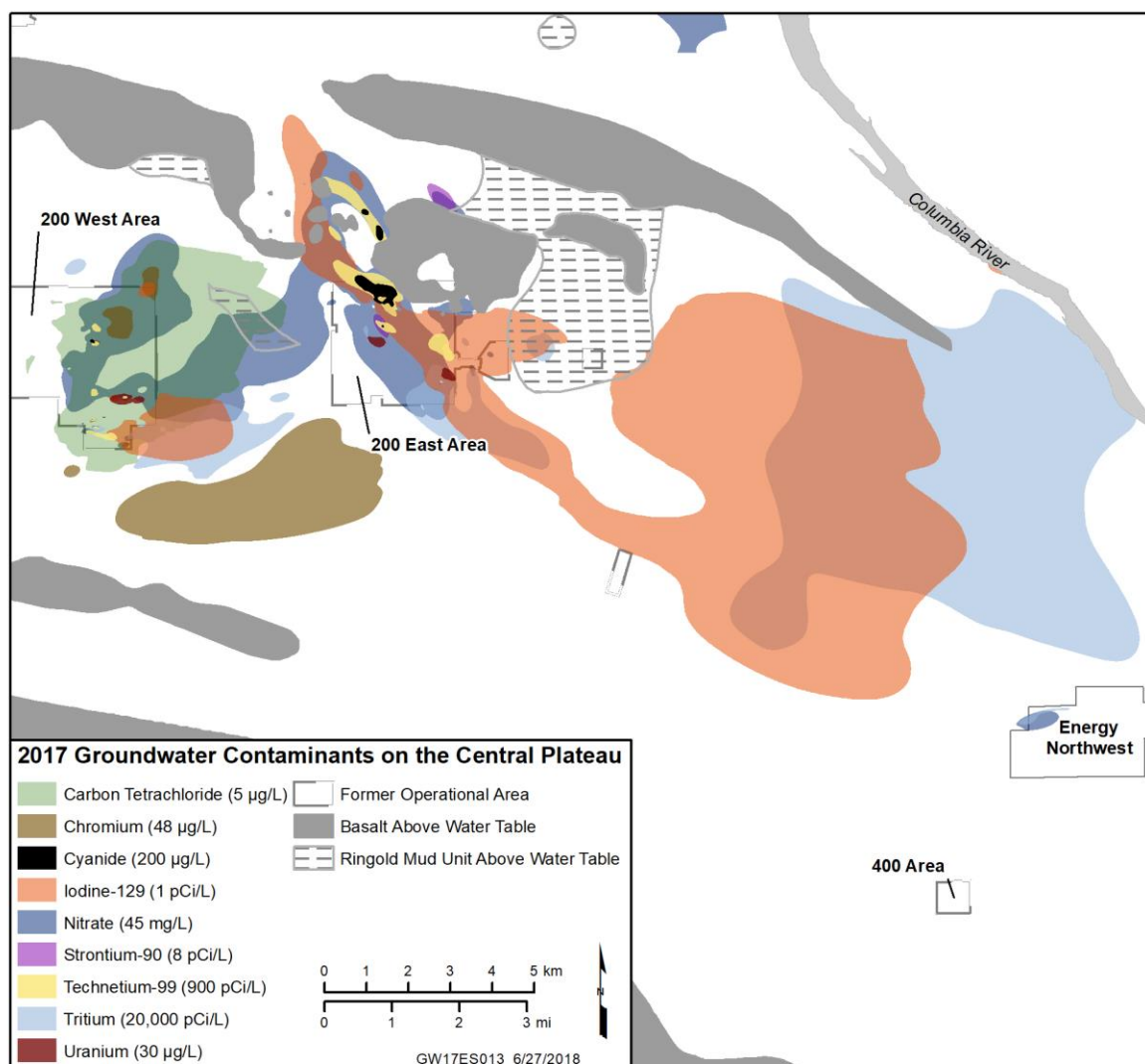


Figure 8-7. Groundwater Contaminant Plumes in the Central Plateau.

Table 8-4. Central Plateau Groundwater Contaminants, 2016 and 2017.

Ground-water Interest Area	Year	Maximum Concentrations							
		Carbon Tetra-chloride (µg/L)	Chromium (µg/L)	I-129 (pCi/L)	Nitrate (mg/L)	Sr-90 (pCi/L)	Tc-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)
200-BP	2017	N	37.5	9.67	1,590	511	36,000	53,700	2,970
	2016	N	50.2	5.27	1,510	4,470	32,700	61,400	3,790
200-PO	2017	N	110	10.9	120	13.3	5,360	133,000	61
	2016	0.17	85	8.91	146	13.7	1,950	418,000	23.9
200-UP	2017	412	224	22.8	221	19.1	13,700	218,000	5,000
	2016	801	460	20.2	531	15.3	39,000	250,000	2,400
200-ZP	2017	1,960	160	1.46	620	2.12	11,100	60,300	4.3
	2016	2,320	180	1.2	708	N	10,700	58,800	6.5
Regulatory standard		5	48	1	45	8	900	20,000	30
Half-life (years)		N/A	N/A	1.6E+07	N/A	28.8	212,000	12.3	>159,000
Mobility		Multi-phase	High to moderate	High	High	Slight	High	High	Moderate
Colors and listed values indicate maximum concentration, as follows:									
		<div style="display: flex; align-items: center;"> <div style="width: 20px; height: 15px; background-color: #90EE90; border: 1px solid black; margin-right: 5px;"></div> <div>≥ Standard and <10 × standard</div> </div>							
		<div style="display: flex; align-items: center;"> <div style="width: 20px; height: 15px; background-color: #FFFF00; border: 1px solid black; margin-right: 5px;"></div> <div>≥10 × standard and <100 × standard</div> </div>							
		<div style="display: flex; align-items: center;"> <div style="width: 20px; height: 15px; background-color: #FFA500; border: 1px solid black; margin-right: 5px;"></div> <div>≥100 × standard and <1,000 × standard</div> </div>							
		N = not detected or not analyzed							
		N/A = not applicable							

Table 8-5. Summary of CERCLA Groundwater Remediation on the Central Plateau . (2 Pages)

Operable Unit	CERCLA Decision Status	Groundwater Contaminants of (Potential) Concern ^a	Current Groundwater Remediation	Mass Removed in 2017 (and Since Startup)
200-BP-5	Implemented action memorandum (2016); submitted draft RI report (2015)	Cyanide, iodine-129, nitrate, strontium-90, technetium-99, tritium, uranium	Removal action: Groundwater extraction (2015–2017)	Cyanide: 44 kg (102 kg) Nitrate: 17,071 kg (87,261 kg) Technetium-99: 95.1 g (171 g) Uranium: 123 kg (137 kg)

Table 8-5. Summary of CERCLA Groundwater Remediation on the Central Plateau . (2 Pages)

Operable Unit	CERCLA Decision Status	Groundwater Contaminants of (Potential) Concern^a	Current Groundwater Remediation	Mass Removed in 2017 (and Since Startup)
200-PO-1	Submitted RI report (2012) and RI addendum (2015)	Iodine-129, tritium, nitrate, strontium-90, technetium-99, uranium	None required	Not applicable
200-UP-1	ROD for interim remedial action signed (2012)	Technetium-99, uranium, carbon tetrachloride, hexavalent chromium, total chromium, iodine-129, nitrate, tritium	Interim actions: pump-and-treat near U-Plant (2015–2017) pump-and-treat at WMAS-SX (2012–2017) Hydraulic containment for iodine-129 (2015–2017) Monitored natural attenuation	Nitrate: 31,716 kg (179,523 kg ^b) Technetium-99: 33.8 g (351 g ^b) Uranium: 17.9 kg (937 kg ^b)
200-ZP-1	ROD for final remedial action signed (2008)	Carbon tetrachloride, hexavalent chromium, total chromium, iodine-129, nitrate, technetium-99, trichloroethene, tritium	pump-and-treat and monitored natural attenuation	Carbon tetrachloride: 1,906 kg (26,802 kg ^b) Chromium: 89.4 kg (409 kg) Nitrate: 349,770 kg (1,524,760 kg)
200-DV-1 ^c	Implemented action memorandum (2016); characterization of the deep vadose zone in progress	Nitrate, technetium-99, uranium (perched water)	Removal action: Perched water extraction (2011–2017)	Nitrate: 1,324 kg (2,102 kg) Technetium-99: 2.7 g (5.2 g) Uranium: 78 kg (157 kg)

^a Contaminants of concern are listed for operable units with RODs for final action. The primary contaminants of potential concern are listed for the other operable units.

^b Totals includes mass from pump-and-treat system under earlier RODs for interim action.

^c Deep vadose zone operable unit

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

RI = remedial investigation

ROD = Record of Decision

WMA = waste management area

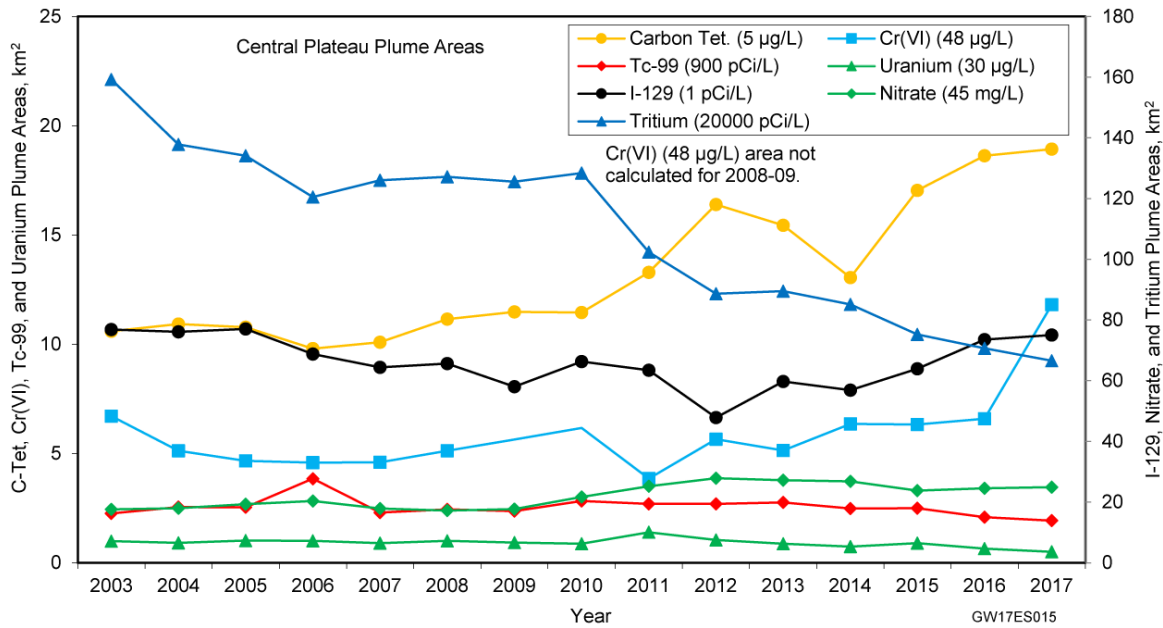


Figure 8-8. Plume Areas in the Central Plateau.

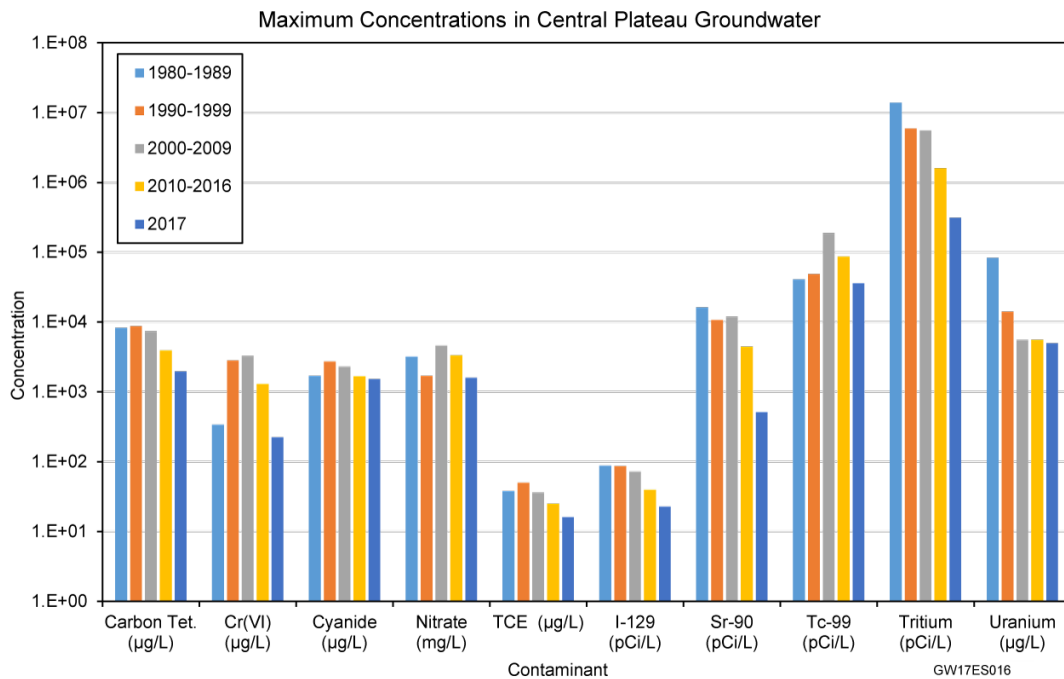


Figure 8-9. Maximum Concentrations of Central Plateau Contaminants over Time.

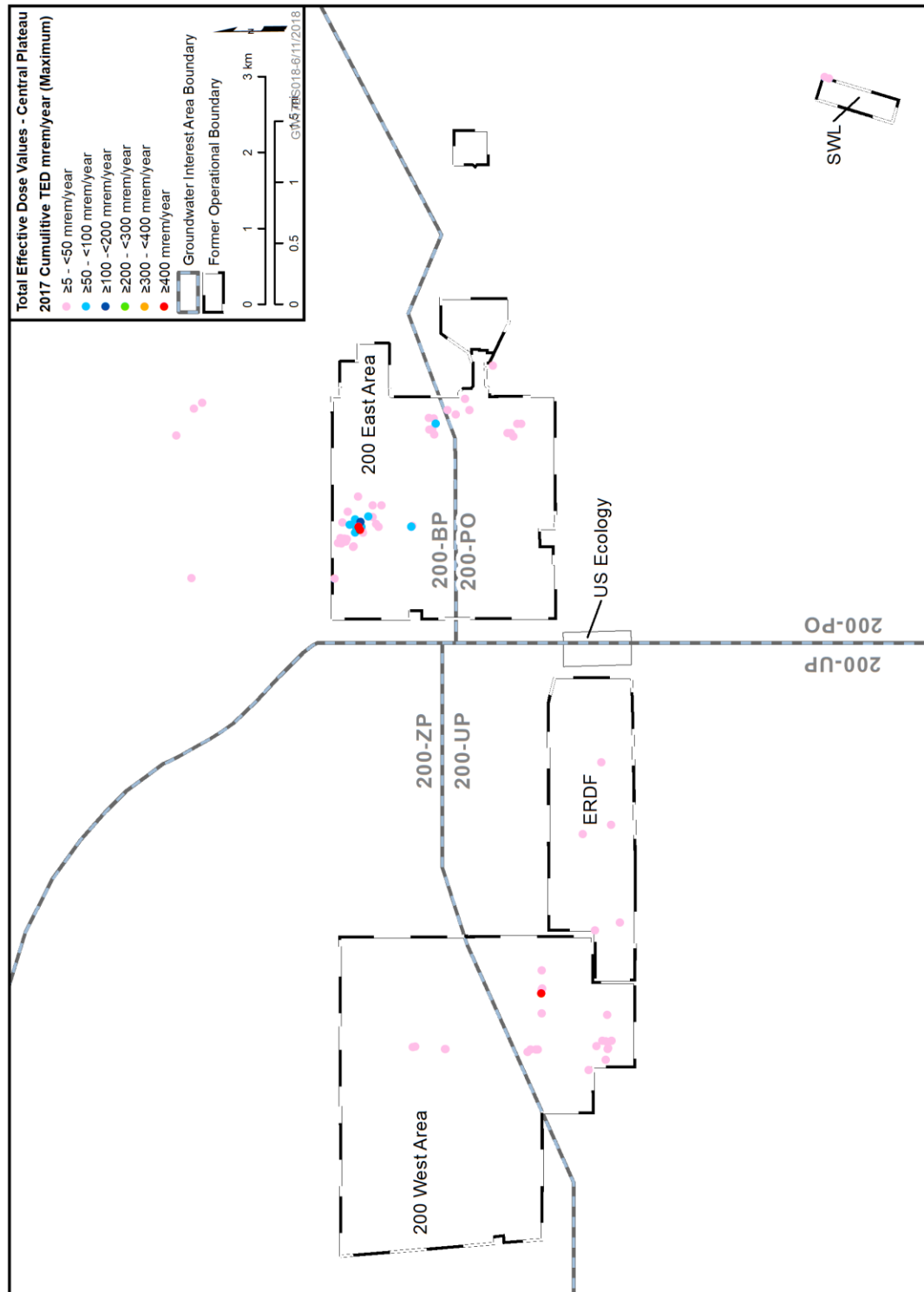


Figure 8-10. Groundwater Dose Calculation for the Central Plateau.

The following activities or changes occurred in the Central Plateau in 2017:

- **200-BP**
 - New groundwater extraction well 299-E33-360 became active in 2017 as a part of a groundwater removal action. Concentrations of technetium-99, uranium, and other contaminants in nearby monitoring wells declined as a result of remedial actions. The part of the uranium plume with concentrations greater than 30 µg/L shrank by about 60% between 2016 and 2017.
- **200-PO**
 - The large tritium plume originating from sources in the 200-East Area continued to shrink in 2017 due to dispersion and radioactive decay.
- **200-UP**
 - Six dual-purpose monitoring-extraction wells were installed for the pump-and-treat system, and five monitoring wells were installed to characterize the southeast chromium plume.
 - The size of the uranium plume near U-Plant declined between 2016 and 2017 as a result of groundwater remediation. Groundwater extraction near Waste Management Area S-SX caused chromium and technetium-99 concentrations to decline.
- **200-ZP**
 - As a result of remediation by the 200-West pump-and-treat, carbon tetrachloride concentrations are declining in locations where the highest levels were formerly present. The interpreted extent of the plume at lower concentrations (3.4 µg/L cleanup level) expanded between 2016 and 2017 based on the monitoring data and a computer simulation. These parts of the plume are not captured by the pump-and-treat system and will attenuate naturally over time, as described in the [200-ZP-1 ROD \(EPA et al. 2008\)](#).
 - Four new injection wells were installed for the pump-and-treat system; two of these began operating in 2017.
- **RCRA**
 - New monitoring wells were installed for 216-A-37-1 Crib (one well), 216-A-29 Ditch (three wells), and 216-B-3 Pond (one well).
 - The Nonradioactive Dangerous Waste Landfill began groundwater quality assessment in 2017 as a result of a new critical mean exceedance.
 - New monitoring requirements for the Liquid Effluent Retention Facility were implemented through a revision to the Hanford RCRA Permit⁴ in 2017. New interim status groundwater monitoring plans were implemented for the 216-A-37-1, 216-B-3, and 216-S-10 Pond and Ditch.
- **New wells**
 - Table 8-6 lists wells installed or decommissioned at the Central Plateau in 2017.

Table 8-6. Summary of Central Plateau Wells or Boreholes Drilled or Decommissioned in 2017.

Groundwater Interest Area	Wells or Boreholes Drilled	Wells or Instrument Boreholes Completed	Wells or Boreholes Decommissioned	Comment
200-BP	2	1	2	Included one boring for the 200-DV-1 Operable Unit.
200-PO	6	6	1	
200-UP	15	14	1	Included one boring for the 200-DV-1 Operable Unit and five pilot test wells for the 200-WA-1 Operable Unit.
200-ZP	7	4	3	Included three borings for the 200-DV-1 Operable Unit.
Total	30	25	7	

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2017 Highlight

Routine Surveillance Soil Sampling

A total of 98 surface soil samples were collected on the Hanford Site in 2017. The concentrations of radionuclides at these locations are consistent with those seen in previous years.

Special Soil Sampling

Special soil sampling was conducted at 19 locations near the Plutonium Finishing Plant (PFP) to assess potential impacts from the open-air demolition that took place in late 2017. Analytical results indicate radionuclide concentrations are consistent with those seen in previous years at these locations and at other locations in the 200-West Area.

Radiological Surveys

Radiological surveys performed near operational area on the Hanford Site in 2017 identified 16 instances of radiological contamination in surface soil, resulting in 12 locations posted as contamination areas and four locations cleaned up with soil removal.

9.0 Soil Monitoring

JE Cranna

Radiological monitoring of soil is conducted onsite near Hanford facilities and operations and onsite away from facilities and operations. Soil sampling is also performed offsite at perimeter and distant locations and in nearby communities. The environmental surveillance soil monitoring program complements Hanford Site emissions monitoring, including the Hanford ambient air monitoring network. Contaminant data collected are used to:

- Assess the impact of Hanford Site operations on the concentrations of manmade radionuclides in soil
- Determine the effectiveness of effluent monitoring and controls within facilities
- Confirm contaminant control measures at waste disposal sites during waste site remediation and at radioactive contamination areas
- Determine concentrations of naturally occurring radionuclides and those from fallout unrelated to Hanford Site activities
- Provide long-term radionuclide contamination trends in soil at undisturbed locations
- Detect and monitor unusual conditions associated with a potential release or spread of radioactive material.

Soil is an integrating sample medium that accounts for contaminants released to the atmosphere either directly (gaseous effluent), indirectly (re-suspension/deposition), or through liquid effluent waste streams that are subsequently used for irrigation.

Soil samples have been collected on and around the Hanford Site for more than 50 years; consequently, a significant data set exists that documents onsite and offsite levels of manmade radionuclides in and around the Hanford Site. These data provide a baseline to which Hanford Site emissions and unplanned releases can be compared.

Soil samples from offsite locations are collected every 3 to 5 years and were last collected in 2015. Offsite soil sampling is used for long-term trend analysis and is not used in dose model calculations. The sampling frequency of every 3 to 5 years is consistent with the guidance provided in the DOE handbook [DOE-HDBK-1216-2015](#), *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

9.1 Hanford Site Soil Sampling

Surface soil sampling is required by the *Hanford Site Radioactive Air Emissions License #FF-01* (FF-01) (Section 5.1.2) as a qualitative indicator of the environmental monitoring program. It also is a recommended practice per [DOE-HDBK-1216-2015](#).

Soil sampling data is used to evaluate long-term accumulation trends and provide baseline data to quantify short-term accumulations due to fugitive or accidental releases of Hanford Site radiological materials. Soil contamination can occur as the result of direct deposition from facility emissions, re-suspension and movement of contaminants from radioactively contaminated surface soil areas, or translocation of buried waste by biological intrusion.

Surface soil samples were collected on or adjacent to waste disposal sites, as well as from locations downwind, near, or within the boundaries of operating facilities and remedial action sites. The location and analyses of soil samples collected in 2017 are depicted in Table 9-1. The number of soil samples per operational area are summarized in Table 9-2.

Table 9-1. Hanford Site Soil Monitoring Locations and Sample Analyses. (2 Pages)

Soil Monitoring Location	EDP Codes ^a	Collection Period	Analyses
200-East Area	D053, D055, D057, D059, D061, D063 ^b , D065, D067, D069, D071, D072, D073, D075, D076, D077, D078, D079, D143 ^c	May	⁹⁰ Sr, Pu-iso, U-iso, GEA
200 ETF (200-East Area)	D457, D459, D464	May	⁹⁰ Sr, Pu-iso, U-iso, GEA
Trench 94 (200-East Area)	D458, D460, D461	May	⁹⁰ Sr, Pu-iso, U-iso, GEA
200-West Area	D001, D005, D013, D015, D019, D023, D025 ^b , D027, D029, D035, D037, D039, D041, D047, D049, D051, D111 ^c	May	⁹⁰ Sr, Pu-iso, U-iso, GEA
Plutonium Finishing Plant (200-West Area)	D007, D009, D031, D033, D043, D045 ^b	May	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am
ERDF at N482 (200-West Area)	D146	May	⁹⁰ Sr, Pu-iso, U-iso, GEA

Table 9-1. Hanford Site Soil Monitoring Locations and Sample Analyses. (2 Pages)

Soil Monitoring Location	EDP Codes ^a	Collection Period	Analyses
300 Area	D120, D121, D123 ^b , D125, D126, D132 ^c , D140 ^c , D207	May	⁹⁰ Sr, Pu-iso, U-iso, GEA
400 Area	D130	May	⁹⁰ Sr, Pu-iso, U-iso, GEA
600 Area	D081, D083, D085 ^b , D087, D089, D091, D093, D095, D097, D099, D101, D103, D105, D107, D109, D113 ^c , D145 ^c	May	⁹⁰ Sr, Pu-iso, U-iso, GEA
618-10 Burial Ground	D179, D180, D181, D182	December	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am
^a EDP Code=environmental data point code = sample location code ^b Collocated sampling location with WDOH ^c Quality assurance duplicate sample ERDF = Environmental Restoration Disposal Facility ETF = Effluent Treatment Facility GEA = Gamma Energy Analysis ⁹⁰ Sr = Strontium-90 ²⁴¹ Am = Americium-241 Pu-iso = isotopic plutonium (²³⁸ Pu, ^{239/240} Pu) U-iso = isotopic uranium (²³⁴ U, ²³⁵ U, ²³⁸ U) WDOH = Washington State Department of Health			

Table 9-2. Number of Soil Samples per Operational Area.

Number of Samples	Operational Area (discrete samples analyzed)							
	200-East ^a	200-West ^a	Trench 94	ETF	ERDF	300 Area ^a	400 Area	600 Area ^a
74	18	23	3	3	1	8	1	17
^a Includes one or more duplicate samples. ETF = Effluent Treatment Facility ERDF = Environmental Restoration Disposal Facility								

9.1.1 Sampling and Analysis

Samples were collected and analyzed according to DOE/RL-2013-53, *Hanford Site Environmental Surveillance Master Sampling Schedule for Calendar Year 2017*. Onsite soil samples are collected annually and, as a cost-savings measure, collections in the 200 and 600 Areas are alternated between even and odd numbered years, aligning with even and odd numbered sample locations. Individual soil samples are approximately 2.2 lb (1.0 kg) and consist of five plugs of soil. The soil is sampled using a shallow (cookie cutter) coring device producing a core approximately 1 in. (2.5 cm) deep and 4.3 in. (11 cm) in diameter. Five cores are combined to create one sample. Areas with heavy vegetation cover are avoided and any vegetation in the sample is removed. Soil samples are sieved in the field to remove potential sample intrusions (e.g., rocks and plant debris). The soil samples are packaged in two plastic bags (double bagged) and transported to an analytical laboratory. Samples are dried in the laboratory prior to analysis to remove residual moisture.

Soil samples were analyzed for strontium-90, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239/240, and gamma-emitting radionuclides. In support of the current deactivation and decommissioning (D&D) project at the Plutonium Finishing Plant (200-West Area), and especially for

monitoring during the demolition of the Americium Recovery Facility, an americium-241 alpha energy analysis was added to the analyte list at six soil monitoring locations (D007, D009, D031, D033, D043, and D045) near the PFP complex.

9.1.2 Soil Sampling Results

The analytical results from soil samples collected on the Hanford Site in 2017 are summarized in Appendix C, Table C-5. While there are no specific DOE limits for radionuclide concentrations in soil, the 2017 onsite soil sample results can be compared to other benchmarks including Hanford Site background concentrations ([DOE/RL-96-12](#)), radionuclide concentrations resulting from natural sources and worldwide fallout as observed in offsite soil samples, and dose-based limits for soil that have been developed for the Environmental Surveillance program to support calculation of a 1 mrem/yr dose threshold to an offsite member of the public ([DOE/RL-91-50](#)). More recently, soil radiological preliminary remediation goals (PRGs) have been developed for an outdoor worker exposure scenario for use in the Remedial Investigation/Feasibility Study (RI/FS) Reports for the Inner Area source operable units located within the Central Plateau of the Hanford Site ([ECF-HANFORD-16-0133](#)). These values may also be useful for comparison with onsite soil sample results. Values for these various soil benchmarks for key radionuclides are shown in Table 9-3. These levels are listed for comparison only and are not regulatory requirements. Generally, radionuclide concentrations in soil samples collected from the 200, 300, 400, and 600 Areas were near or below the Hanford Site background concentrations and well below the dose-based reporting limits for an offsite member of the public and the PRGs for the outdoor worker exposure scenario. The cesium-137 soil value in the 200 Areas was slightly above the Hanford Site background level, but they were significantly lower than the PRGs for the 200 Area outdoor worker exposure scenario.

Table 9-3. Concentration Limits for Selected Radionuclides (pCi/g).

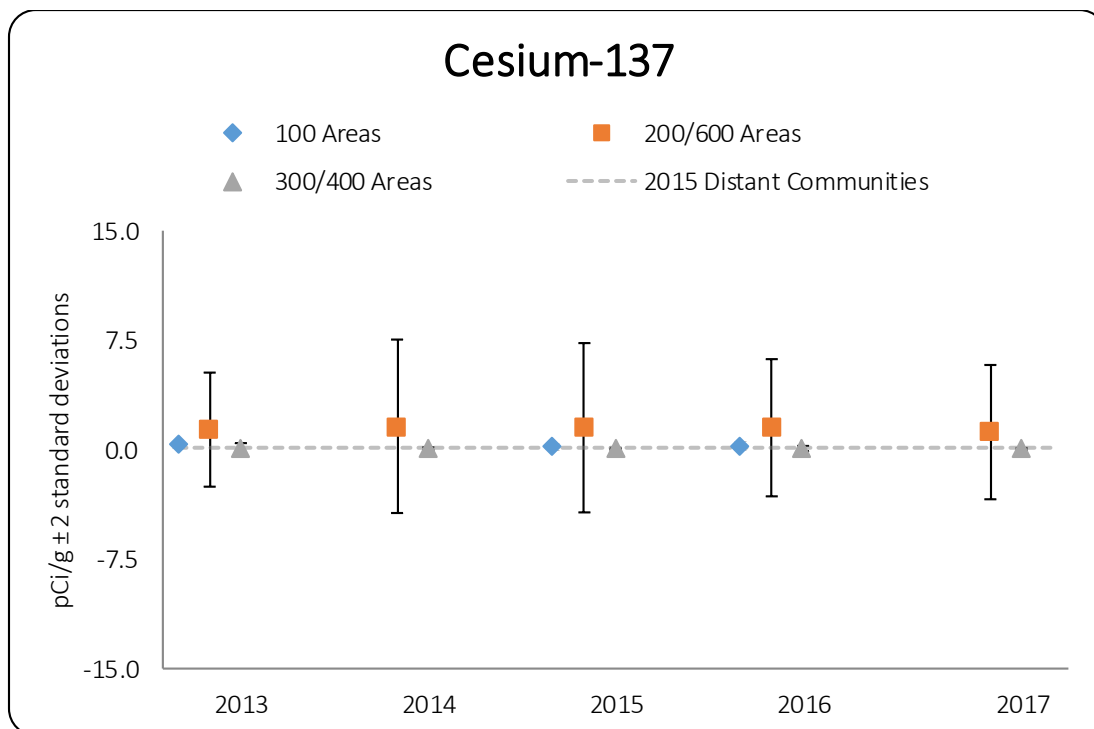
Isotope	Hanford Background 90 th Percentile ^a	Environmental Surveillance Dose-based Reporting Limit for Offsite Exposure Scenarios ^b	Preliminary Remediation Goal for the Outdoor Worker Exposure Scenario ^c
Americium-241	N/A	20	613
Cesium-137	1.05	0.51	10.8
Plutonium-238	0.004	33	3,438
Plutonium-239/240	0.025	31	2,971
Strontium-90	0.178	55	1,190
Uranium-234	1.10	150	2,201
Uranium-235	0.109	2.3	36
Uranium-238	1.06	11	170

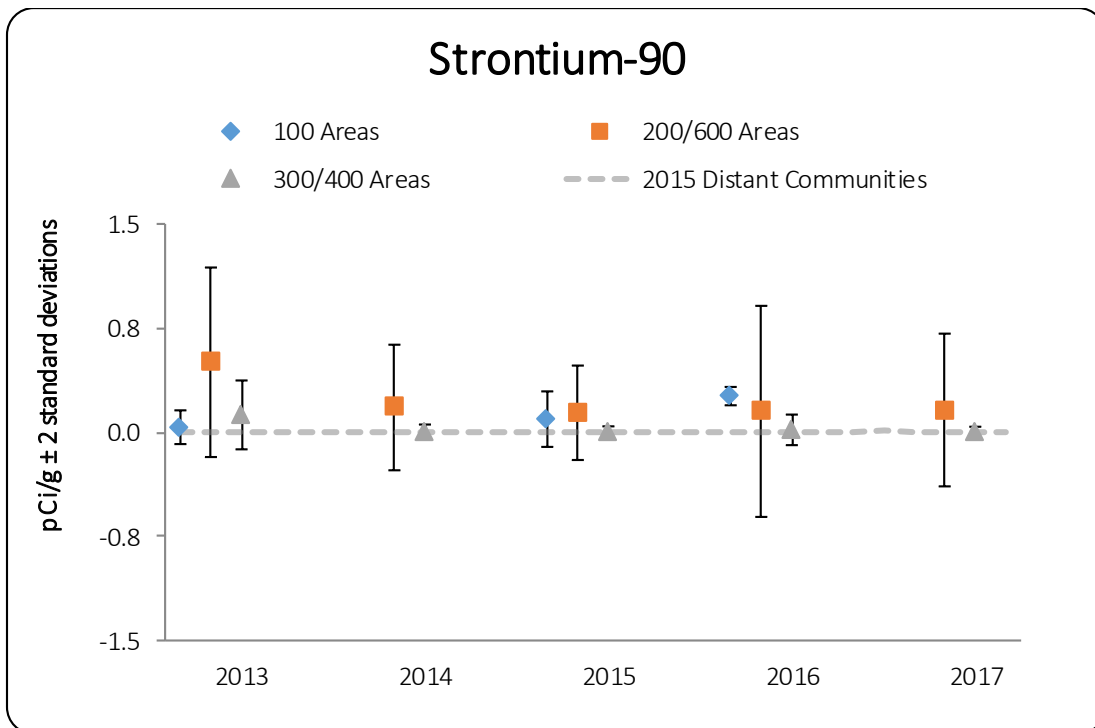
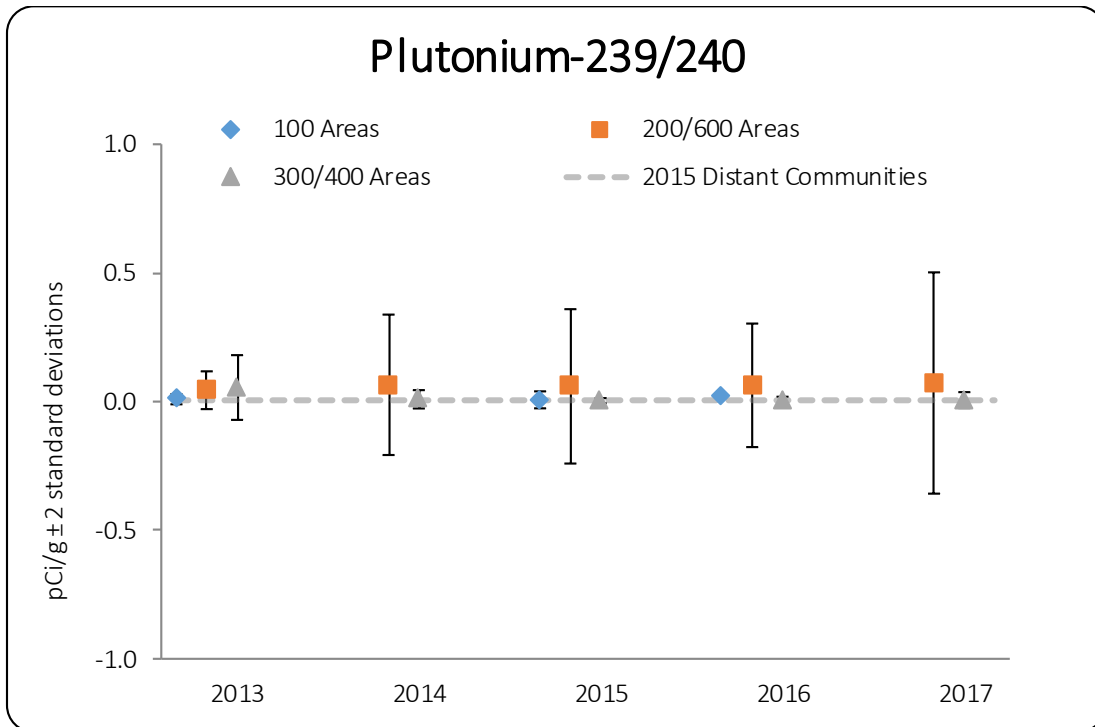
^a Values published in Hanford Site Background: Part 2, Soil Background for Radionuclides ([DOE/RL-96-12](#)).

^b Dose-based reporting limits established in reference to radionuclide contamination that could lead to an offsite public receptor dose of 1 mrem/yr if the condition persisted for an entire year. These limits are based on the inadvertent ingestion and external radiation exposure pathways as specified in Table 4-1 of the Hanford Site Environmental Monitoring Plan ([DOE/RL-91-50](#), Rev. 7).

^c Soil radiological Preliminary Remediation Goals developed using U.S. Environmental Protection Agency guidance as specified in *Calculation of Soil Radiological Preliminary Remedial Goals for the Outdoor Worker Scenario* ([ECF-HANFORD-16-0133](#)) that correspond to a target cancer risk level of 1×10^{-4} that are protective of an outdoor worker based on direct contact (incidental soil ingestion and direct external gamma exposure) and the inhalation pathways.

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 in 2017 at locations in the 200-East, 200-West, 300, 400, and 600 Areas were comparable to those seen in previous years. Radionuclide concentrations in soil samples collected from or adjacent to waste disposal facilities in 2017 were higher than the concentrations in samples collected further away. Historically, the 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. Consistent with historical detections, cesium-137, strontium-90, plutonium-239/240, uranium-234, and uranium-238 were detected in the 2017 soil samples. Figure 9-1 shows the annual average soil concentrations of selected radionuclides in the 100, 200, 300, 400, and 600 Areas. Appendix C, Table C-5 shows the annual average and maximum concentrations of radionuclides in surface soil samples by area during 2017 and for the preceding 5 years.





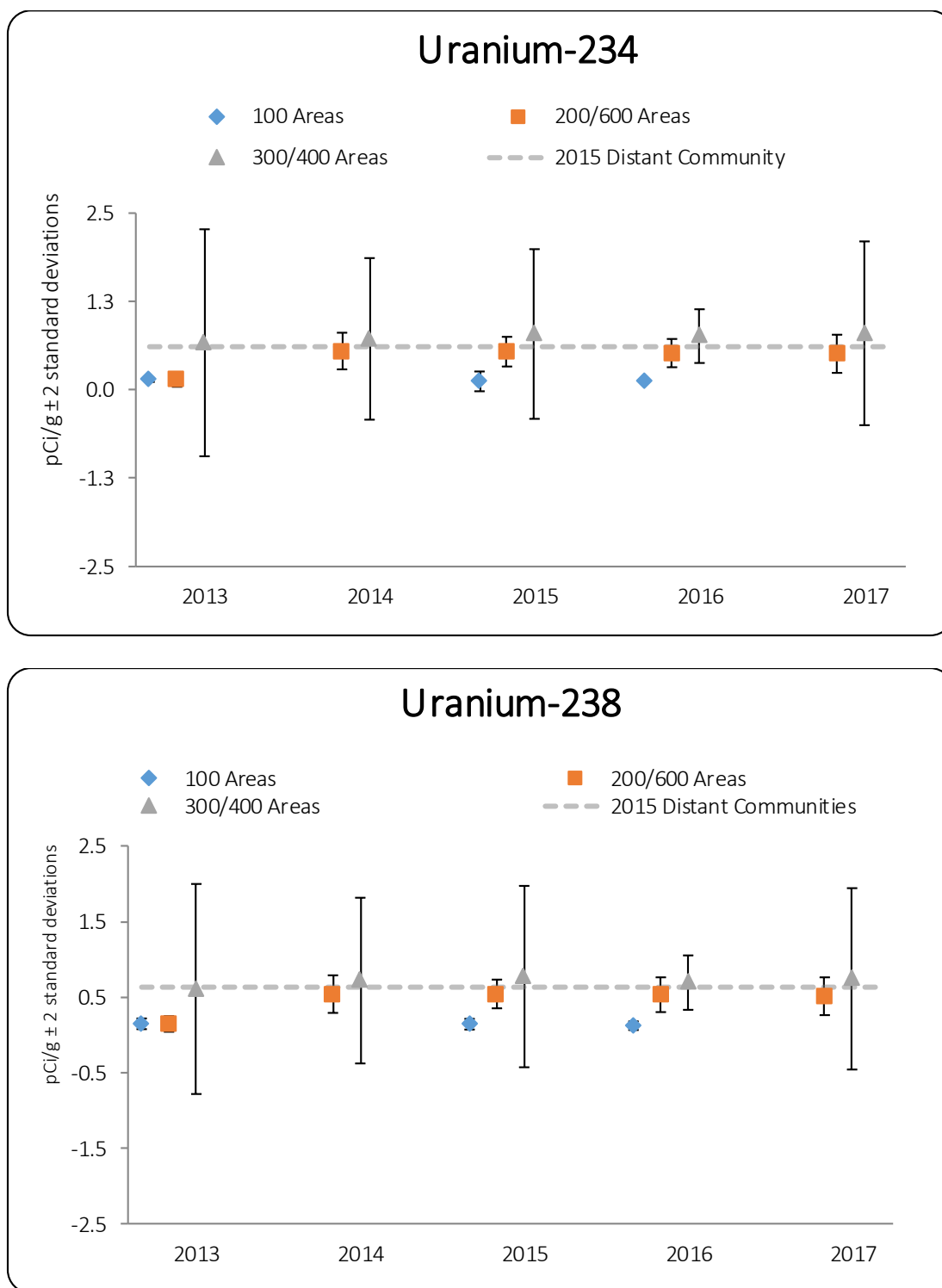


Figure 9.1. Average Concentrations of Select Radionuclides in Hanford Site Soil Samples, 2013–2017.
(As a result of figure scale, some uncertainties [error bars] are concealed by the point symbol)

Soil sampling was conducted at 23 locations in the 200-East Area, including ETF and Trench 94 (discussed below) during 2017. Generally, radionuclide levels measured in the 2017 soil samples were similar to those measured in previous years. Cesium-137, strontium-90, uranium-234, and uranium-238 detection frequencies were similar to those seen in previous years.

Field detectable radiological contamination was identified during the collection of soil at sampling location D063 (218-C-9 Trench, East). A “speck” with a reading of 80,000 dpm/100 cm² beta-gamma activity was found at one of the five subsample locations. The sample was collected in accordance with the Environmental Soil Sampling procedure (RC-PRO-RC-60561) and transported to the laboratory as radioactive material. Laboratory analysis of the sample detected strontium-90 at 1.9 pCi/g, which is also the maximum strontium-90 concentration detected for the entire 2017 routine soil sampling event. This finding is likely associated with legacy strontium-90 contamination from hot-semiworks and not associated with any recent airborne deposition, which would have been detected at other locations within the sampling area.

In May 2017, a portion of the roof of the PUREX Storage Tunnel 1 on the Hanford Site collapsed. Routine soil samples collected at nine locations, in the vicinity of, and shortly after the PUREX tunnel collapse, detected the usual radionuclides expected in the 200-East Area soil (i.e., cesium-137, strontium-90, uranium-234, and uranium-238). All results were within historic ranges except a slightly elevated cesium-137 concentration (16 pCi/g) in a soil sample collected at the north boundary of the 200-East Area. This cesium-137 result is slightly higher than the 200-East Area 10-year historical concentration range.

During 2017, routine soil sampling was conducted at 22 locations in the 200-West Area, including ERDF. Radionuclide levels measured were similar to previous years. Frequency of detection percentages for cesium-137, strontium-90, uranium-234, uranium-238, plutonium-239/240, and americium-241 were also similar to those seen in previous years.

Soil sampling was conducted at 15 locations in the 600 Area in 2017. Radionuclide levels measured in these samples were similar to those measured in previous years. Frequencies of detection for cesium-137, strontium-90, uranium-234, uranium-238, and plutonium-239/240 were also similar to those seen in previous years.

Soil samples were collected at six locations in the 300 Area and one location in the 400 Area. These samples measured cesium-137, uranium-234, and uranium-238 at concentrations similar to those seen in previous years.

To comply with WDOH Notice of Construction requirements, surface soil deposition sampling was conducted during 2017 around the Effluent Treatment Facility and Trench 94 of the 218-E-12B waste site in the 200-East Area. Radionuclide levels measured in the 2017 soil samples were similar to those measured in previous years.

A soil sample is collected annually at the Environmental Restoration Disposal Facility (ERDF) from a predominantly downwind sampling location. Radionuclide levels measured downwind of ERDF were comparable to previous years.

9.1.2.1 Uranium. Soil samples collected in the 300 Area showed concentrations of uranium-234 and uranium-238 that were comparable to historical data but remained slightly higher than those measured in the 200 Area. The higher uranium levels in the 300 Area were expected due to known uranium releases to the environment during past fuel-fabrication operations and recent remediation efforts.

9.1.2.2 Plutonium. Plutonium-239/240 was detected in approximately 55% of soil samples collected from the 200 and 600 Areas. The majority of these detections were from locations in the 200-West Area. The concentrations measured were similar to those seen in previous years.

9.1.2.3 Strontium-90. Strontium-90 was detected in approximately 70% of the samples collected in the 200 and 600 Areas. The concentrations measured were within historical ranges.

9.1.2.4 Cesium-137. Cesium-137 was detected in soil samples collected from the 200, 300, 400, and 600 Areas. Cesium-137 concentrations were within historical ranges.

9.1.2.5 Americium-241. Americium-241 analysis was performed on four samples associated with the 618-10 Burial Ground Remediation Project and on 25 samples associated with the PFP complex. Americium-241 was detected at 24 of the 29 locations at concentrations similar to those seen in 2016.

9.1.3 Non-routine Soil Sampling

9.1.3.1 Post-Remediation 618-10 Burial Ground Soil Sampling. In 2017, soil samples were collected at four locations associated with the 618-10 Burial Ground Remediation Project north of the 300 Area. Collection of before, during, and after remediation soil samples is a requirement set forth in the Air Monitoring Plan for the Remediation of the 618-10 Burial Ground (PLN-0010). The before samples were collected in February 2011, the during samples were collected in March of 2012, and the after samples were collected in December 2017. The during soil samples, collected at two of the four sampling locations (D181 and D182), showed americium-241 and plutonium-239/240 above the Hanford Site 10-year average. The after soil samples collected at D182 showed americium-241 concentrations slightly above the Hanford Site 10-year average. Appendix C, Table C-6 provides a summary of selected analytical results for samples collected at the 618-10 Burial Ground.

9.1.3.2 Plutonium Finishing Plant Soil Sampling. During demolition of the Plutonium Finishing Plant (PFP) elevated readings were found on worker lapel air samplers. Subsequently, the Washington Department of Health's (WDOH) evaluation of air modeling data indicated a potential release to the north of PFP near the Vernita rest area. WDOH collected a surface soil sample at the Vernita rest area on December 18. On December 20 Environmental Surveillance personnel collected a sample adjacent to the WDOH selected location for verification purposes. An evaluation of this sample found that cesium-137, uranium-234, uranium-235, and uranium-238 were detected, with the uranium concentrations trending slightly higher than in previous years at this location. Appendix C, Table C-7 shows the concentrations of select radionuclides in soil samples collected at the Vernita Bridge rest area.

To assess potential impacts to the environs in the vicinity of PFP from the open-air demolition that took place in late 2017, a special soil sampling event was conducted. On February 6 and 7, 2018, while PFP demolition work was on hold, samples were collected from 19 locations near the facility. Results from this 2018 sampling event are included in this report on 2017 sampling events for clarity and timeliness. The analyte list for this event was limited to contaminants known to be present at PFP (i.e., plutonium,

americium, and gamma-emitting radionuclides). Analytical results show radionuclide concentrations and frequencies of detection similar to those seen in previous years at these locations and at other locations in the 200-West Area. Appendix C, Table C-8 presents the data from samples collected near PFP.

9.2 Radiological Contamination Surveys

JE Cranna, JW Wilde

Radiological surveys are performed in and near Hanford operational areas to monitor the presence or movement of radioactive materials or to verify radiological conditions at specific project sites. All sites are field surveyed for alpha and beta-gamma radiation.

Radiological surveys performed in 2017 identified 16 instances of radiological contamination in surface soil. Of the 16, 12 were posted as contamination areas and the other four were cleaned up and disposed of onsite in licensed burial grounds. Table 9-4 summarizes the general locations of soil contamination incidents discovered during 2017 and Table 9-5 provides the number of contamination incidents from 2000 through 2017.

Table 9-4. Hanford Site Soil Contamination Incidents discovered in 2017.

Location	2017 Incidents
100 Area	2
200-East Area	
Tank farms	1
Burial grounds	0
Cribs, ponds, and ditches	9
Fencelines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	0
Liquid Effluent Treatment Facility/Effluent Treatment Facility	0
Miscellaneous	1
200-West Area	
Tank farms	2
Burial grounds	0
Cribs, ponds, and ditches	0
Fencelines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	0
Miscellaneous	0
Cross-site transfer line	0
200-BC cribs and trenches	0
200-North Area	0
300 Area	1
400 Area	0
600 Area	2
Total	16

**Table 9-5. Hanford Site Soil Contamination
Incidents from 2000 through 2017.**

Year	Incidents
2000	25
2001	20
2002	22
2003	30
2004	19
2005	20
2006	25
2007	17
2008	16
2009	28
2010	22
2011	10
2012	10
2013	21
2014	22
2015	20
2016	17
2017	16

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RC-PRO-RC-60561. *Environmental Soil Sampling*. Rev. 9. Mission Support Alliance, LLC, Richland, Washington.

2017 Highlight

Routine Vegetation Sampling

A total of 50 vegetation samples were collected on the Hanford Site in 2017. The concentrations of radionuclides in these samples are consistent with those seen in previous years.

Wildlife Surveillance

Hanford collects and analyzes wildlife samples that sportsmen may collect. In 2017, mountain whitefish, walleye, Canada goose and cottontail rabbit were collected and submitted to laboratories for radiological and metals analyses. A total of 47 animals were collected in 2017.

10.0 Biota Monitoring

JR Draper

The U.S. Department of Energy's (DOE) subcontractor Mission Support Alliance (MSA) monitors the biota, including state and federally listed species, to assess the abundance, vigor or condition, and distribution on the Hanford Site. The associated data is used by DOE and Hanford Site contractors to support environmental cleanup and restoration activities, mitigation actions, and land use planning and to maintain compliance with ecological resource laws. MSA's Ecological Compliance staff conducts ecological compliance reviews for most projects on the Hanford Site to determine if the proposed scope of work will adversely impact biological resources and to provide recommendations to reduce environmental impacts.

10.1 Agricultural Monitoring

ME Hoefer

Food and farm products (i.e., alfalfa, cherries, corn, leafy vegetables, melons, milk, potatoes, tomatoes, and wine must) were collected in 2017 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 microsievert [μSv]/yr) threshold and ingestion pathways for annual intake, assuming 100% of each food originated in the affected area.

Water removed from the river immediately downstream of the Hanford Site is used to irrigate a small portion of agricultural crops in Benton and Franklin counties. The majority of irrigation water utilized by Franklin County residents originates at Grand Coulee Dam and is provided through its extensive water delivery systems (i.e., canals). Likewise, Benton County relies heavily on the Yakima River for irrigation purposes.

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 the following:

- Analytical results obtained from similar samples collected from the same regions over long periods of time
- Samples collected at downwind locations to results from samples obtained from generally upwind or distant locations
- 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 2017 were below the analytical laboratory detection levels; however, some potential Hanford Site-produced contaminants (e.g., tritium) were found at low levels in some samples. Data for potassium-40 and beryllium-7 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/yr (10 μ Sv/yr) (DOE/RL-91-50). Agricultural products sampled in 2017 are listed in Table 10-1 and described in the following sections.

10.1.1 Milk

Milk samples were obtained quarterly in 2017 from several dairies in the East Wahluke and Sagemoor sampling areas. Milk was obtained from one dairy in the Sunnyside area during the first two quarters of 2017. The Sunnyside area dairy closed in July 2017 and personnel were unable to collect a third quarter sample.

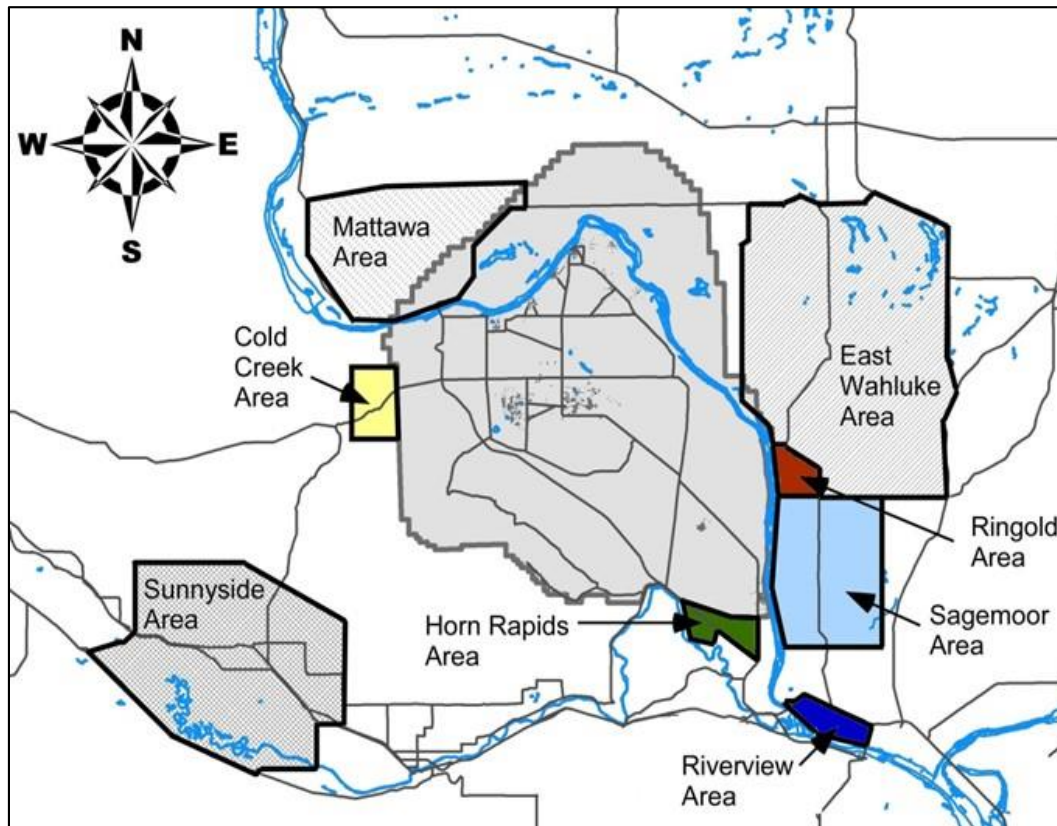


Figure 10-1. Agricultural Monitoring Locations.

NOTE: Duplicate information may or may not be included in this data.

Table 10-1. Agricultural Monitoring Location.

Product	Sampling Locations	Analytes
Apricots	East Wahluke, Riverview, Sagemoor, and Sunnyside	^{14}C , Gamma, Sr-90
Corn	East Wahluke, Riverview, Sagemoor, and Sunnyside	^{14}C , Gamma, Sr-90
Leafy vegetables	Riverview, Sagemoor, and Sunnyside	Gamma, Sr-90
Melons	East Wahluke, Riverview, Sagemoor, and Sunnyside	^{14}C , Gamma, Sr-90
Milk	East Wahluke, Sagemoor, and Sunnyside	Gamma, Sr-90, Tritium
Potatoes	East Wahluke, Riverview, and Sunnyside	Gamma, Sr-90
Tomatoes	Riverview and Sunnyside	Gamma, Sr-90, Tritium
Wine must	Columbia Basin, Mattawa, and Yakima Valley	Low-level Tritium, Gamma

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 was 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 strontium-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 dairy generally upwind of the Hanford Site.

10.1.1.1 Tritium. Tritium was detected in all milk samples collected in 2017. Twelve samples were collected but only seven were analyzed due to laboratory issues with five samples. Overall concentrations of the seven detections ranged from a maximum of 36 pCi/L (1.3 Bq/L) in a Sagemoor area sample to a minimum of 14 pCi/L (0.52 Bq/L) in an East Wahluke area sample. Annual average concentrations for the three sampling areas were 25 pCi/L (0.93 Bq/L). Specific location average was 27 pCi/L (1.0 Bq/L) for Sagemoor (n = 3); 23 pCi/L (0.85 Bq/L) for East Wahluke (n = 3); and 25 pCi/L (0.93 Bq/L) for Sunnyside (n = 1). Overall averages were similar to historical concentrations in all areas.

10.1.1.2 Strontium-90. No detectable concentrations were found in 2017 milk samples.

10.1.1.3 Cesium-137. No synthetic gamma emitters were detected in milk samples collected and analyzed in 2017.

10.1.1.4 Potassium-40. Naturally occurring potassium-40 was detected in all milk samples collected in 2017. Concentrations ranged from a maximum of 1,640 pCi/L (61 Bq/L) in a Sagemoor area sample to a minimum of 1,300 pCi/L (48 Bq/L) in an East Wahluke sample. The Sunnyside area had a maximum of 1,450 pCi/L (54 Bq/L) and the overall average was 1,472 pCi/L (54 Bq/L) for all results.

10.1.2 Fruit, Vegetables, and Farm Products.

Alfalfa, cherries, corn, leafy vegetable (e.g., lettuce), melon, potato, tomato, and wine must samples were collected from upwind and downwind sampling areas during the 2017 growing season (Figure 10-1; Table 10-1). All fruit and vegetable samples were analyzed for gamma-emitting radionuclides and strontium-90. Corn, leafy vegetables, and melons were also analyzed for carbon-14 for additional monitoring due to support Waste Treatment Plant monitoring. Wine must was analyzed for gamma-emitting radionuclides and low-level tritium. Tomato samples were also monitored for tritium (Table 10-1) and showed no detectable concentrations during 2017.

Two alfalfa samples (Sagemoor, Sunnyside) and two leafy vegetable samples (East Wahluke, Sagemoor) had detectable concentrations of beryllium-7; however, these concentrations were within historical range and follow typical result patterns. One cherry sample (Riverview) and one additional sample of leafy vegetables (East Wahluke) had detections of strontium-90, but values reported were well below DOE project dose-based reporting limits and were within historical limits measured at these locations. All fruit and vegetable concentrations of cesium-137, cobalt-60, and tritium were reported as non-detects and were well within historical range.

All but one wine must sample collected in 2017 had detectable concentrations of tritium but were well within the historical range. Mattawa area wine must had an average of 5.7 pCi/L while the Columbia River Priest Rapids Dam fixed-station water average was 14.9 pCi/L. The Columbia Basin area winery had an annual tritium average of 39.2 pCi/L while the Columbia River Richland Pumphouse fixed-station water had an annual average of 24.5 pCi/L. Irrigation results in the Riverview (15.3 pCi/L) and Horn Rapids (16.4 pCi/L) area were similar to wine and the fixed-station location in Richland as slightly higher average concentrations were reported when compared to upriver and distant community locations. All

wine values for 2017 were well below the Washington State drinking water standard of 20,000 pCi/L (740 Bq/L).

All alfalfa, cherry, corn, leafy vegetable, melon, potato, tomato, and wine must samples had detectable concentration levels of naturally occurring potassium-40.

10.2 Fish and Wildlife Monitoring

JW Wilde

The fish and wildlife species sampled and analyzed for Hanford Site operations-produced contaminants during the 2017 calendar year included mountain whitefish (*Prosopium williamsoni*), walleye (*Prosopium williamsoni*), 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 offsite human consumption. Figure 10-2 shows the locations on and around the Hanford Site where fish and wildlife were collected in 2017. Samples of fish and wildlife were analyzed for selected (suspected or known to be present at the Hanford Site) 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.

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.

Table 10-2. Number of Wildlife Monitoring Samples Submitted for Analysis.

Biota	Offsite Locations	Onsite Locations	Gamma	Strontium-90	Trace Metals
Fish (mountain whitefish)	1	2	10	10	2
Fish (walleye)	1	2	15	15	4
Mammals (cottontail)	0	1	1	1	0
Waterfowl (Canada goose)	1	2	11	11	0

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, strontium-90 has a biological half-life in hard tissue from 14 to 600 days ([PNL-9394](#), *Ecotoxicity Literature Review of Selected Hanford Site Contaminants*).

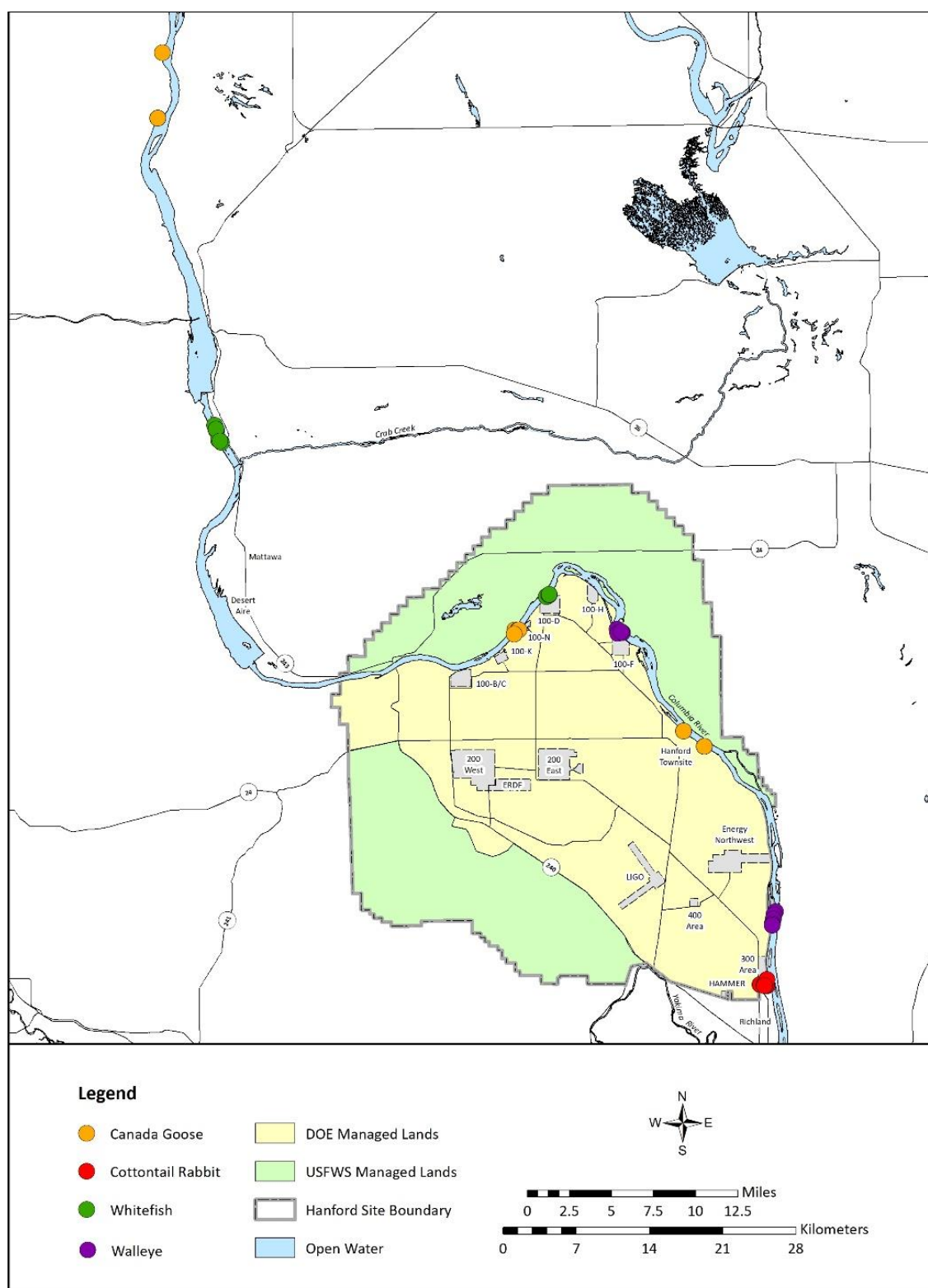


Figure 10-2. Animal Monitoring Locations.

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](#)]).

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 2017, 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 two locations along the Hanford Reach, including a Reference Area (eight along the 100-D shoreline and eight from the reference location at Priest Rapids Lake above Priest Rapids Dam). One whole fish from the 100 Areas was sent to the WDOH. Five samples including one duplicate and one split sample used composited fish to achieve sample mass. Four fish from the 100 Areas created one composite, and four fish from the Reference Area made up the other. A total of 10 samples were comprised of the 16 collected fish, 8 in the 100 Areas and 8 from the Reference Area. 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 detected in a single split sample from the Reference Area, the parent sample did not show detectable results. Strontium-90 was not detected above the required limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in whitefish samples collected from the Reference Area or the Hanford Reach location.

Uranium. Uranium isotopes (uranium-234, uranium-235, uranium-238) were detected in two samples submitted. One sample was from the Reference Area above Priest Rapids Dam and a single sample from the Hanford Reach. Uranium-234 was reported at 1.05E-02 pCi/g in the 100 Area sample and 1.02E-02 pCi/g in the Reference Area sample. Uranium-238 was only detected in the 100 Area sample at 1.05E-02 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 2017 metal analyses for the whitefish samples.

Table 10-3. Metals Analyses for the Mountain Whitefish Samples.

Isotope	Samples	Detects
Aluminum	2	0
Antimony	2	0
Arsenic	2	0
Barium	2	0
Beryllium	2	0
Cadmium	2	0
Chromium	2	2
Copper	2	2
Lead	2	0
Manganese	2	0
Mercury	2	2
Nickel	2	0
Selenium	2	2
Silver	2	0
Thallium	2	0
Thorium	2	0
Uranium	2	0
Zinc	2	2

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. The Washington Department of Health lists mountain whitefish as a species retaining high concentrations of

chemical contaminants and metals, and consumption should be limited to one meal per month (<https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories>).

10.2.2 Walleye

In 2017, walleye were sampled and analyzed for radiological contaminants, walleye are a major game fish and a favorite food along the Hanford Reach of the Columbia River for anglers, which could potentially contribute to human exposure through digestion. Many sportsmen have found that the flesh of the walleye is one of the best eating freshwater fish anywhere.

Sixteen walleye were collected from three locations along the Hanford Reach, including a Reference Area (five from waters adjacent to the 100 Areas, five fish from waters adjacent to the Hanford Townsite through the 300 Area and six fish from Priest Rapids Lake above Priest Rapids Dam). One whole fish from each area was sent to the WDOH. A total of fifteen samples (including 2 duplicates and a single split sample) were comprised of the 13 remaining fish. The following are the radiological results for the 15 walleye samples analyzed.

Cesium-137. Manmade gamma-emitting radionuclides including cesium-137 was detected in only one sample (0.0412 pCi/g) above the reporting limit (0.03 pCi/g [0.001 Bq/g] wet weight) for the muscle samples analyzed. These results are consistent with those reported historically near the Hanford Site.

Strontium-90. Strontium-90 was detected in a single split sample from the Reference Area, the parent sample did not show detectable results. Strontium-90 was not detected above the required limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in any of the additional walleye samples collected from the Reference Area or the Hanford Reach location. The single sample detection was (0.103 pCi/g [0.0038 Bq/g]) from the 100 Areas. This sample was obtained from carcass (bone and tail) of this fish and would not be a normally consumed portion of the fish.

Uranium. Uranium isotopes (uranium-234, uranium-235 and uranium-238) were detected in a single sample submitted. The single sample from the Hanford Reach was collected in waters adjacent to the Hanford Townsite through the 300 Area. Uranium-234 was reported at 5.17E-03 pCi/g (1.91E-04 Bq/g) in the 100 sample

Trace Metals. Four whitefish samples were analyzed for 18 different trace metal concentrations. Only four trace metals were detected in samples that were above the analytical detection limit at any location. Table 10-4 provides a summary of the 2017 metal analyses for the whitefish samples. Uranium metal detections in these analyses are not radioactive isotopic analyses as described in the paragraph above.

Table 10-4. Metals Analyses for the Mountain Whitefish Samples. (2 Pages)

Isotope	Samples	Detects
Aluminum	4	0
Antimony	4	1
Arsenic	4	0
Barium	4	0
Beryllium	4	0

Table 10-4. Metals Analyses for the Mountain Whitefish Samples. (2 Pages)

Isotope	Samples	Detects
Cadmium	4	0
Chromium	4	0
Copper	4	0
Lead	4	0
Manganese	4	0
Mercury	4	4
Nickel	4	0
Selenium	4	0
Silver	4	0
Thallium	4	0
Thorium	4	0
Uranium	4	2
Zinc	4	4

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. The Washington Department of Health lists walleye as medium concern as a species retaining concentrations of chemical contaminants and metals within the Hanford Reach, and consumption should be limited to two meals per month

(<https://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories>).

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 2017, Nuttall's cottontails 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. A single cottontail rabbit was collected from the 300 Area. The following data is from the single sample analyzed.

Cesium-137. Cesium-137 was not found above detection limits (0.03 pCi/g [0.001 Bq/g] wet weight) in the cottontail rabbit sample submitted for analysis in 2017. This result is consistent with a decline in cesium-137 levels in wildlife examined from the preceding years.

Strontium-90. No strontium-90 was detected in the single rabbit captured in 2017. 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. In addition, maximum concentrations in the figure are represented by the upper bar.

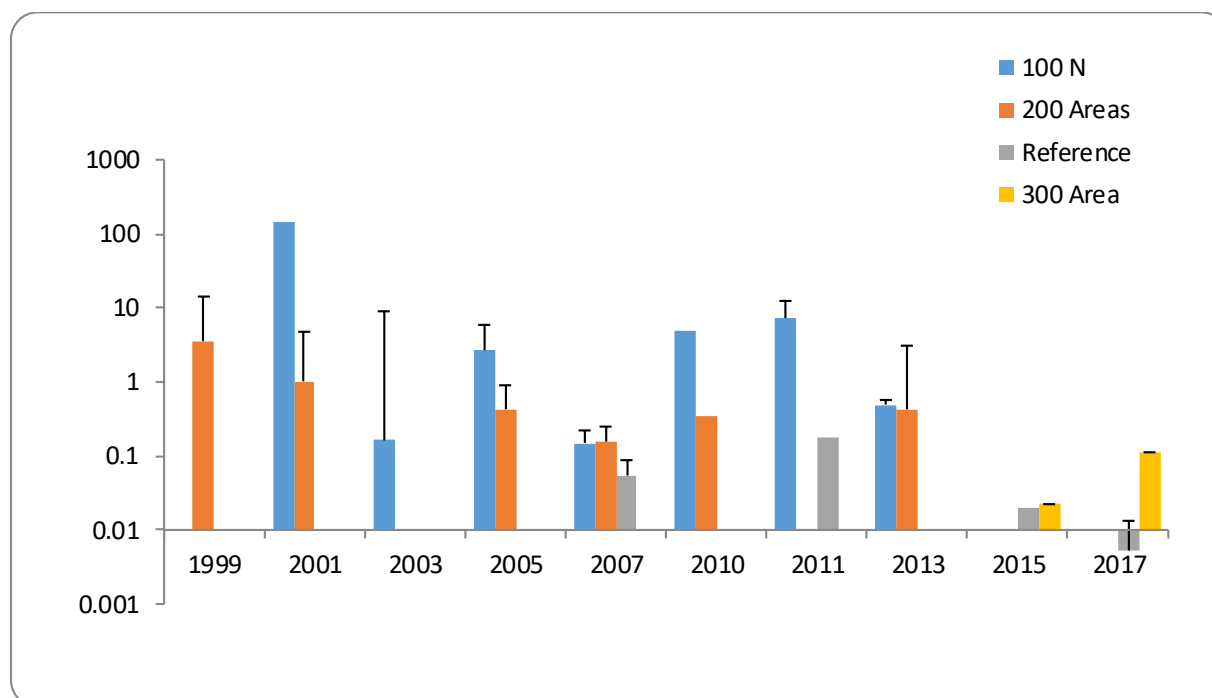


Figure 10-3. Strontium-90 Concentrations in Cottontail Bone Samples.

10.2.4 Waterfowl

During 2017, 14 Canada geese were collected along the Hanford Reach of the Columbia River: 6 between the Hanford Townsite and the 300 Area, 4 near the 100 Areas, and 4 geese from the Reference Area in the Wanapum pool area. Sampling efforts focused on young of the year birds whose entire life cycle before collection would have occurred on the Hanford Site. Three geese were submitted to WDOH, the remaining 11 geese were monitored for cesium-137 in muscle and strontium-90 in bone. Radionuclide levels found in muscle and bone samples analyzed during 2017 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 2017. 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 was detected in a single split sample, the parent of the split showed no detectable concentrations. The remaining samples were below the analytical detection limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in samples collected in 2017. Comparisons of the maximum and median strontium-90 concentrations reported for waterfowl bone samples (collected at the Hanford Site since 1999) 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 2017 compared to previous years. Note that maximum concentrations in the figure are represented by the upper bar.

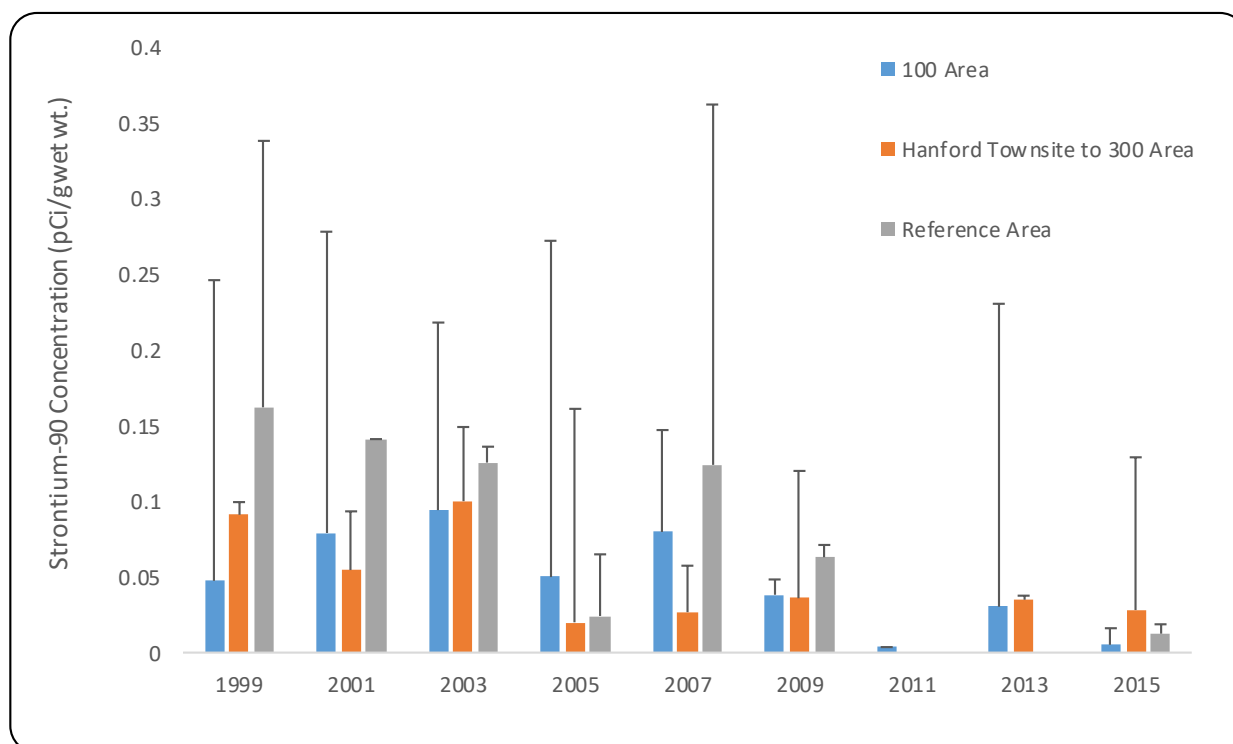


Figure 10-4. Strontium-90 Concentrations in Canada Goose Bone Samples.

10.3 Vegetation Monitoring

JE Cranna

Radiological monitoring of native vegetation is conducted onsite near Hanford facilities and operations, and onsite away from facilities and operations. Vegetation sampling is also performed offsite at perimeter and distant locations and in nearby communities. Contaminant data collected are used to:

- Determine the effectiveness of effluent monitoring and controls within facilities
- Assess the adequacy of contaminant containment at waste disposal sites, waste site remediation, and contamination areas
- Detect and monitor unusual conditions associated with a potential release or spread of radioactive material
- Provide long-term radionuclide contamination trends
- Provide complimentary monitoring to airborne sampling methods for atmospheric releases.

Vegetation is an integrating sample medium that accounts for contaminants released to the atmosphere either directly (gaseous effluent), indirectly (re-suspension/deposition), or through liquid effluent waste streams that are subsequently used for irrigation or from uptake of contaminants via their root system.

Deep-rooted vegetation (e.g., tumbleweeds, sagebrush) growing over underground sources of radionuclides may selectively uptake contaminants (e.g., cesium, strontium) into their tissues. When radionuclides are transported from roots to above surface portions of the plant, surface contamination may result, which poses a potential risk of environmental/biological transport or human contact.

Vegetation samples have been collected on and around the Hanford Site for more than 50 years, and a significant data set exists that documents onsite and offsite levels of manmade radionuclides in and around the Hanford Site. These data provide a baseline to which unplanned releases are compared.

Vegetation samples from offsite locations are collected every 3 to 5 years and were last collected in 2015. Offsite vegetation sampling is used for long-term trend analysis and is not used in dose model calculations. The sampling frequency of every 3 to 5 years is consistent with the guidance provided in [DOE-HDBK-1216-2015](#), *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

10.3.1 Hanford Site Vegetation Monitoring

Vegetation samples are collected on or adjacent to waste disposal sites, as well as from locations downwind, near, or within the boundaries of operating facilities and remedial action sites.

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 location and analyses of vegetation samples collected in 2017 are depicted in Table 10-5. The number of vegetation samples per operational area are summarized in Table 10-6.

Table 10-5. Hanford Site Vegetation Monitoring Locations and Sample Analyses.

Location	EDP Codes ^a	Collection Period	Analyses
100-N Area	Y719, Y724	September	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
200-East Area	V053 ^b , V055, V057, V061, V063 ^c , V065, V075, V076, V077, V078, V079, V141 ^b	May	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
200-West Area	V015 ^b , V019, V025 ^c , V029, V037, V039, V041, V043, V047, V049, V051, V139 ^b	May	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
Plutonium Finishing Plant (200-West Area)	V007 ^b , V009, V031, V045 ^c , V111 ^b	May	⁹⁰ Sr, Pu-iso, U-iso, GEA, ²⁴¹ Am
300 Area ^(e)	V123 ^{b, c} , V132 ^b	May	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
400 Area	V130	May	⁹⁰ Sr, Pu-Iso, U-Iso, GEA
600 Area	V081, V083 ^b , V085 ^c , V087, V089, V091, V095, V097 ^b , V099, V101, V103, V105, V107, V109, V113 ^b , V143 ^b	May	⁹⁰ Sr, Pu-Iso, U-Iso, GEA

^a EDP Code=environmental data point code = sample location code
^b Quality assurance duplicate sample
^c Collocated sampling location with WDOH
 ERDF = Environmental Restoration Disposal Facility
 ETF = Effluent Treatment Facility
 GEA = Gamma Energy Analysis
⁹⁰Sr = Strontium-90
²⁴¹Am = Americium-241
 Pu-iso = isotopic plutonium (²³⁸Pu, ^{239/240}Pu)
 U-iso = isotopic uranium (²³⁴U, ²³⁵U, ²³⁸U)
 WDOH = Washington State Department of Health

Table 10-6. Number of Vegetation Samples per Operational Area.

Number of Samples	Operational Area (discrete samples analyzed)					
	100-N	200-East ^a	200-West ^a	300 Area ^a	400 Area	600 Area ^a
50	2	12	17	2	1	16

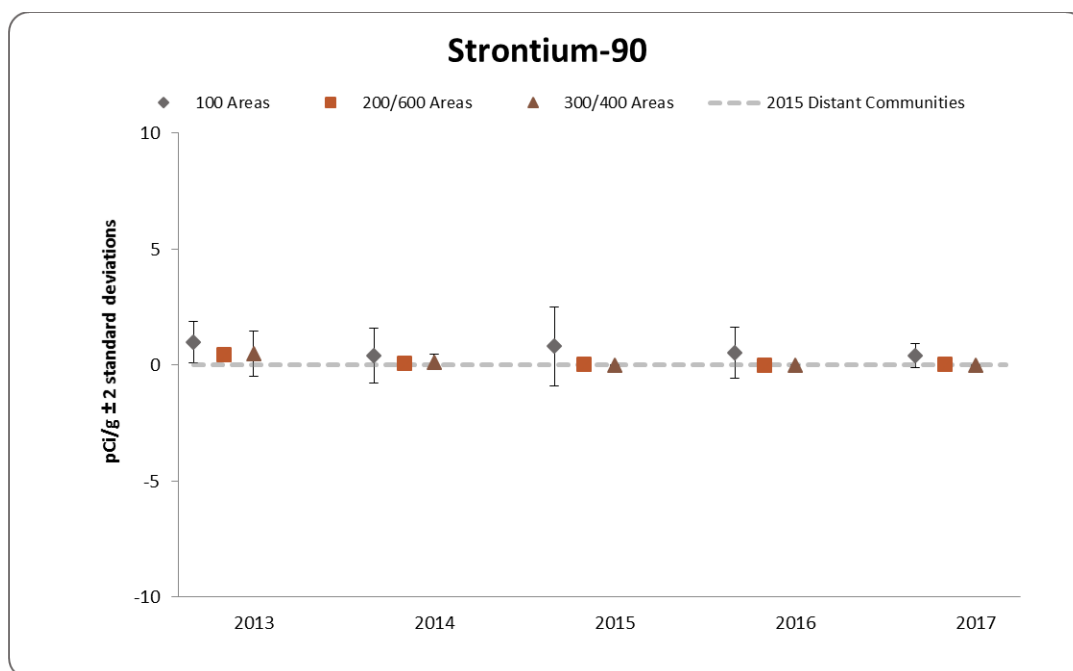
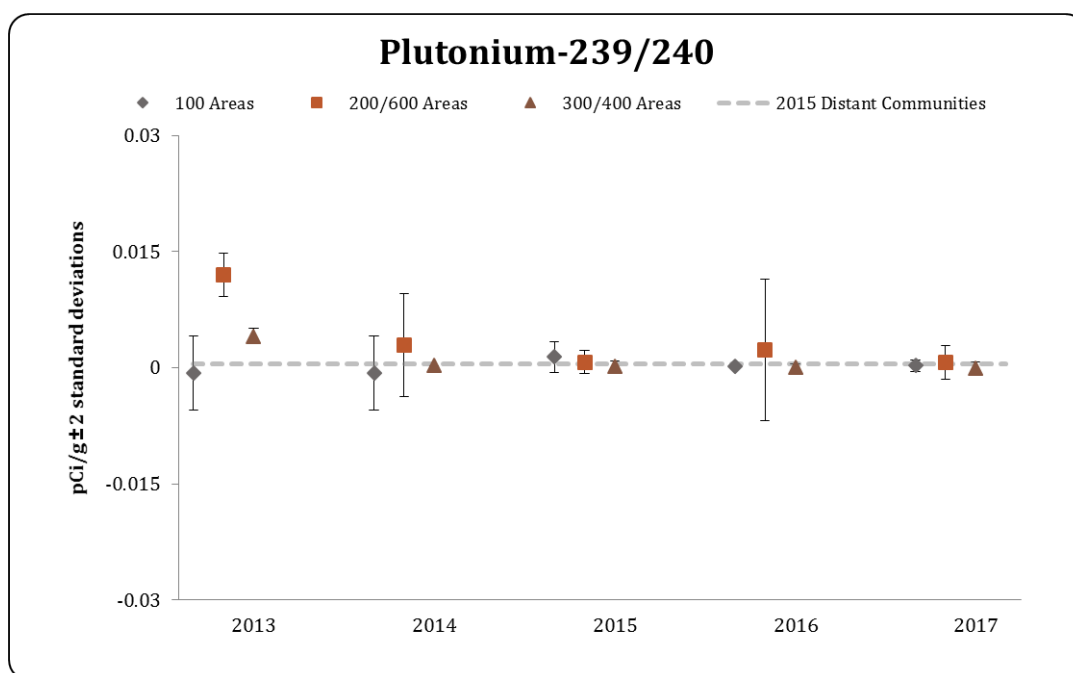
^a Includes one or more duplicate samples.

10.3.1.1 Sampling and Analysis. Samples were collected and analyzed according to DOE/RL-2013-53, *Hanford Site Environmental Surveillance Master Sampling Schedule for Calendar Year 2017*. Onsite vegetation samples are collected annually. Collections in the 200 and 600 Areas are alternated between even and odd numbered years, aligning with even and odd numbered sample locations. Individual vegetation samples (approximately 17.6 oz [500 g]) consist 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 are dried prior to analyses and analytical results are reported on a dry weight basis.

Vegetation samples were analyzed for strontium-90, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239/240, and gamma-emitting radionuclides. In support of the current deactivation and decommissioning (D&D) project at the Plutonium Finishing Plant (200-West Area), and especially for monitoring during the demolition of the Americium Recovery Facility, an americium-241 alpha energy analysis was added to the analyte list at four vegetation monitoring locations (V007, V009, V031, and V045) near the PFP complex.

10.3.1.2 Vegetation Monitoring Results. The analytical results from Hanford Site vegetation samples collected in 2017 were compared with concentrations of radionuclides measured in samples collected offsite at various locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin Counties in 2015. These comparisons are used to differentiate concentrations of Hanford Site-produced contaminants from levels resulting from natural sources and worldwide fallout.

In general, radionuclide concentrations in vegetation samples collected from or adjacent to waste disposal facilities in 2017 were similar to or slightly higher than concentrations in samples collected further away, including concentrations measured offsite in 2015. Cesium-137, strontium-90, plutonium-239/240, uranium-234, and uranium-238 were detected in the 2017 vegetation samples at locations and concentrations consistent with previous years. Figure 10-5 shows the annual average vegetation concentrations of selected radionuclides in the 100, 200, 300, 400, and 600 Areas. Appendix C, Table C-20 shows the annual average and maximum concentrations of radionuclides in vegetation samples by area during 2017 and for the preceding 5 years.



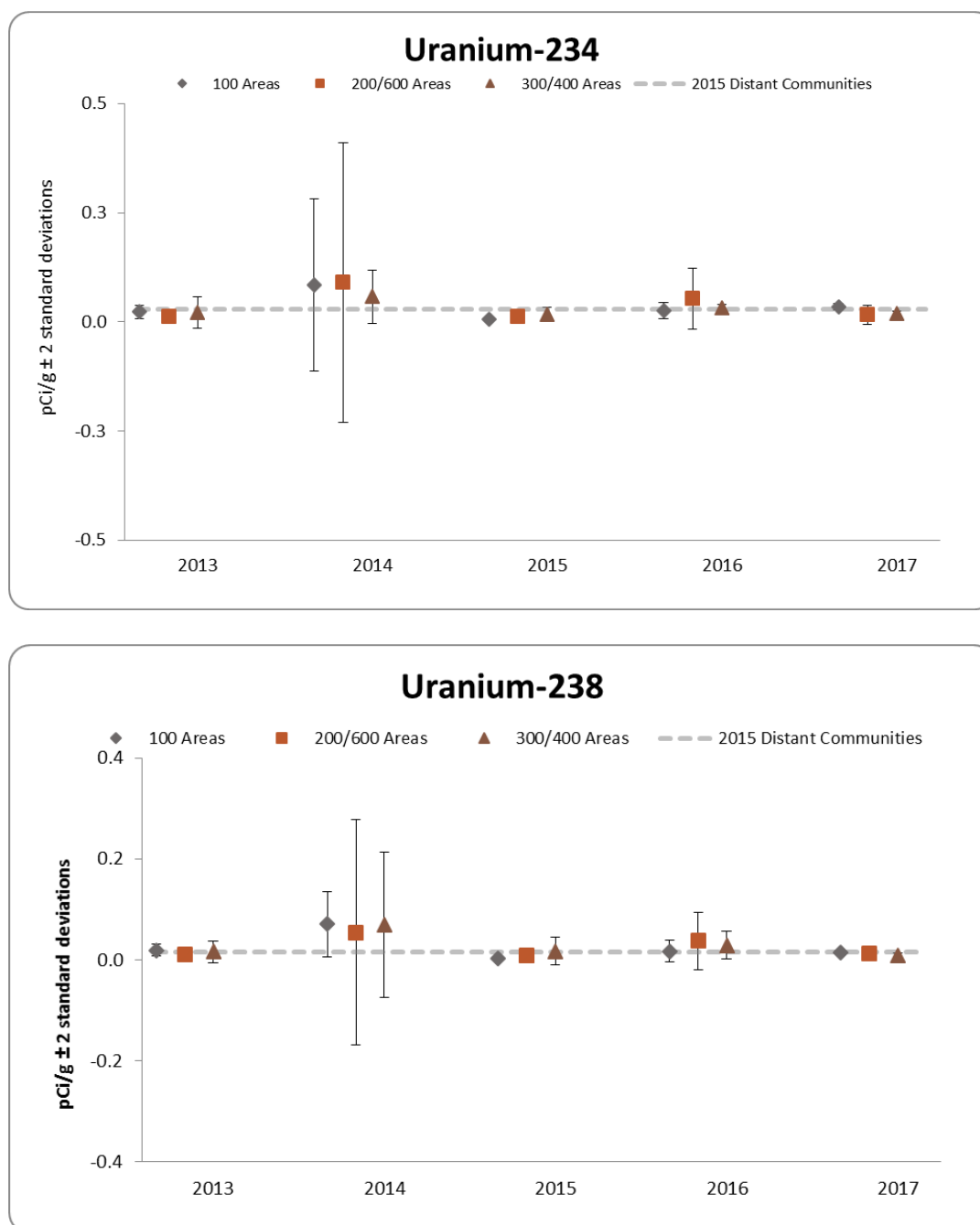


Figure 10-5. Hanford Site Vegetation Average Concentrations of Select Radionuclides.

Uranium. Uranium-234, uranium-235, and uranium-238 were detected in approximately 70% of the vegetation samples at concentrations that were consistent with historical concentrations. The uranium levels are a result of uranium releases to the environment during past fuel-fabrication operations in that area.

Plutonium. Plutonium-239/240 was detected in 36% of the vegetation samples collected in the 200 and 600 Areas. Plutonium-239/240 concentrations were slightly below historical ranges.

Strontium-90. Strontium-90 was detected in both samples collected at 100-N and in approximately 18% of the samples in the 200 and 600 Areas. Concentrations of strontium-90 were within historical ranges

Cesium-137. Cesium-137 was detected in two samples in the 200 Areas. One sample from the 200-East Area had a slightly elevated cesium-137 concentration compared to historical data.

10.3.2 Radiological Contamination Surveys

JE Cranna, JW Wilde

Radiological surveys are performed in and near Hanford operational areas to monitor the presence or movement of radioactive materials or to verify radiological conditions at specific project sites. All site are field surveyed for alpha- and beta-gamma radiation.

Radiological surveys performed in 2017 identified 23 instances of radiological contamination in vegetation; all 23 were Russian thistle (*Salsola tragus*) plants or fragments. Of the 23, one location was posted as a contamination area and 22 were cleaned up and disposed of at a licensed facility.

Section 10.3.3 provides a discussion of the vegetation control on the Hanford Site. Table 10-7 summarizes the general locations of vegetation contamination incidents discovered in 2017. Table 10-8 provides the number of contamination incidents from 2000 to 2017.

Table 10-7. Hanford Site Vegetation Contamination Incidents Discovered in 2017. (2 Pages)

Location	2016 Incidents
100 Area	0
200-East Area	
Tank farms	2
Burial grounds	2
Cribs, ponds, and ditches	1
Fence lines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	0
LERF/ETF	6
Miscellaneous	1
200-West Area	
Tank farms	5
Burial grounds	3
Cribs, ponds, and ditches	1
Fence lines	0
Roads and railroads	0
Unplanned release sites	0
Underground pipelines	1
Miscellaneous	1

Table 10-7. Hanford Site Vegetation Contamination Incidents Discovered in 2017. (2 Pages)

Location	2016 Incidents
Cross-site transfer line	0
600 Area burial grounds	0
200-North Area	0
300 Area	0
400 Area	0
600 Area	0
1100 Area	0
Total	23
ETF = Effluent Treatment Facility	
LERF = Liquid Effluent Treatment Facility	

Table 10-8. Hanford Site Vegetation Contamination Incidents from 2000 through 2017.

Year	Incidents
2000	66
2001	20
2002	16
2003	32
2004	60
2005	66
2006	75
2007	62
2008	127
2009	109
2010	36
2011	10
2012	18
2013	35
2014	50
2015	48
2016	45
2017	23

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 4,689 ac (1,898 ha) were treated with herbicides in 2017 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, 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 72 ac (29 ha) of noxious weeds on the Hanford Site were treated with herbicides in 2017 on rangeland, industrial areas, along roadways, and abandoned rail lines.

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 2017 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 2017 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. If diligent control efforts are continued over the next few years, the yellow starthistle population at Hanford can change 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 the 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 aerial 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. In 2017, rush skeletonweed was controlled over several hundred acres spread among three of the populations at 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 south of the Wye Barricade. Reduction in active control efforts over the past few years 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 and thereby prevent flowering and seed production. The plants can 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 not controlled in 2017 due to limited resources for the effort.

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 2017, applications of herbicide were used to control knapweed on hundreds of acres of rangeland, on roadways and railroad right-of-ways, 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. Several biological control agents are established at the Hanford Site.

Tackweed (Tribulus terrestris). Tackweed has become increasingly common on the Hanford Site over the past several years. In 2017, tackweed at the Hanford Site was controlled by manually removing weeds in critical areas.

Purple Loosestrife (Lythrum salicaria). The banks of the Columbia River and islands along the Hanford Site are monitored for purple loosestrife. 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 water levels along the Columbia River destroy the biological control organisms as they attempt to over-winter in the soil at the base of the plants. Winter mortality prevents

effective population control agents from developing. No control measures were applied in 2017 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 2016. 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 2016 and 2017 was not sufficient for effective herbicide application. It is expected that these trees will be sprayed with herbicide in 2018.

Spotted Knapweed (*Centaurea maculosa*). Spotted knapweed at the Hanford Site has been controlled so that sprouts or seedlings are rare. In 2017, 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 near the Hanford Site; however, it is expected that the population is too small and scattered to sustain a biological control population. *Cyphocleonus* is known to use diffuse knapweed. 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.

10.4 Waste Site Remediation and Revegetation

RC Roos, JM Rodriguez

In 2017, only 1 ac (0.4 ha) across the Hanford Site was 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 waste sites. In the past few years, trial plots combining grass seeding with fertilizer treatment has shown great promise for establishing robust populations of perennial grass. As resources are made available, trial plots will be expanded into production level trials.

Vegetative caps on waste sites perform three primary functions:

- **Prevent Erosion.** A well-designed and maintained grass cap stabilizes soil and prevents erosion on waste sites by physically covering the soil surface and serves as a windbreak, reducing wind velocity at the soil surface.
- **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 in the wind, 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.

- **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 to 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.

10.5 References

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2017 Highlight

A project to review and assess the current regional conservation priority of previously identified plant communities and to identify additional communities that may be of conservation concern was completed for the DOE-managed portions of the Hanford Site.

Hanford Site archaeologists completed 75 NHPA Section 106 cultural resources reviews

11.0 Resource Protection

11.1 Ecological Protection

JW Wilde, KJ Cranna, JE Grzyb, ES Norris, JJ Nugent, JA Pottmeyer

Ecological monitoring is performed on the Hanford Site to collect and track data needed to ensure compliance with various environmental laws, regulations, and policies governing U.S. Department of Energy (DOE) activities. Ecological monitoring data provide baseline information about the plants, animals, and habitat under DOE stewardship at Hanford required for decision making under the [National Environmental Policy Act of 1969](#) (NEPA) and [Comprehensive Environmental Response, Compensation, and Liability Act of 1980](#) (CERCLA).

The DOE/EIS-0222-F, [Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement](#), (CLUP) evaluated future land-use planning at the Hanford Site to facilitate decision making about the site's uses and facilities for a 50-year period. DOE adopted the CLUP to balance land-use with the preservation of important ecological and cultural values of the Hanford Site.

The DOE/RL-96-32, [Hanford Site Biological Resources Management Plan](#), (BRMP) is identified by the CLUP as the primary plan 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]¹ 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 through 5), providing a graded approach to monitoring biological resources based on the level of concern for each resource.

¹The CLUP document uses a different acronym (BRMaP, in place of BRMP used here) for abbreviating the *Hanford Site Biological Resource Management Plan* document.

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*](#); [*Bald and Golden Eagle Protection Act*](#); [*Migratory Bird Treaty Act of 1918*](#) (MBTA); as well as compliance with executive orders, DOE Orders, and DOE resource management guidance
- Providing data for environmental impact and ecological risk assessments
- 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 Community Element Occurrences

JA Pottmeyer

In 2017, a project to review and assess the current regional conservation priority of previously identified plant communities and to identify additional communities that may be of conservation concern was completed for the DOE-managed portions of the Hanford Site. Plant communities that are considered rare or relatively unprotected and vulnerable to disturbance are considered a conservation priority and are tracked by the Washington State Natural Heritage Program (WNHP) as an element occurrence. Central Hanford represents a large area that has not been converted to agricultural or other uses, so some of the dominant plant communities onsite are high priorities for conservation in Washington. Particularly significant for the Hanford Site is the high conservation status of active and stabilized dunes and shrub-steppe systems.

The 2017 study began with an evaluation of element occurrences that had been previously described for the Hanford Site. Field visits were made to each of these sites in the spring to evaluate condition, which was based upon the composition and relative coverage of species groups (i.e., shrubs, grasses, and forbs) and the amount of influence from invasive species. The sites were documented with a series of photo points that were revisited from earlier studies or established for this project. Subsequent to the field visits, sites likely to represent a regional conservation priority and qualify as an element occurrence were evaluated using Ecological Integrity Scorecards (Rocchio et al. 2017).

The following six areas on the Hanford Site were proposed as element occurrences as a result of this study:

- **Central Hanford Dunes** - 33,376 ac (13,507 ha). The Central Hanford dunes is a large dynamic system encompassing dunes at a range of amplitudes and at all stages of stabilization.
- **Dunes North of Gable Mountain** –2,078 ac (841 ha). Covering a smaller area than the Central Hanford Dunes, this dune field also consists of a mix of dune formations in several phases of stabilization.
- **Winterfat Community on Umtanum Ridge** –215 ac (87 ha). This habitat is within a basin shaped by basalt uplands on the southern slope of Umtanum Ridge. The winterfat (*Krascheninnikovia lanata*) – Sandberg bluegrass (*Poa secunda*) community is among one of the last known occurrences in Washington. This area was assessed prior to the fire on Umtanum Ridge in July 2017, and the post-fire survival of the winterfat component has not yet been determined.
- **Vernita Grade** –119 ac (48 ha). This community supports a higher diversity and cover of native forbs and microbiotic crust that are typically found in sagebrush steppe habitats. The cheatgrass (*Bromus tectorum*) cover is also generally lower.
- **North Slope of Gable Mountain** - 445 ac (180 ha). This area contains the largest occurrence of big sagebrush (*Artemisia tridentata*) / bluebunch wheatgrass (*Psuedoregnaria spicata*) habitat onsite. This setting also supports a generally higher diversity of forbs and microbiotic crusts than is typically found elsewhere in the region.
- **300 Area Dunes** –390 ac (158 ha). This dune area is primarily made up of stabilized components and is comprised of mature late seral-shrubs and a wide diversity of forbs.

Additional upland areas that did not meet the criteria for designation as element occurrences were identified as habitats that should be considered as conservation priorities on the Hanford Site. These areas include the following:

- Lithosols on Gable Mountain, Gable Butte, and Umtanum Ridge, particularly areas with rich assemblages of buckwheat species (*Eriogonum* spp.)
- Cliff and canyon areas on Umtanum Ridge
- Vernal pools on East Umtanum Ridge, Gable Butte, and Gable Mountain.

11.1.1.1 Vernal Pools. Shallow ephemeral wetlands, or vernal pools, in very small to rarely large depressions occur throughout the exposed, volcanic scablands on the Columbia Plateau. These pools are characterized by fresh water inundation for much of the winter and spring followed by dramatic lowering of the water table at the approach of summer. On the Columbia Plateau, vernal pools are geographically limited but can be locally common (Rocchio and Crawford 2015b). In the State of Washington, the Columbia Plateau Vernal Pool ecosystem is considered to be imperiled, that is with a high to moderate risk of extirpation (Rocchio and Crawford 2015a). Figure 11-1 shows a vernal pool on the Hanford Site.



Figure 11-1. Vernal Pool Area on Gable Butte (March 2017).

In 1997, during surveys done on the Hanford Site for the U. S. Department of Energy (DOE), The Nature Conservancy (TNC) located three previously undocumented clusters of approximately 20 vernal pools. The Hanford Site pools were located on the east end of Umtanum Ridge, in the central part of Gable Butte, and at the eastern end of Gable Mountain (TNC 1998). The fall and winter of 1996 through 1997 was unusually wet; 9.7 in. (25 cm) of precipitation fell from October 1996 through March 1997 compared with a normal (30-year average) precipitation of 4.85 in. (12.3 cm) during the same period. Snowfall during the fall and winter of 1996-97 totaled 40.5 in. (103 cm) compared with a normal snowfall of 15.3 in. (38.9 cm) (MSA 2018).

The fall and winter of 2016/2017 was also an unusually wet period with 6.86 inches (17.4 cm) of precipitation, which included 28 in. (71 cm) of snow falling between October and the end of February. During the late winter of 2017, the vernal pools documented in 1996 and 1997 were rediscovered and found to contain significant amounts of water. Roughly 25 vernal pools were found on Umtanum Ridge, Gable Butte, and Gable Mountain during 2017. The locations of these pools are shown in Figure 11-2.

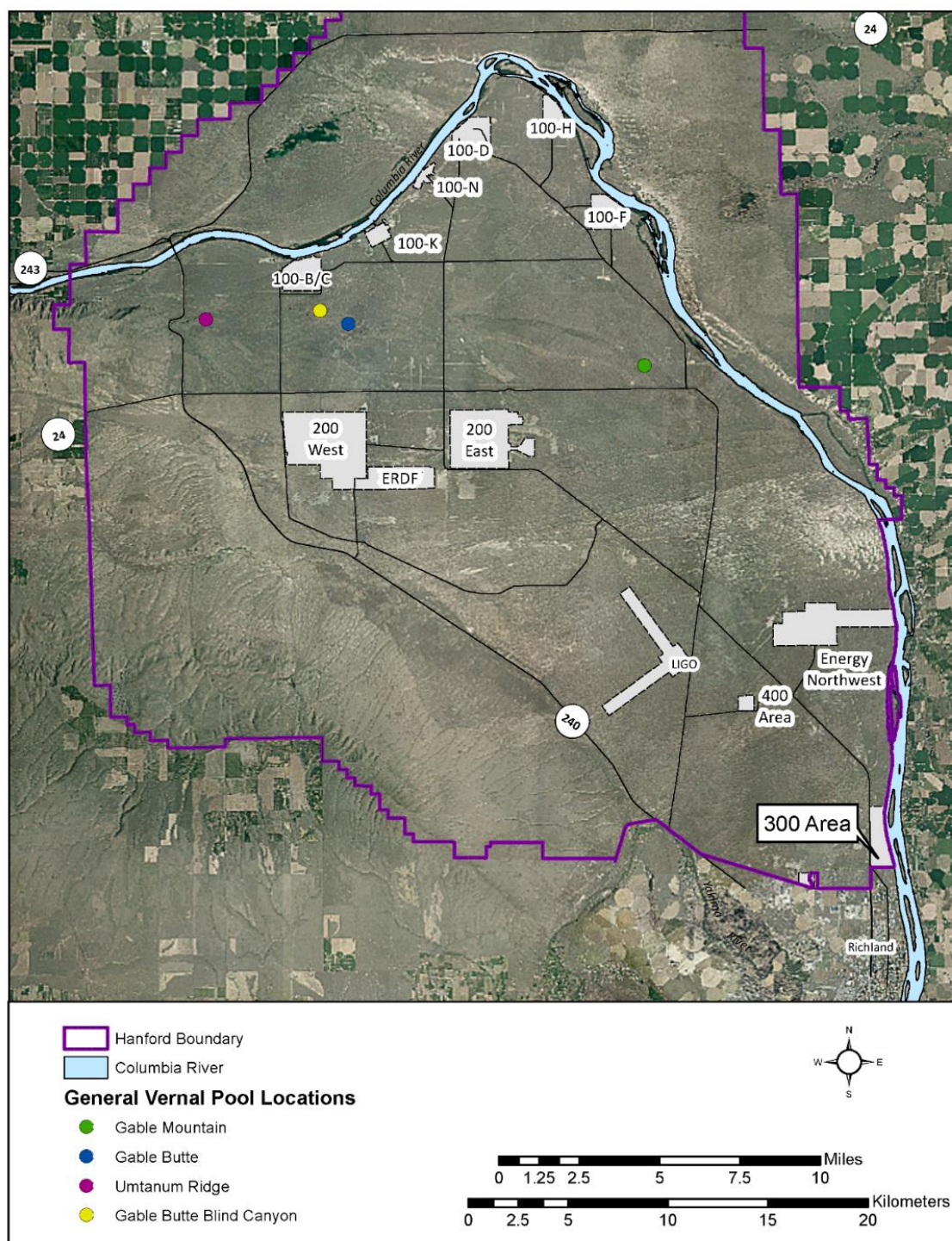


Figure 11-2. General Location of the Vernal Pool Areas on the Hanford Site.

The size of the pools vary based on the size of the local depressions and the amount of precipitation received. In 2017, pools ranged in area from 1.73 ac (0.70 ha) to puddle-sized; the median size of the pools large enough to measure (larger than roughly 10 m² [0.001 ha or 0.0025 acre]) was 0.09 ac

(0.036 ha). Many of the pools appeared as though they are filled with water most years but that has not been documented to date.

Because vernal pools have not been tracked or well-studied on the Hanford Site, and because they represent an imperiled ecosystem in Washington State, monitoring of these pools was initiated during the 2017 season. The purpose of this monitoring was to:

- Locate and map the vernal pools located on the central Hanford Site managed by the DOE
- Provide a seasonal timeline for the pools
- Describe the vegetation present in the vernal pools as well as its distribution within the pools
- Document wildlife use of the pools through the use of trail cameras
- Look for evidence of the use of the pools as a breeding area for anurans
- Document pool use by aquatic crustaceans, insects, and/or other macroinvertebrates
- Identify occurrences of any federal or Washington State-listed species in the pools, including any endemic species or state-listed species of concern.

Vernal pools were revisited periodically during 2017 until the pools dried out and vegetation had become established. Overall, the smaller vernal pools lasted only a few weeks and were dry by mid-March. The larger pools, however, still contained water well into the spring. Although the exact dates of dry out are unknown, it is clear that at least five or six pools were still present in mid-May.

Surveys of the vegetation present in the vernal pools occurred in mid-summer after all of the pools had dried out. A total of 47 species of vascular plants were observed in Hanford's vernal pool basins in 2017. Overall, approximately 62% of the species found in the pools were native while the rest were introduced. About 72% of the species in the pools were annuals. As is typical of seasonal wetlands, many of the plants found in the vernal pool basins after they dried up are nonhydrophytes; 43% are strictly upland species while an additional 30% are facultative upland plants. Of the remaining species, only purple-stem monkeyflower (*Erythranthe floribunda*) is considered an obligate wetland species. Four species (lowland cudweed [*Gnaphalium palustre*], hairy gumweed [*Grindelia hitsuta*], toad rush [*Juncus bufonius*], and rabbitsfoot grass [*Polypogon monspeliensis*]) are generally found in wetlands. The remaining seven species are facultative species, occurring in both wetland and non-wetlands.

One species, *Erythranthe suksdorfii* (Suksdorf's monkeyflower) found in the vernal pools in all three Hanford locations is listed as a Washington State Sensitive species (WNHP 2017). Suksdorf's monkeyflower is a small plant, which is generally only 1 to 4 in. (3 to 10 cm) tall. Most of the plants seen in the vernal pool basins were at the larger end of that range and seemed to be quite robust.

As noted above, 38% of the species documented in the vernal pools were non-native species, many of which are somewhat weedy or invasive in habit. Some of the native annual species found are also considered to be weeds. Overall, almost half of the species noted in the vernal pools are listed as invasive in *Weeds of the West* (Whitson et al. 2012), and four species (kochia [*Kochia scoparia*], broad-leaved pepperweed [*Lepidium latifolium*], Russian knapweed [*Rhaponticum repens*], and field bindweed [*Convolvulus arvensis*]) are listed as noxious weeds by the Washington State Noxious Weed Control Board (2017). In the absence of other pressures on the vernal pools at the Hanford Site (e.g., heavy grazing and agricultural use), these species may pose the greatest threat to vernal pool ecosystems on the Hanford Site.

Evidence of the use of vernal pools by the larger mammals on the Hanford Site was found in every vernal pool studied during spring 2017. Footprints made by Rocky Mountain elk (*Cervus elaphus nelsoni*), mule deer (*Odocoileus hermionus*), and coyote (*Canis latrans*) were sometimes so numerous that the basin of the vernal pools and the surrounding area were pockmarked by the numerous indentations. The microhabitat afforded by these footprints were often the sites for the germination of the annuals colonizing the pools after dryout. Scat left by elk, mule deer, coyote, and Nuttall's cottontail rabbit (*Sylvilagus nuttallii*) was also common in and adjacent to the pools. Other signs of wildlife use included elk antler sheds and coyote dig sites. The trail cameras placed at selected vernal pools also recorded the use of pools at all three locations by mule deer, elk, and coyotes. The trail cameras usually operated for a few days at a time because curious elk generally knocked them down.

Although there were no formal surveys of bird use at the Hanford Site vernal pools in 2017, incidental observations included sightings of waterfowl, wading birds, and sagebrush dwelling passerines at the pools.

- Waterfowl observed included four Bufflehead ducks (*Bucephala albeola*) and several pairs of Mallards (*Anas platyrhynchos*). Both the Mallards and the Buffleheads were on the surface of the pools feeding when observed; all of the birds remained feeding through the site visits. The diversity of aquatic invertebrates in the pools was credited with providing high protein foods for dabbling ducks.
- Shorebirds seen included a Greater Yellowlegs (*Tringa melanoleuca*) feeding along the margin of a pool and Least Sandpipers (*Calidris minutilla*) feeding in the mud along pool margins
- An empty Horned Lark (*Eremophila alpestris*) nest was found in the basin of a pool that had dried out in mid-March.
- A Western Meadowlark (*Sturnella neglecta*) was captured by a trail camera. It is interesting to note that Horned Larks and Western Meadowlarks were two of three most commonly observed passerines in a study of avian use of vernal pools on the Santa Rosa plateau (Baker et al. 1992).

Because vernal pools often are found at a distance from more permanent water sources and some pools may not fill each year, waterfowl and shorebirds are considered to be an important dispersal agent for propagules among vernal pool groups. This dispersal may have important consequences for populations and species diversity of vernal pool plants and invertebrates (Silveira 1998; Baker et al. 1992).

Great Basin spadefoot toads (*Spea intermontana*) occur primarily in shrub-steppe habitats and are known to breed in the ephemeral pools and sloughs adjacent to the Columbia River on the Hanford Site. In late April 2017, a large number of spadefoot toad larvae were seen in the largest vernal pool on Gable Butte. Although the duration of this vernal pool in 2017 is not certain, significant water was still present when the tadpoles were observed.

Although no fairy shrimp were found in any of the pools in 2017, a variety of macro-invertebrates were observed in the pools including diving beetles, water boatmen, mosquito larvae, midge larvae, and water striders.

11.1.2 Fish and Wildlife Monitoring

JW Wilde

This section provides inventory, monitoring, and survey information for fish and wildlife evaluated at the Hanford Site during 2017. This information is provided in context with historical data and trend information. Historically, three fish and wildlife species (fall Chinook salmon [*Oncorhynchus tshawytscha*], steelhead [*Oncorhynchus mykiss*], and bald eagles [*Haliaeetus leucocephalus*]) have been monitored annually on the Hanford Site. 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, calendar year 2017 monitoring also included ferruginous hawk nest monitoring, roadside bird surveys, burrowing owls, pollinators, ground squirrels and bats. The sections below provide summaries of the monitoring results; additional reports on these species can be found at <http://www.hanford.gov/page.cfm/EcologicalMonitoring>.

11.1.2.1 Fall Chinook Salmon

JJ Nugent

Commonly referred to as king salmon, Chinook (*Oncorhynchus tshawytscha*) are the largest of the 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 et al. 2012, Wagner et al. 2013, Lindsey and Nugent 2014, Nugent and Wilde 2015, Nugent 2016, USDOE 2018, MSA 2018). 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 sub-sections (100-B/C, 100-K, 100-N, 100-D, 100-H, 100-F, Dunes, and 300 Area) were defined to better monitor the abundance and distribution of fall Chinook salmon 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.

In 2017, three surveys were completed along the Hanford Reach (October 23, November 6, and November 19). 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 2017 (8,648) was the ninth highest count since 1948 and was less than the previous 10-year average (10,800). The historical trend in redd counts since 1948 is shown in Figure 11-2. Fall Chinook salmon redd counts on the Hanford Reach in 2017 decreased by 34.8% from the 2016 count (13,268). Although the redd count decreased in 2017, the recent annual redd count was more similar to the previous 20-year average (8,943).

Table 11-1. Summary of Fall Chinook Salmon Redd Counts by Areas for the 2017 Aerial Surveys in the Hanford of the Columbia River.

Area	Description	10/23/2017	11/6/2017	11/19/2017	Maximum Count
0	Islands 17-21 (Richland)	0	2	0	2
1	Islands 11-16	11	120	280	280
1a	Savage Island/Hanford Slough	0	0	0	0
2	Islands 8-10	19	864	900	900
3	Near Island 7	0	22	670	670
4	Island 6 (lower half)	5	680	900	900
5	Island 4, 5, and upper 6	11	418	911	911
6	Near Island 3	0	40	500	500
7	Near Island 2	0	281	790	790
8	Near Island 1	2	145	330	330
8a	Upstream of Island 1 to Coyote Rapids	0	0	0	0
9	Near Coyote Rapids	0	0	80	80
9a	Upstream of Coyote Rapids to China Bar	0	0	0	0
China Bar	China Bar/Midway	4	14	75	75
10	Near Vernita Bar	85	1310	3200	3200
11	Upstream of Vernita Bar to Priest Rapids Dam	0	0	10	10

Table 11-2. Summary of Fall Chinook Salmon Redd Counts by Sub-areas Adjacent to Hanford Site Operations for the 2017 Aerial Surveys in the Hanford Reach of the Columbia River.

Sub-area	10/23/2017	11/6/2017	11/19/2017	Maximum Count
300 Area	0	2	0	2
Dunes	0	0	0	0
100-F	0	22	670	670
100-H	11	418	911	911
100-D	2	145	330	330
100-N	0	0	0	0
100-K	0	0	0	0
100-BC	0	0	80	80

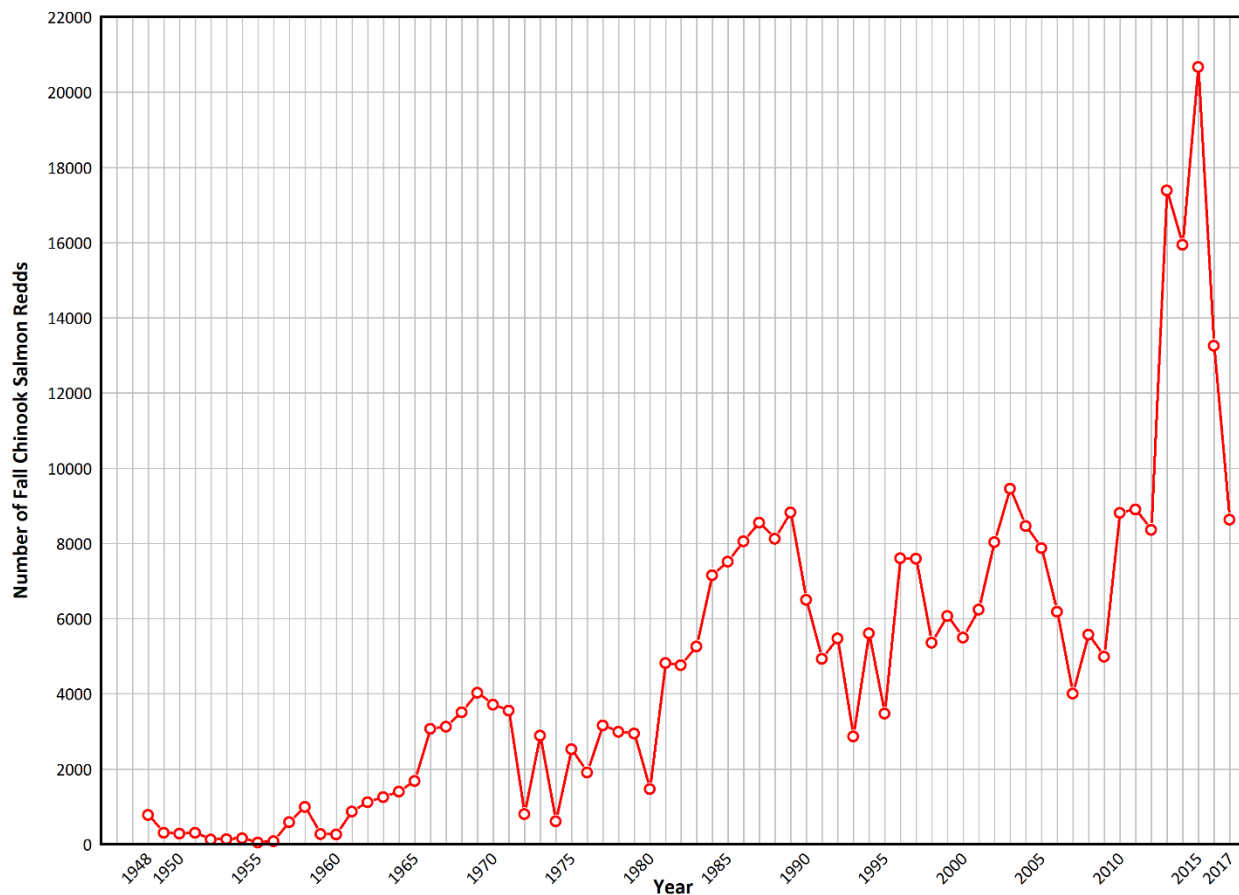


Figure 11-3. Visual Hanford Reach Fall Chinook Salmon Redd Counts 1948 to 2017.

11.1.2.2 Bald Eagle

JE Grzyb

[DOE/RL-94-150, Bald Eagle Management Plan for the Hanford Site](#), 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 660-ft (200-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 9 a.m. and 3 p.m. after notification of Hanford Site Ecological Compliance staff.

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. During the 2017/2018 season (as of March 7, 2017), 56 night roost surveys and 1 boat surveys were conducted. The Washington Department of Fish and Wildlife (WDFW) defines a communal or night roost as “a tree or a group of trees in which at least 3 eagles roost for at least two nights and during more than one year” (Stinson et al. 2007). Night roost surveys were conducted at dusk from 15 minutes prior to sunset until dark. Night roost surveys were conducted biweekly at eight locations between November 13, 2017, and February 26, 2018. With the revised version of DOE/RL-94-150 released in 2017, the 2017/2018 eagle monitoring efforts was the first season conducted under the revised night roost and nest buffer regulations.

The entire Hanford Reach will be surveyed by boat two times during the 2017/2018 season (December 11, 2017, and March 19, 2017). Boat surveys are used to determine the number, age class, and distribution of eagles present on the Hanford Reach. 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. During the third night roost survey on December 11, 2017, the maximum count of 82 bald eagles on the Hanford Reach was observed for the 2017/2018 season, which was far less than the record maximum count of 141 documented during the 2014/2015 season but remains higher than the historic average maximum count of 25 eagles (1961 to 2013). This was most likely a result of the high number of adult fall Chinook salmon spawning in the Hanford Reach in recent years. Spawning-out salmon carcasses that accumulate along the Hanford Reach provide bald eagles their primary food source. During 2017/2018 boat surveys, adult eagles were observed sitting on a nest at the Bonneville Power Administration’s (BPA) sub-station tower location for the second consecutive season (near the Upstream of Wooded Island nest that was occupied during the 2012/2013 to 2014/2015 seasons).

Nest site surveys will be conducted following the night roost season at locations determined to be active nest sites. Nest sites will be monitored for nesting activities (e.g., a pair defending the nest from other eagles, nest tending, and pair bonding behaviors). As of March 26, 2018, eagles appeared to be using the White Bluffs Peninsula nest, and the BPA nest both of which were confirmed to be successful in the 2016/2017 monitoring season. Eagles also appeared to be attempting to nest in the Hanford Townsite at the same location where a nest was unsuccessful in 2016/2017. Mission Support Alliance (MSA) staff will continue to monitor the nests to determine the outcome of the nesting attempts. All complete nest monitoring season efforts are illustrated below in Figure 11-4. In 2018, a complete bald eagle monitoring report will be included in the comprehensive EIS annual report, and available online at

<http://www.hanford.gov/page.cfm/ecologicalmonitoring>. Bald eagles were removed from the federal endangered and threatened species list in July 2007 and were down-listed from sensitive to no concern by the WDFW in January 2017. Federal laws including the *Bald and Golden Eagle Protection Act of 1940* and the MBTA still provide protection for eagles, their nest trees, and communal night roosts.

11.1.2.3 Ferruginous Hawk Nesting Territory Occupancy and Productivity Monitoring

JJ Nugent

The Ferruginous Hawk, a Washington State threatened species ([WDFW 2018](#)) and the largest of the North American Buteo species, inhabits grassland, shrub-steppe, and desert habitats of western North America from southern Canada to central Mexico. The species nests in 17 U.S. states and 3 Canadian provinces (i.e., Washington, Oregon, Idaho, Nevada, California, Utah, Arizona, New Mexico, Texas, Oklahoma, Colorado, Kansas, Wyoming, Nebraska, South Dakota, North Dakota, Montana, Manitoba, Saskatchewan, and Alberta) and overwinter in the southwestern and south-central U.S. and Mexico (Ng et al. 2017). Generally, Ferruginous Hawks begin arriving in Washington to nest in mid-February and begin laying eggs in mid-March. Most eggs hatch in May and most young fledge from late May through late July (WDFW 1996). Ferruginous Hawks build large stick nests. On the Hanford Site, Ferruginous Hawks have been found nesting on cliffs, rock outcrops, trees, and transmission towers.

Nesting Ferruginous Hawks were uncommon on the Hanford Site prior to 1987, with only one or two pairs nesting each year on basalt outcroppings on the side hills of Rattlesnake Mountain (Fitzner and Newell 1989). In 1987, four pairs of Ferruginous Hawks were observed nesting on the relatively new 230-kV transmission towers associated with the Washington Public Power Supply System reactors (now known as Energy Northwest). Construction of the transmission towers began in 1976, and lines were energized between December 1976 and July 1981. In 1988, seven Ferruginous Hawk nests were observed on 230-kV transmission towers and one in a tree. In 1991, 1992, and 1993, 11 active Ferruginous Hawk nests were reported each year on the entire Hanford Site (eight to 10 active nests on the central Hanford Site) (Fitzner et al. 1994; Nugent 1995). The majority of these nests were located on the newly built transmission towers. A decrease in the number of nesting Ferruginous Hawks on the Hanford Site has occurred since the 1990s. Clayton (2005) reported four nesting pairs on transmission towers in 2005 and WDFW (Livingston 2012) documented two nesting pairs on transmission towers in 2010. The number of occupied Ferruginous Hawk nests have remained stable on the Hanford Site since 2010 with two to four nests occurring each year (all on transmission towers) from 2012 to 2016 ([Nugent et al. 2013](#); [Nugent et al 2014](#); [Nugent et al. 2015](#); [Nugent et al. 2016](#); [Nugent 2016](#)). In 2016, a productivity survey was conducted and a total of six young were produced on the Hanford Site at three nest sites (two young at each nest site) ([Nugent 2016](#)).

Ferruginous Hawks are especially sensitive to human disturbance and incursion into their nesting areas. On the Hanford Site, nesting Ferruginous Hawks are protected using WDFW guidelines (WDFW 2004). Buffer zones of 3,281 ft (1,000 m) are established around active nests. Road closure signs are placed in the roads where they intersect with the 3,281 ft (1,000 m) buffers. Nest areas are protected from all human disturbance within 820 ft (250 m) between March 1 and May 31, and within 3,281 ft (1,000 m) for prolonged (greater than 0.5 hour) activities during the entire nesting and fledging season (March 1 to August 15). The identification of active nests sites during annual surveys allows for the protection of nesting Ferruginous Hawks.

Seventeen traditional Ferruginous Hawk nesting territories have been identified on the DOE-RL managed lands of the Hanford Site. Two surveys were conducted in 2017, one occupancy survey and one productivity survey. The occupancy survey took place May 18. All 17 traditional Ferruginous Hawk nesting territories were visited and assessed for occupancy. The productivity survey was performed on June 21. Most young are 2 to 5 weeks old at this time. A surveyor visited the occupied territories, counted the young at each nest, and aged them based on plumage (Moritsch 1985).

Three Ferruginous Hawk nesting territories were occupied on DOE-RL managed lands of the Hanford Site in 2017 (Figure 11-5) but only two territories were successful. One young each was produced at two of the nests. The unsuccessful nest was built on a transmission tower but was found on the ground during the productivity survey.

MSA has conducted 2 years (2016 and 2017) of occupancy and productivity surveys of Ferruginous Hawk nesting territories on the Hanford Site. Three nesting territories were occupied each year with three successful nests in 2016 and two successful nests in 2017. Six juveniles were fledged in 2016 for an average of two juveniles per successful nest and two juveniles were fledged in 2017 for an average of one juvenile per successful nest. No cause was detected for the decrease in Ferruginous Hawk productivity on the Hanford Site in 2017 but many studies have correlated nest success and productivity to the abundance of major prey (Ng et al. 2017). The severity (cold and wet) of the winter preceding the 2017 nesting season may have depressed small mammal populations or promoted heavy vegetation growth making hunting difficult.

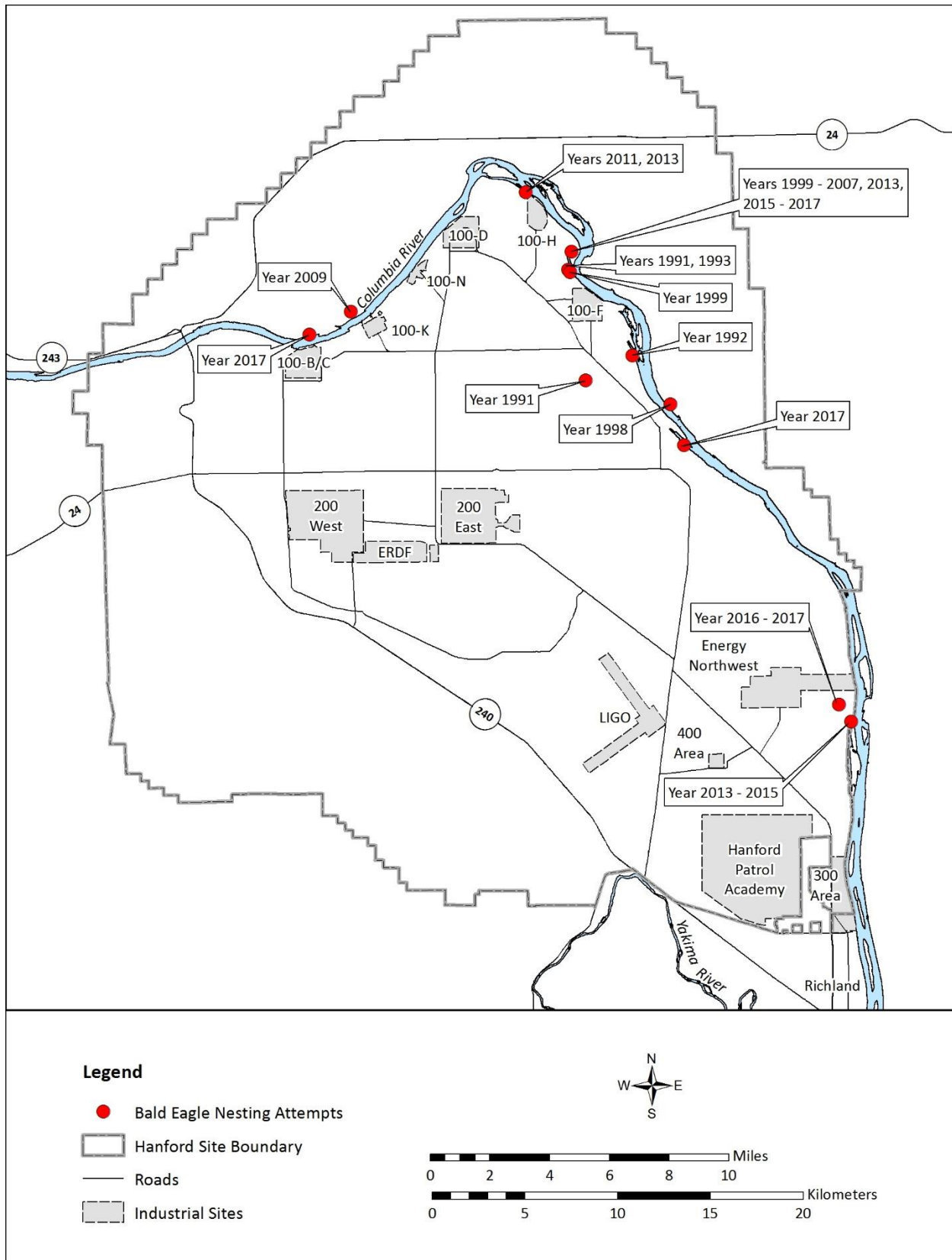


Figure 11-4. Location of Known Bald Eagle Nesting Attempts on the Hanford Site.

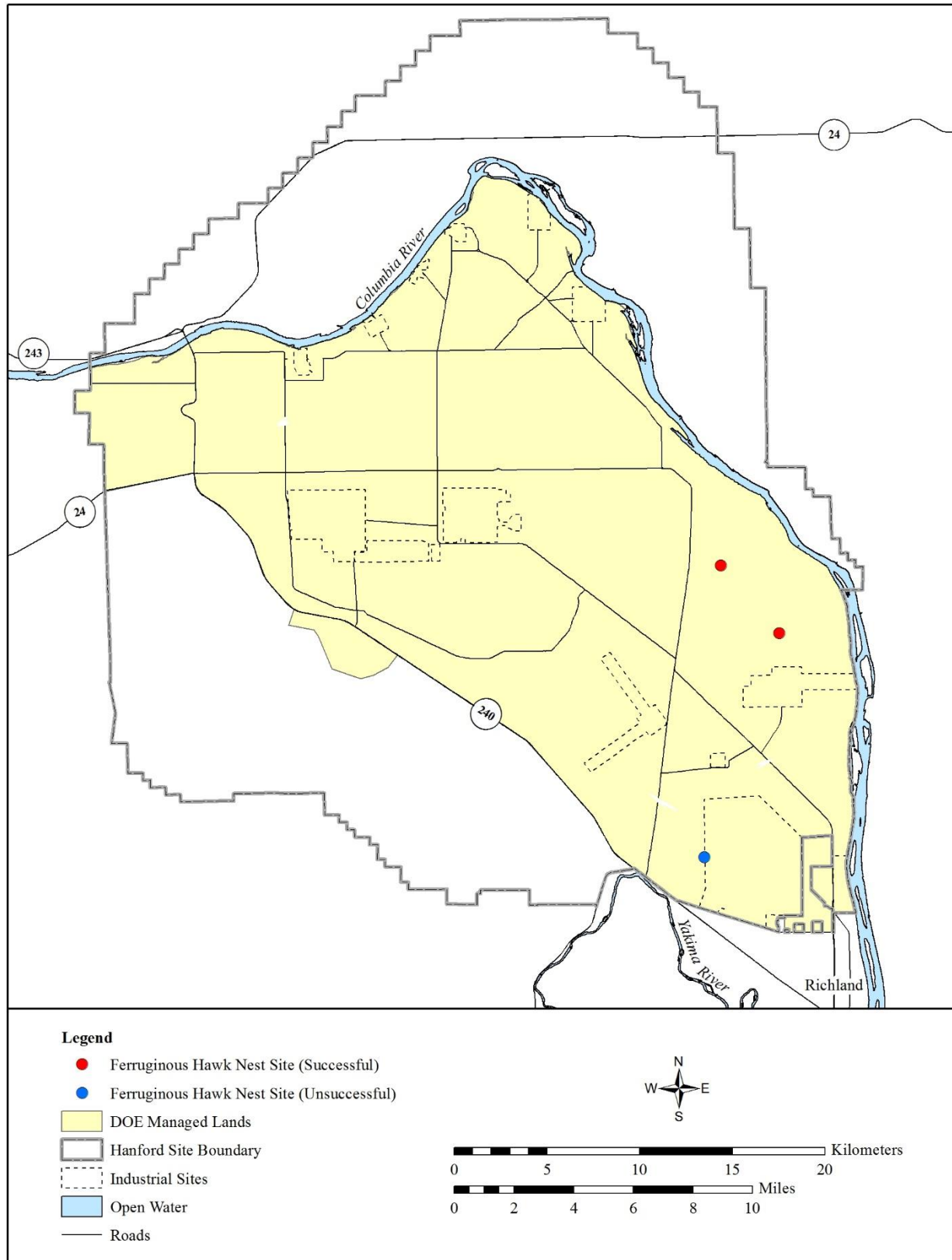


Figure 11-5. Active Ferruginous Hawk Nests Observed on DOE-RL Managed Lands of the Hanford Site in 2017.

11.1.2.4 Burrowing Owls

JE Grzyb

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 sitewide 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.

The fundamental objective of the fiscal year (FY) 2017 monitoring efforts was to document the distribution and abundance of Burrowing Owls on the DOE-RL managed portions of the Hanford Site. The primary goal was to design and implement an approach to detect new or previously undocumented nest burrows on the Hanford Site as well as formerly known sites. In addition, Owl Artificial Nest Burrows Systems (ABS) were surveyed and necessary maintenance was performed. Surveys focused on areas that were mapped as potential nest habitat for Burrowing Owls. A geographic information system was used to perform a geometric intersection of map layers consisting of areas with characteristics likely to be suitable for Burrowing Owl nesting habitat. The selected map layers show areas with gentle slopes (0 to 6%), little to no shrubs, and that do not contain active or stabilized sand dunes or rock outcrops. Areas that met this criteria were considered potential Burrowing Owl nesting habitat.

Broadcast surveys were conducted between May 17 and June 28, 2017. A total of 305 locations were surveyed including 304 directly on the designated survey points and one offset due to a contamination closure. Walking distances to each point varied greatly from just a few meters up to several kilometers. Six Burrowing Owls were detected at five locations on the Hanford Site during broadcast-call surveys. A seventh Burrowing Owl was discovered earlier in the spring while conducting Townsend ground squirrel surveys on April 11, 2017. This owl burrow was revisited during a broadcast-call survey on May 25, 2017, and was determined to be abandoned due to the absence of the owls and presence of spider webs and growing vegetation in the burrow entrance. Figure 11-6 shows all of the survey site locations and Burrowing Owls discovered during the FY 2017 surveys. The five Burrowing Owl detections occurred in four different habitat areas. These were located in the Hanford Townsite Area, the 100-D/100-H Area, the Gable Butte/Gable Mountain area, and in the Cold Creek Highway 240 Area.

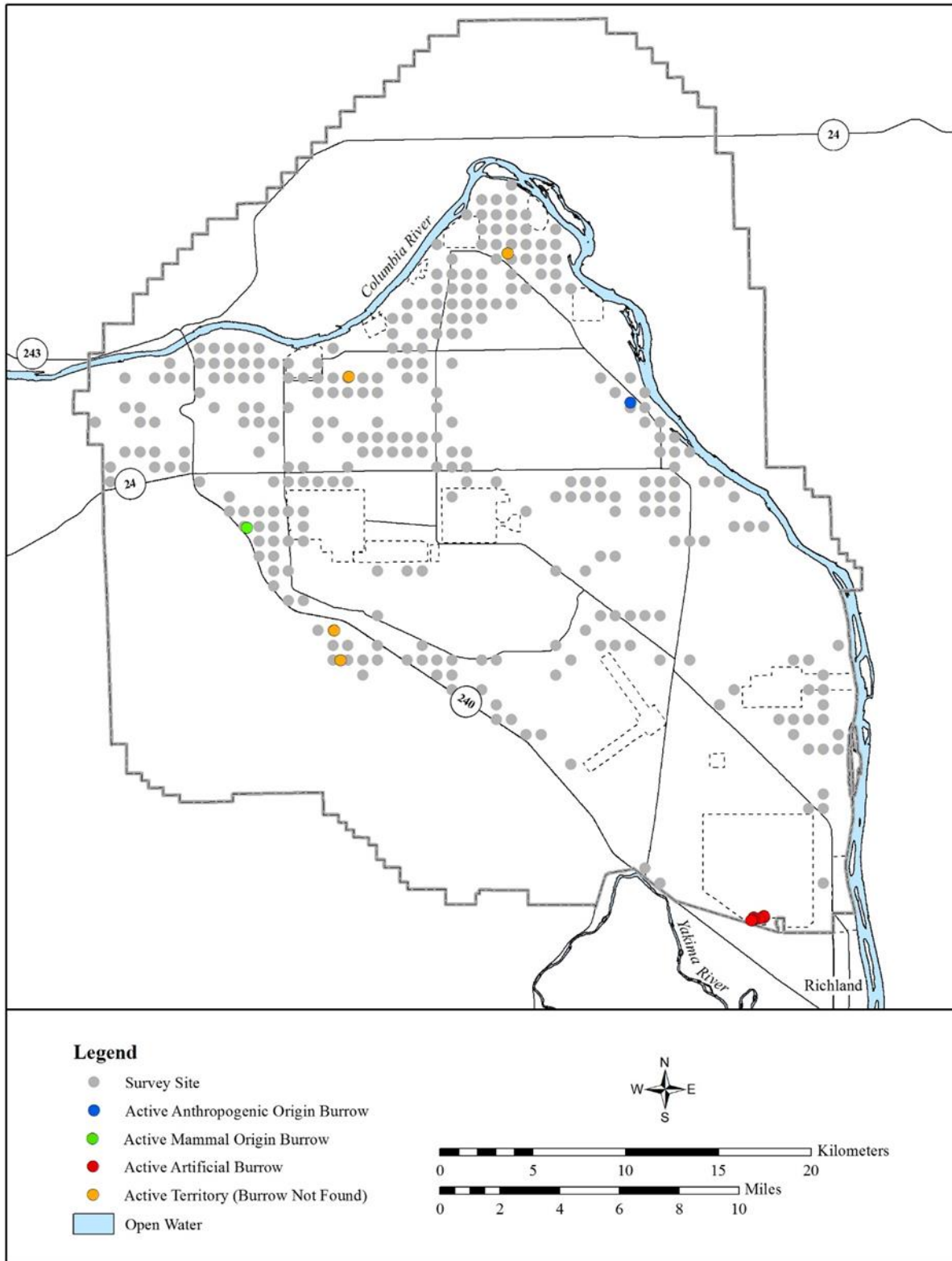


Figure 11-6. Survey Site Locations and Burrowing Owls Discovered During the FY 2017 Surveys.

Natural burrows on the Hanford Site are typically those created by badgers; and despite the burrows life expectancy being much shorter than those of anthropogenic or artificial specific origin, numerous badger burrows that appear to be suitable for owl use have been observed in many locations on the Hanford Site. The data collected during the FY 2017 monitoring efforts suggest that the use of natural burrows continues to decline. All three of the natural burrows found to be active in 2015 have since been deemed inactive. During this year's rigorous efforts, there were no natural active burrows located. This should not discount the possibility of natural burrows being present based on the fact that there was both visual and acoustic confirmation of Burrowing Owls in areas previously unknown to be inhabited. The area in which active anthropogenic burrows were observed in 2015 (Hanford Townsite's old orchard) was confirmed to still be active in 2017. The HAMMER facility had a total of 8 active artificial burrows in 2017 and 12 in 2015. This is a 33.3% decline in the number of active burrows at the HAMMER facility since it was last monitored. Although there was a decrease in owl numbers, the ABS at the HAMMER complex continues to be used, implying that owls are continuing to produce offspring in the colony. The success of this mitigation action suggests that additional onsite mitigation would be successful in preserving the remaining owl population on central Hanford. Relatively close geographically, the Umatilla Army Depot has made large efforts to install ABS when it was believed the breeding population of Burrowing Owls was down to four pairs. The efforts of the Global Owl Project and the Army with use of ABS on that site have brought the population back to estimates of over 58 breeding pairs as of the 2017 nesting season (Johnson 2017, personal communication with Global Owl Project).

Based on the results of this review, this resource should be monitored again in 2019 (biennial). The focus should return to all potential habitat areas in which active burrows have been documented since 2010 and habitat areas similar to the historical sites. These efforts can be used to evaluate if family units have vacated active areas relocating to previously occupied areas. Future studies of active colonies should also consider documenting colony characteristics. Determining production from nest burrows and possible young mortality before fledging may provide explanation for population declines.

Due to the development and removal of infrastructure, natural disturbances, site cleanup activities, and other land use alterations, the landscape of the Hanford Site is continually changing. With the minimal use of natural burrows and continued loss of accompanying anthropogenic burrows, installation of ABS in active colony locations should be evaluated. Since the installation of the HAMMER complex burrows, updated designs and techniques have been developed for installation of Burrowing Owl burrows (Johnson et al. 2013). The new designs will not only provide adequate burrow locations for the existing populations to increase in number but provide a monitoring opportunity and easier maintenance for greater longevity. Additional ABS installed on Hanford should provide meaningful contributions to slowing the rate of population decline and provide a direct link to conservation and recovery of the species on Hanford.

11.1.2.5 Roadside Bird Surveys

JW Wilde

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 federally listed as threatened or endangered. In addition, the Hanford Site and surrounding area provide refuge for 17 state-listed species including numerous birds (e.g., ferruginous hawks, state threatened; American white pelican (*Pelecanus erythrorhynchos*), state threatened; and bald eagle, 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 2017, roadside surveys were performed during breeding season (May and June). Four Hanford routes (Figure 11-7) were surveyed one time each in 2017. For the 2017 breeding season surveys, a total of 1,223 individual birds were documented, similar to the 1,219 individuals counted during breeding period surveys in 2016 and 1,227 individuals from same period in 2015. Forty-Four bird species were documented in the 2017 breeding season survey (Table 11-3), which was down slightly from the 50 species and the 51 species seen in breeding period surveys during 2016 and 2015, respectively.

The Old Fields survey route had the highest species diversity with 44 identified. The Army Loop Road survey route had the lowest species diversity at 12 species (Table 11-3). The Cliff Swallow (*Petrochelidon pyrrhonota*) was the most abundant species documented. The surveys documented 296 individuals on two survey routes, nearly 25% of the total number of individuals seen. This was due to a very high number of breeding swallows present around the reactor areas during the morning of the survey. The typically abundant species were present in high numbers once again. The Horned Lark (*Eremophila alpestris*) had 223 individuals, 18.29% of surveyed individuals, and the Western Meadowlark (*Sturnella neglecta*) had 218 individuals, 13.95% of all individuals counted. The Horned Lark was counted on 79 survey points (79%) while the Western Meadowlark was documented on 70 survey points (70%). While the Cliff Swallow had the highest number of individuals counted, it was only seen on 14 points during the surveys, 14.00% of survey points. These three species accounted for over half of the individuals counted during the 2017 surveys (56.52%).

Surveys from the breeding season during the most recent 5 years (2012 through 2016) were compiled and the average number of individuals, total number of species seen, and Shannon's Diversity index calculations (USFWS 1999) were calculated (Table 11-4) and compared to the data seen in 2017.

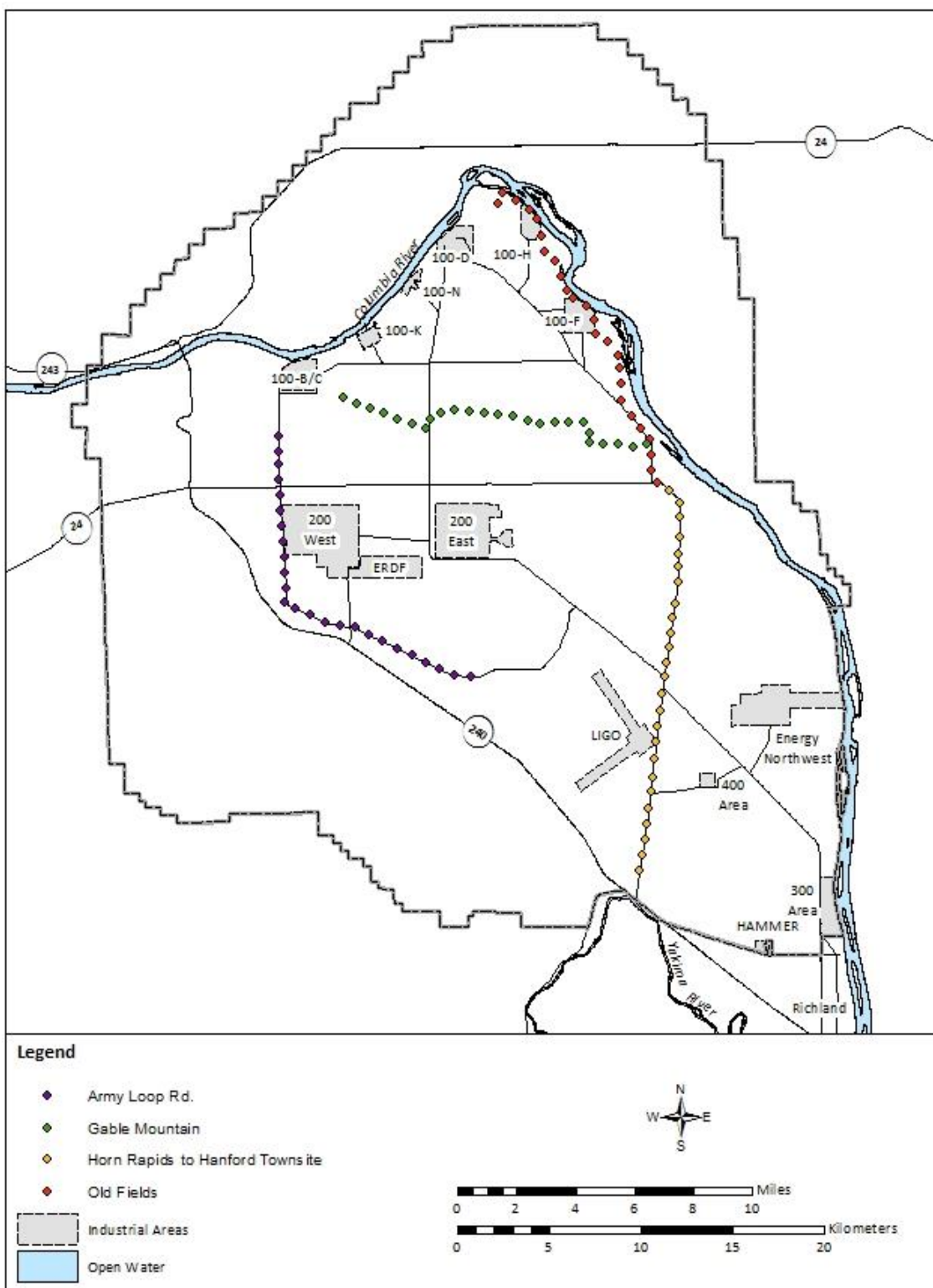


Figure 11-7. Roadside Bird Survey Routes Surveyed for Calendar Year 2017.

Table 11-3. Species Richness and Abundance Counted During the 2017 Breeding Season Roadside Bird Survey Routes on the Hanford Site Sorted by Route.

Route Name	Surveys Performed	Species Richness	Abundance
Army Loop Road	1	12	79
Gable Mountain	1	16	180
Horn Rapids to Hanford Townsite	1	15	196
Old Fields	1	36	768
Total	4	44 ^a	1223
^a Unique species identified			

Table 11-4. 2017 Survey Data Compared to the Past Five Year Cumulative Data and Shannon's Diversity Index and Evenness on the Four Hanford Routes (2012-2016).

Route Name	5-year Average	2017 Counts (+/- to Average)	5-Year Ecological Species Diversity ^a	2017 Ecological Species Diversity ^a	5-Year Evenness	2017 Evenness
Army Loop Road	133.6	79 (-54.6)	4.97	5.28	0.498	0.669
Gable Mountain	188.4	180 (-8.4)	7.9	7.14	0.634	0.709
Horn Rapids to Hanford Townsite	245.8	196 (-49.8)	5.7	4.81	0.534	0.580
Old Fields	674	768 (+94)	18.4	11.8	0.706	0.688
Average	310.45	305.75 (-4.7)	9.24	7.26	0.593	0.662
Cumulative	1241.8	1223 (-18.8)	17.1	13.8	0.664	0.694
^a Shannon's index expressed as N ₁						

The Hanford bird monitoring program documents the presence, abundance, and distribution of species of concern on the Hanford Site. Both the U.S. Fish and Wildlife Service (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. Additional information detailing migratory bird monitoring efforts is available at <http://www.hanford.gov/page.cfm/ecologicalmonitoring>.

11.1.2.6 Pollinators

ES Norris

By enabling successful plant reproduction, pollinating insects support the health of nearly all other organisms in the environment that rely on healthy plant populations for food and shelter. Bees are the most important group of pollinators worldwide (Kearns et al. 1998, Michener 2007). Within the last century, rapid declines in both wild and managed bee populations have been recorded throughout the world (Kearns et al. 1998, Goulson et al. 2005, Biesmeijer et al. 2006). Habitat loss and fragmentation are major causes of bee population declines, especially for wild bees as they rely on flowering plants for

forage and nesting (Potts et al. 2010, Winfree et al. 2009). Wild bees can have foraging ranges as small as 492 ft (150 m), making local habitat structure especially important (Gathmann and Tscharntke 2002). The greatest abundance of wild bees is suspected to be in semi-desert, arid environments, especially within western North America (Linsley 1958, Koh et al. 2016). This habitat classification matches the Hanford Site environment, suggesting the Hanford Site may have abundant wild bee populations. Many species of native bees, honey bees, bumble bees, and butterflies have been documented on the Hanford Site (Zack 1997); however, pollinator-specific studies focusing on these insects are uncommon.

This study was designed to collect abundance and diversity data on Hanford Site pollinators, specifically bees and butterflies. Additionally, information from this study can be used to identify which plant communities attract a high abundance and diversity of bees. This information will be used to inform management, mitigation, and revegetation decisions so that they can support diminishing bee populations. Though the populations of bees likely vary significantly year to year, this study can also be used to provide a general baseline of the expected bee population at Hanford. After these data are collected, the plants that best support pollinator populations will be recommended for use in revegetation projects and added to DOE/RL-2011-116, *Hanford Site Revegetation Manual* (HSRM). A long-term goal of this effort is to increase pollinator habitats on the Hanford Site.

The main focus of this report is insect pollinators belonging to the order Hymenoptera, the insect order containing bees. Monitoring for this study focused on this group of pollinators due to their perceived declines, abundance onsite, and pollinating effectiveness. Insects of the order Lepidoptera (butterflies and moths) were also collected and considered while making plant recommendations but were not the main focus of this study.

In order to meet the goals and objectives of this study, multiple plant communities were sampled across different seasons. The study sites are within four different habitats that are common throughout the Hanford Site in order to maximize the applicability of the data collected to future land management in this area. The four habitat types investigated were categorized as Steppe Grassland, Early Colonizing Species, Late Successional Mixed Shrub, and Late Successional Sagebrush. A total of eight study sites were investigated with two study sites in each of the habitat types. The eight sites were also divided into four near-river sites and four inland sites (Figure 11-8). Each site was circular with a radius of 164 ft (50 m).

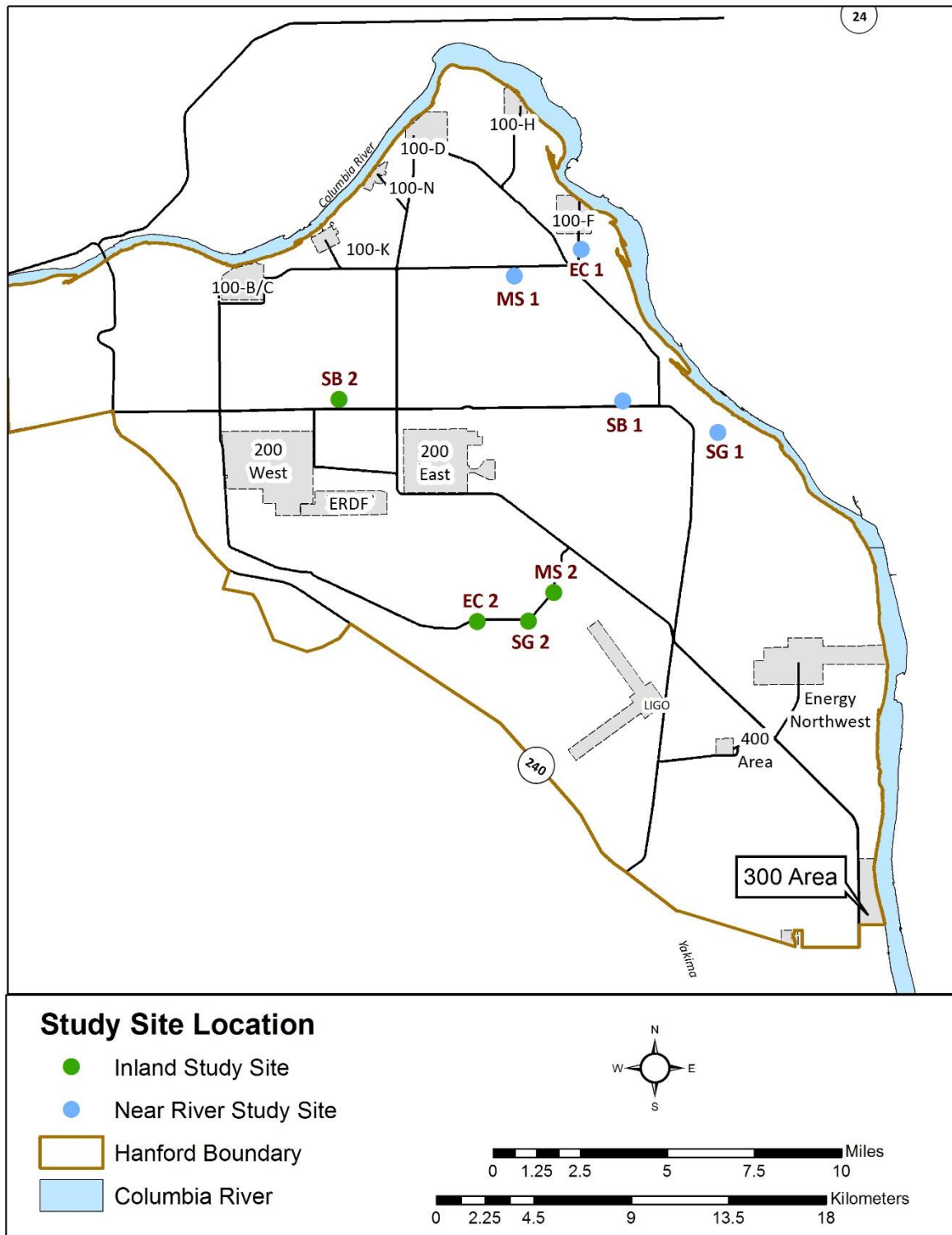


Figure 11-8. The Eight Pollinator Study Site Locations.

Pollinator abundance and diversity data, along with blooming plant data, were collected weekly at each study site. Site surveys took place from mid-March to mid-October (during a vast majority of the season) when insect pollinators were active. Surveys at each site involved setting up a pan trap to capture bees, butterflies, and moths, and conducting bloom surveys to measure abundance and diversity of blooming plants.

Throughout the course of this study, 1,902 bees and 139 butterflies and moths were collected from pan traps and identified to the tribe or genus level. In addition, 157 bees and 26 butterflies and moths were observed foraging on plants within the study areas. Five of the six North American families of bee were represented in our study sample, with the exception being Melittidae, which was also not collected in the 1997 entomological survey of the Hanford Site (Zack 1997). Bees of the family Halictidae were the most abundant and represented about 72% of all bees collected (Figure 11-9). A single genus within the family Halictidae (*Lasioglossum*) represented about 56% of all the bees collected. The diversity of bees collected, measured by the number of unique tribes/genera identified each week, had a strong positive correlation with abundance ($r = 0.81$; $p < 0.001$). May, September, and October had higher diversity per amount of bees collected than the other months, matching the increased diversity of available flowering plants in the study sites.

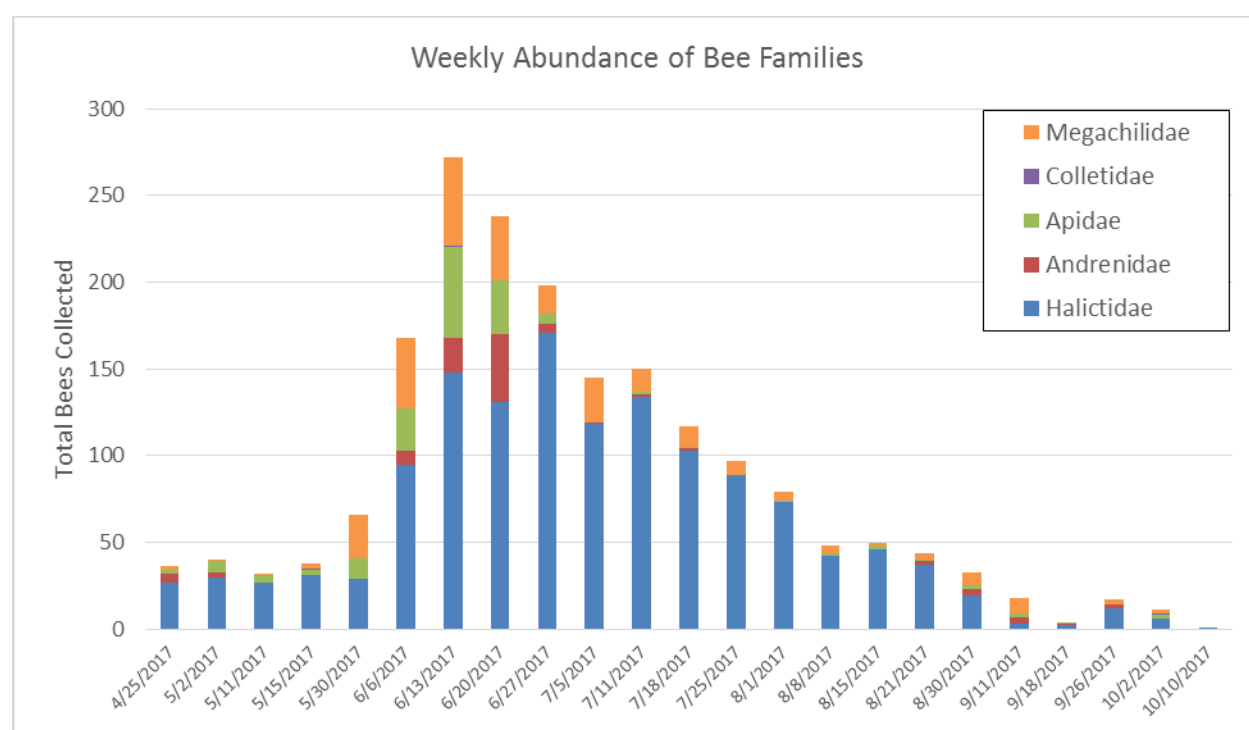


Figure 11-9. Total bees collected weekly, broken down by family, 4/25/2017 – 10/10/2017.

The numbers of bees and butterflies collected varied tremendously throughout the study period. The total number of pollinators collected peaked on June 13, 2017, at 279 pollinators. June had the highest number of bees collected and May had the highest number of butterflies and moths collected. Seasonal pulses in genera and tribes were seen along with seasonal pulses in families.

When comparing bee abundance across all sites, the steppe grassland near-river site had significantly more bees trapped than five of the seven other sites. This site averaged 19 bees trapped per week and was the closest to both the Columbia River and to agricultural activities across the river. This site also had the highest percentage of non-native plants, making up the foraging resources for bees (66%), and 20 of the 25 bees observed at this site were foraging on non-native species. The early colonizing species inland site also averaged 19 bees trapped per week. This site was dominated by native species, notably green rabbitbrush (*Chrysothamnus viscidiflorus*), Carey's balsamroot (*Balsamorhiza careyana*), longleaf phlox (*Phlox longifolia*), hoary tansyaster (*Machaeranthera canescens*), and pale-evening primrose (*Oenothera pallida*). This site had sandy soils and was part of a semi-stabilized dune complex.

A total of 23% of all bees observed were foraging on Blue Mountain prairie clover (*Dalea ornata*). This plant bloomed in May and continued through June, blooming during the time period when the most bees were collected. Snow buckwheat (*Eriogonum niveum*), wingnut cryptantha (*Cryptantha pterocarya*), and pale-evening primrose (*Balsamorhiza careyana*) also attracted a large number of bees and butterflies.

Data analysis of this study has not been completed, and as such the full management, mitigation, and revegetation implications are not fully formed. Future actions stemming from this study could include monitoring of pollinator activity at revegetation sites meant to increase pollinator habitat, installation and monitoring of bee nest boxes, and/or conducting a version of this study annually in order to detect changes in pollinator abundance or diversity.

11.1.2.7 Ground Squirrels

JE Grzyb

The Townsend's ground squirrel is listed as a State Candidate species by the Washington Department of Fish and Wildlife (WDFW; WDFW 2018) and is ranked as a Level 3 resource in the BRMP. Their range is limited to the Columbia Basin of Washington State where they are found west of the Columbia River. The crucial window to observe and monitor ground squirrels begins in late January after hibernation and ends in late May when estivation begins. These months are the longest active period for ground squirrels and, thus, are the best time for monitoring. Ground squirrels breed and rear young during this time; age determination is easier because the juveniles are significantly smaller than the adults. Protective maternal alarm calls are also used at this time, maximizing the likelihood of detecting occupied colonies.

Prior to 2012, six Townsend's ground squirrel colonies were documented on the Hanford Site. During 2012 and 2013, MSA surveyed 45 diamond transects totaling 108 mi (173 km), covering 2,565 ac (1,038 ha) and documented the status of the previously known colonies (Lindsey et al. 2012; Lindsey and Nugent 2013). No new colonies were detected during the transect surveys and one of the six colonies documented prior to 2012 (300 Area colony) was found to still be occupied. An additional seven previously undocumented colonies were identified during surveys focused on areas where ground squirrels were incidentally encountered during compliance reviews and other surveys. The historically active colony and the seven newly found active colonies were re-surveyed in 2015. In 2015, the 300 Area colony and four others were observed to be active.

The two objectives of the 2017 ground squirrel monitoring effort was to assess the status and size of the 2015 active ground squirrel colonies and apply the Hanford Site Townsend's ground squirrel habitat suitability model to locate new colonies. Systematic transect searches for new colonies within the areas

of high habitat suitability were performed. The transects were completed by two surveyors, with each surveyor covering a 98-ft (30-m)-wide swath, for a total of 197 ft (60 m) wide along the length of the transects. Surveyors searched for active ground squirrel burrows along each transect. When burrows were found the surrounding area were to be flagged and surveyed out to 197 ft (60 m).

The five Townsend's ground squirrel colonies that were known to be active in 2015 were resurveyed on April 4, 2017. These colonies surveyed included the Vineyard, Clay Cliff, Goose Egg, Gator, and 300 Area. Of these five colonies, Vineyard, Gator, and Goose Egg were found to be active. The perimeter of colony holes were mapped and compared to the size recorded in 2015. The Vineyard colony slightly increased in size from 1.24 to 1.5 ac (0.5 to 0.6 ha). This colony is actually larger than the recorded measurements due to extending off of the Hanford Site onto adjacent land. The Gator colony decreased from 12.6 to 4.45 ac (5.1 to 1.8 ha), and one squirrel was observed crossing Route 240 and entering a colony burrow. The size of the Goose Egg colony remained unchanged from 2015. The other two colonies appeared to be inactive with no squirrels or evidence of activity observed. Colony activity for each survey year conducted (2012, 2013, 2015, and 2017) is referenced in Figure 11-10.

Ten Townsend's ground squirrel survey transects were completed between April 5 and May 1, 2017. Transects varied in length ranging from 1.1 to 8.3 mi (1.8 to 13.3 km) (Figure 11-11). Five transects were located along Route 240, four in the McGee Ranch/Umtanum Ridge area and one near the 100-B/C Reactors. Longer transects were completed over multiple days, while multiple shorter ones were completed in 1 day. While much of the area surveyed proved to be quality ground squirrel habitat, there were no new colonies, individual holes, or squirrels observed.

Townsend's ground squirrel numbers continue to decline on the Hanford Site. There are a few probable reasons for this occurrence, including the high number of resident raptors, presence of coyotes and badgers, and climate change. The Hanford Site has a dense population of raptors; the populations are bolstered by the prevalence of artificial nesting structures (e.g., transmission towers, planted trees) on which 90% of the raptor nests were found in 2016 (Nugent 2016). It has been proposed that the high density of raptors on the Hanford Site may be negatively impacting prey species, including Townsend's ground squirrels (Nugent et al. 2015). In a study of the diet of raptors on the Hanford Site, the Buteos (e.g., Ferruginous Hawks, Red-tailed Hawks [*Buteo jamaicensis*], and Swainson's Hawks [*Buteo swainsoni*]) were the primary predators of Townsend's ground squirrels (Fitzner et al. 1981).

It is highly recommended that conservation efforts be put into place to ensure the future of the Townsend's ground squirrel on the Hanford Site. Reintroduction of ground squirrels with the cooperation of state and federal agencies is the suggested route to reinstate a viable population. Currently, the decline in population numbers may have plagued chances of a natural comeback, strongly relying now on the aid of conservation efforts and translocation from surrounding communities.

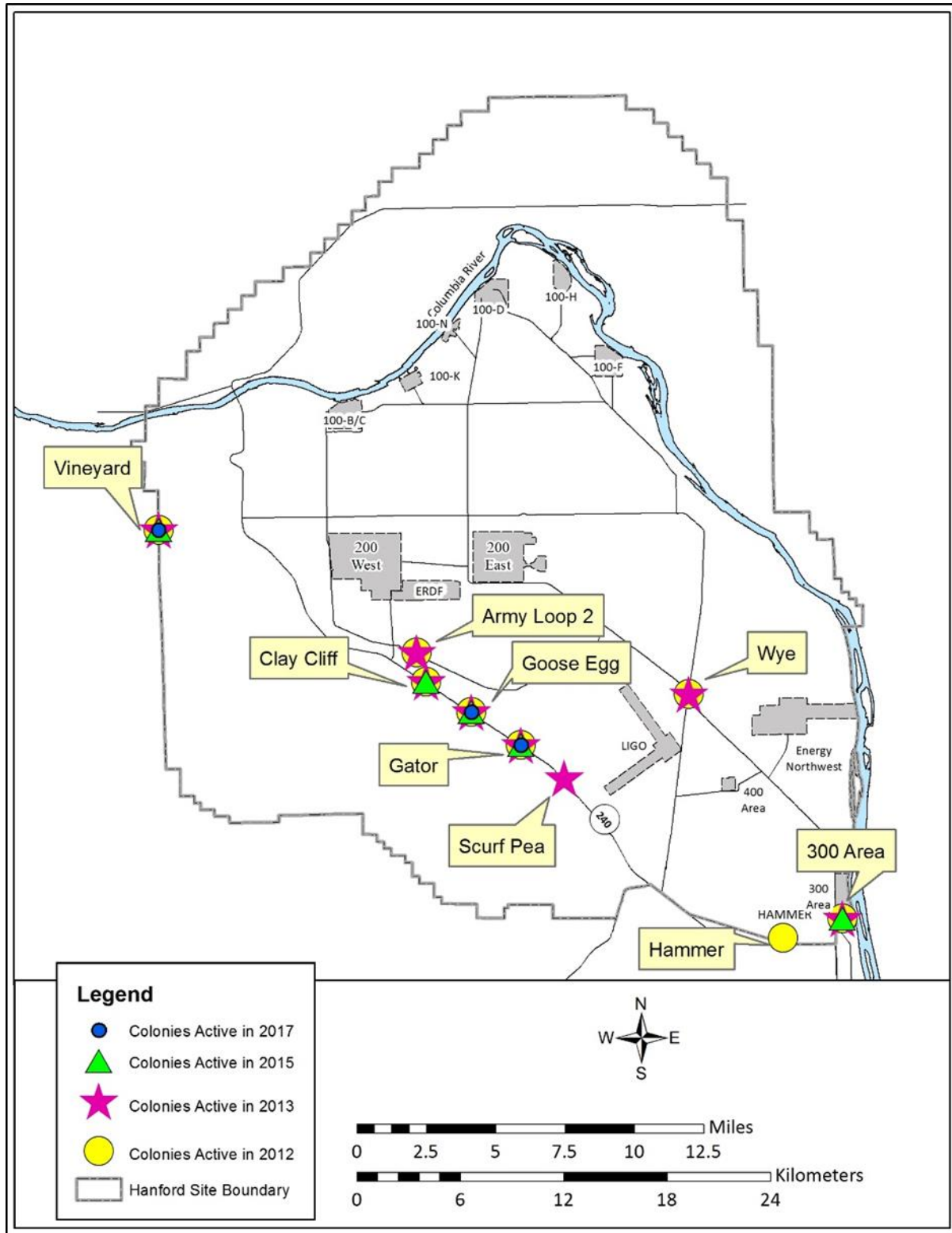


Figure 11-10. Locations of all Known Townsend's Ground Squirrel Colonies on the DOE-Managed Portion of the Hanford Site Active During Each Survey Year.

11.1.2.8 Bat Monitoring

Monitoring and protection of roosting locations is becoming increasingly important with the outbreak of the fungal infection referred to as White Nose Syndrome (WNS). White Nose Syndrome is affecting bats in the eastern United States and Canada and is rapidly expanding westward. Bats save energy during the winter by reducing their body temperature and entering a state of hibernation called torpor. They break these torpor bouts by warming their body temperature back up at regular intervals through the winter; these events are termed “arousals.” Bats are thought to use these arousals for depuration, defecation, grooming, breeding, and possibly drinking. Although these arousals represent a relatively small portion of the time the bats spend winter roosting, a large amount (up to 80%) of their energy stored for the season is burned during arousals (Thomas et al. 1990). Bats are thought to increase the number of arousals due to WNS, likely for additional grooming. Although other factors may be contributing, the excessive arousals cause bats to exhaust their energy stores prior to the end of the winter, resulting in starvation. This disease spreads quickly through roosting colonies and causes fatality rates up to 100% at infected winter roosts (more information available at whitenosesyndrome.org). The expansion of this disease occurred westward in 2016 when a little brown myotis (*Myotis lucifugus*) was found in Western Washington. With the disease now present in the state, it is extremely important to monitor and characterize roosts to provide a baseline in case the disease reaches this area. Bat researchers must follow strict WNS protocols established by the U.S. Fish and Wildlife Service (FWS) and other agencies when working with bats ([WNS 2016](#)).

The Hanford Site maternity roost in the 183-F Clearwell is believed to be the largest known *Myotis yumanensis* in the state. During June 2016, a count of bats emerging from the roost documented between 3,300 and 3,600 using the 183-F Clearwell. The clearwell had seen a population estimate as high as 6,600 in July 2012. Population counts have been performed five times on the 183-F Clearwell since 2009 (2009, 2011 twice, 2012, 2016). While 2012 saw record numbers, the average population from those five counts is 4,111 bats and a median of 3,777 bats.

Mist netting activities took place on April 26, 2017, with the support of Hanford Site biologists and radiological control technicians with WDFW biologists. Two single high mist nests (30 ft [9 m] and 40 ft [12 m]) were located immediately south of the 183-F Clearwell entrance with a triple high 40-ft (12-m) net located to the east end of the clearwell (Figure 11-11). Following sundown, a total of 37 bats were captured in the mist nets as they emerged from the structure.

Seven bats were immediately released from the net, 30 were bagged for additional measurements. All 30 bats were surveyed both for radiological contamination and UV for detection of *Pseudogymnoascus destructans* (*Pd*), the fungus that causes WNS. All bats returned negative for both contamination and UV detection of any fungus. All bats appeared healthy and of normal expected weight, only 2 of 30 bats had any signs of wing damage.



Figure 11-11. Yuma Myotis Bat Being Handled for Measurements, Muzzle, and Wing Swabs

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 2017](#)) and WDFW ([WDFW 2018](#)) maintain state lists.

The purpose of the *Endangered Species Act of 1973* is 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 *Endangered Species Act of 1973*. Washington State regulations also list species as endangered and threatened; however, such a listing does not carry the protection of the federal *Endangered Species Act of 1973*. The National Oceanic and Atmospheric Administration’s 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 11-5 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 11-5. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. (2 Pages)

Species	Status ^a	
	Federal	State
Plants		
Annual sandwort (<i>Minuartia pusilla</i>)		Threatened
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	Threatened
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>)		Sensitive
Miner's candle (<i>Cryptantha scoparia</i>)		Sensitive
Rosy pussypaws (<i>Calyptidium 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
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
Ashy pebblesnail (<i>Fluminicola fuscus</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>) ^b		Candidate
Silver-bordered fritillary (<i>Boloria selene</i>)		Candidate
Fish		
Bull trout (mid-Columbia River; <i>Salvelinus confluentus</i>) ^c	Threatened	Candidate
Chinook salmon (upper Columbia spring-run; <i>Oncorhynchus tshawytscha</i>)	Endangered	Candidate
Leopard dace (<i>Rhinichthys falcatus</i>) ^c		Candidate
Mountain sucker (<i>Catostomus platyrhynchus</i>) ^c		Candidate
River lamprey (<i>Lampetra ayresii</i>) ^c	Species of concern	Candidate
Steelhead (upper Columbia River; <i>Oncorhynchus mykiss</i>)	Threatened	Candidate
Birds		
American white pelican (<i>Pelecanus erythrorhynchos</i>)		Threatened
Bald eagle (<i>Haliaeetus leucocephalus</i>)	Species of concern	None
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

Table 11-5. Federal and State Endangered, Threatened, Sensitive, and Candidate Species. (2 Pages)

Species	Status ^a	
	Federal	State
Flammulated owl (<i>Otus flammeolus</i>) ^c		Candidate
Golden eagle (<i>Aquila chrysaetos</i>)		Candidate
Greater sage grouse (<i>Centrocercus urophasianus</i>)	Species of concern	Threatened
Lewis' woodpecker (<i>Melanerpes lewis</i>) ^c		Candidate
Loggerhead shrike (<i>Lanius ludovicianus</i>)		Candidate
Northern goshawk (<i>Accipiter gentilis</i>) ^c		Candidate
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>Anaxyrus 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>Spermophilus townsendii</i>)		Candidate
Washington ground squirrel (<i>Urocitellus washingtoni</i>) ^c	Candidate	Candidate
White-tailed jackrabbit (<i>Lepus townsendii</i>)		Candidate
^a Endangered=Species in danger of extinction within all or a significant portion of its range; Threatened=Species likely to become endangered in the 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 <i>Endangered Species Act of 1973</i> but of conservation concern within specific U.S. Fish and Wildlife Service regions. ^b Probable but not observed on the Hanford Site. ^c Reported but seldom observed on the Hanford Site.		

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 of 1973* 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); however, one mammal species (Washington ground squirrel) is currently a candidate for federal listing. In addition, 13 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 31 state-level sensitive and candidate species of animals and 15 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 2018) and review and watch lists for plants (WNHP 2017). Species on the state monitor and review lists are not considered species of concern but are monitored for status and distribution (Table 11-5). 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 11-6), along with 10 watch or review list plant species (Table 11-7).

Table 11-6. Washington State Monitored Animal Species.

Species	Species
Birds	Insects
Arctic tern (<i>Sterna paradisaea</i>) ^a	Juba skipper (<i>Hesperia juba</i>)
Ash-throated flycatcher (<i>Myiarchus cinerascens</i>) ^a	Nevada skipper (<i>Hesperia nevada</i>)
Black tern (<i>Chlidonias niger</i>) ^a	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>) ^a	Ruddy copper (<i>Lycaena rubidus 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 chlorophaea</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>Falcorusticolus</i>) ^a	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>) ^a	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>) ^a	Long-legged myotis (<i>Myotis volans</i>) ^b
Western bluebird (<i>Sialia mexicana</i>)	Northern grasshopper mouse (<i>Onychomys leucogaster</i>)
Fish	Pallid bat (<i>Antrozous pallidus</i>)
Pacific lamprey (<i>Entosphenus tridentatus</i>) ^b	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>)	
^a Reported but seldom observed on the Hanford Site.	
^b Federal species of concern.	

Table 11-7. Hanford Site Washington State Review List Plant Species.

Species	State Listing ^a
Beardless wildrye (<i>Leymus triticoides</i>)	Review Group 1
Dryspike Sedge (<i>Carex siccata</i>)	Review Group 1
Flattop broomrape (<i>Orobanche corymbosa</i>)	Review Group 1
Rosette crinklemat (<i>Tiquilia nuttallii</i>)	Review Group 1
Shy gilly-flower (<i>Gilia inconspicua</i>)	Review Group 1
Smooth cliffbrake (<i>Pellaea glabella</i> var. <i>simplex</i>)	Review Group 1t
Smooth willowherb (<i>Epilobium campestre</i>)	Review Group 1
Vanilla grass (<i>Anthoxanthum hirtum</i>)	Review Group 1
Western false dragonhead (<i>Physostegia parviflora</i>)	Review Group 1
Yellow wildrye (<i>Leymus flavescens</i>)	Review Group 1
^a 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

Cultural and historic resources protection on the Hanford Site is conducted under the direction of the DOE-RL Cultural and Historic Resources Program to ensure site compliance with federal cultural resources laws and regulations (Section 2.5). Program activities in 2017 included the following:

- Performed cultural resources reviews for federal undertakings conducted at the Hanford Site in accordance with [National Historic Preservation Act of 1966](#) (NHPA) Section 106 and CERCLA with NHPA as an ARAR
- 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 and Historic Resources Program personnel oversee all cultural resource activities at the Hanford Site. Project-specific NHPA Section 106 compliance workscope in 2017 was performed by staff archaeologists from MSA.

The DOE-RL Cultural and Historic Resources Program also schedules weekly meetings with archaeological staff from MSA to discuss and resolve issues relating to Cultural Resources Management (e.g., survey procedures, site testing, site evaluation, consultations with external parties) with the objective of establishing and maintaining consistency among contractors.

11.3.1 Cultural Resources Reviews

Pursuant to the NHPA Section 106, DOE-RL conducts cultural resources reviews of federal undertakings at the Hanford Site. The Section 106 regulations are also addressed as applicable or relevant and appropriate requirements under the CERCLA Section 121(d), requiring remedial actions to identify and take into account the effects of activities on Historic Properties included in or eligible for inclusion in the National Register of Historic Places (NRHP). NHPA Section 106 cultural resources 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 2017, Hanford Site archaeologists completed 75 NHPA Section 106 cultural resources reviews that included the following:

- Thirty-three undertakings 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 necessary²
 - Twenty-seven were identified as No Historic Properties Affected.
 - Five were determined to have No Adverse Effects to Historic Properties.
 - One was 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.
- Thirty-two projects affected historic buildings and were determined exempt by Hanford Site archaeologists after meeting the DOE-approved historic buildings Programmatic Agreement (PA) (DOE/RL-96-77) exemption criteria following an initial review.
- Eight projects had been reviewed for effects to cultural resources under previous NHPA Section 106 reviews (Previously Reviewed Project Analyses Reviewed Project Analysis [PRPA]).
- Two projects were reviewed and completed by Hanford Site archaeologists under an emergency declaration (Post Reviews) in accordance with Section 5.1.1 of DOE/RL-98-10, [Hanford Cultural Resources Management Plan](#).

The following were completed as part of the reviews described above:

- A total of 2,723.03 ac (1,101.97 ha) of new ground was surveyed for cultural resources from NHPA Section 106 project-specific surveys
- Some undertakings required NRHP (36 CFR 60) eligibility evaluations

²This number does not reflect all full cultural resources reviews initiated in 2017. Additional reviews were initiated in 2017 but completed in 2018 and are not included in this report.

- Most projects cleared under expedited reviews (PA Exemptions and PRPAs) occurred in the 200 Areas of the Hanford Site (Figure 11-12).

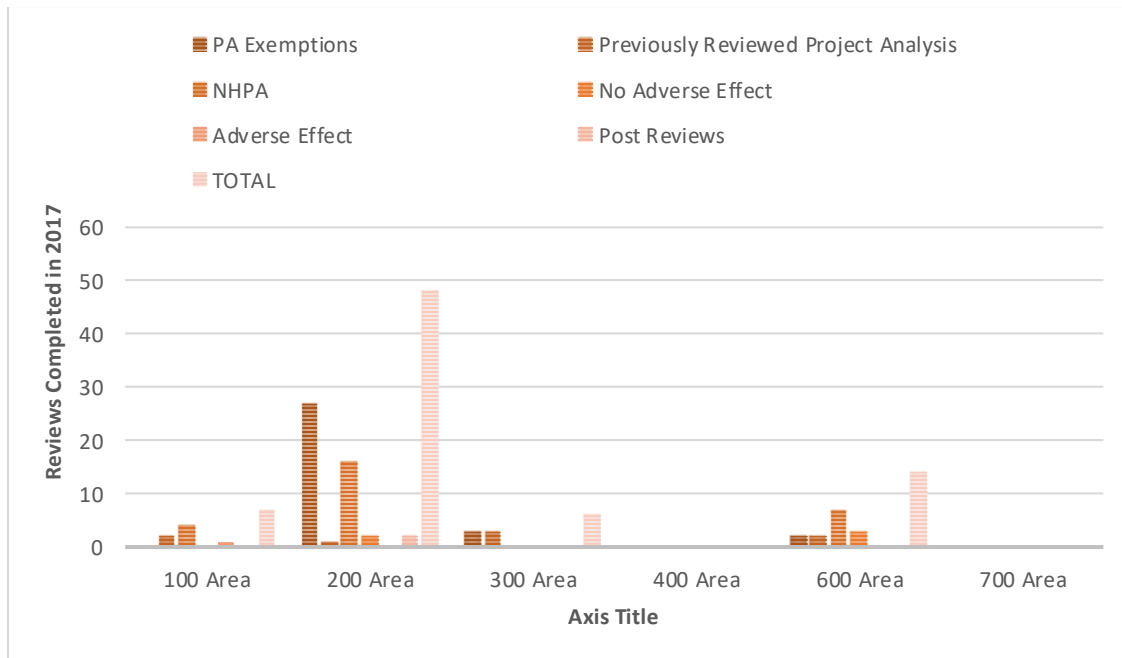


Figure 11-12. Hanford Site National Historic Preservation Act Section 106 Reviews by Area.

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 NHPA Section 110 and the Archaeological Resources Protection Act:

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 onsite inspections to monitor site conditions, assess impacts, and identify protective measures, if necessary.

In 2017, 11 pre-contact archaeological sites were monitored and 1 historic archaeological site was recorded 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 5-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 2017, 11 new archaeological sites were recorded and 5 new isolated finds were located (Table 11-8). National Register evaluations have not been completed on the newly discovered sites. Archaeological site forms for 11 previously recorded archaeological sites were updated. No Historic Property Inventory Forms (HPIF) were completed during the reporting period for components of the Hanford Site's built environment.

Table 11-8. Sites and Isolates Recorded or Updated.

2016	Eligible	Not Eligible	Unevaluated	Total
Site updates	0	0	10	10
New sites	0	0	11	11
New isolates	0	0	5	5
Historic Property Inventory Form	0	0	0	0
Total	0	0	26	26

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 2017. The Hanford Site Section 106 database tracks all cultural resources reviews conducted on the Hanford Site. The Section 106 database tracks dates, actions, letters, and results of the cultural resources 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 2017, 174 new projects were opened, with pertinent information entered as acquired into the Section 106 database. A total of 156³ 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 Geographic Information System (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 2017, a total of 45 polygons delineating completed archaeological surveys were added to the Hanford Site Survey Master shapefiles (map file) and 16 new archaeological sites/isolates, together with associated spatial and contextual information, were added to the GIS Archaeological Site and Isolate database. Spatial and contextual information for

³This number is larger than the number of projects opened because projects from previous years were closed during 2017.

10 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 (WSU-TC) 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 2017.

11.3.3 Cultural Resources Consultations

DOE conducts formal consultations with the Washington State Historic Preservation Officer within the DAHP, Native American Tribes, and other interested parties for cultural resources reviews to comply with NHPA Section 106 and NEPA (Section 2.1.4). DOE-RL consulted with the Washington State Historic Preservation Officer and Native American Tribes on all 27 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 10 meetings in 2017 with Tribal Cultural Resources staff members from the Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of Yakama Nation, and Wanapum. Discussions focused on the cultural resources reviews completed and initiated in 2017, proposed undertakings within traditional cultural property boundaries and view sheds, and approaches to protecting threatened archaeological sites and places containing Native American human remains.

11.4 Collection Management and Curation

M Petrich-Guy and RR Franklin

DOE's National Park Program is responsible for management of the artifacts from Hanford's Manhattan Project and Cold War eras collected in compliance with DOE/RL-96-77. 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. To further public access and education goals, DOE and MSA have formed a unique partnership with Washington State University's Hanford History Project (HHP) for management and curation of this collection. The HHP provides professional curatorial and archival services for the management, conservation, and public access of the Hanford Collection. The Hanford Collection consists of artifacts and multimedia relating to the Manhattan Project and Cold War Era (Figure 11-13). In addition to care, security, and public access to the collection; the partnership provides research opportunities and use in academic programs for undergraduates. WSU-TC also provides a repository for the collection that allows DOE to meet the requirements of [36 CFR 79, "Curation of Federally-Owned and Administered Archaeological Collections,"](#) including protecting these resources from theft, fire, breakage, or deterioration.



Figure 11-13. Artifacts and Multimedia from the Manhattan Project and Cold War Era.

Prior to being moved offsite, 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. Transition of the bulk of the Hanford Collection to WSU-TC curation facility was previously completed in 2016, with the exception of those materials requiring scarce historic media players for review.

Collections tasks for 2017 consisted of reviewing historic media items for public release and transfer to the HHP repository, artifact conservation, and archival processing. Of the materials scheduled for screening in 2017, 189 items (consisting of primarily historic tapes) were reviewed, cleared for public release, and joined the bulk of the Hanford Collection archives at the Hanford History Project repository for integration. Fifteen artifacts and two linear feet of archival material were evaluated for inclusion in the Hanford Collection. These materials were delivered to the Hanford History Project (HHP) repository at WSU-TC, leaving 26 (3.5%) of the 743 tagged artifacts scheduled for collection between 2018 and 2048.

During 2017, the HHP processed and housed artifacts, multimedia were moved offsite, and public access was facilitated to the Hanford Collection and Hanford Outreach Collection. Artifacts continue to be indexed and added to the collections management database, Re:Discovery Proficio. An additional 160 historic items were catalogued during 2017; to date, approximately 406 (33%) of Hanford Collection and Hanford Outreach Collection items collected since 2011 and now housed by HHP have been fully catalogued. Of the 126 linear feet of multimedia within the Collection, the remaining 38 linear feet of the 126 total linear feet (30%) was rehoused and catalogued. Archival processing includes first an in-depth inventory and later the creation of a finding aid to maximize the usefulness of the collection to researchers.

In coordination with DOE's National Park Program, the HHP worked with the public as well as regional and national institutions to implement access to the collection for education and research. As part of public education and outreach efforts. The HHP received and worked with 15 student interns, volunteers, and research/usage requestors; as well as participated in 7 outreach events that reached hundreds of members of the public in the Tri-Cities. Artifacts, multimedia, and information were supplied to several museums (e.g., Washington State Historical Society; The REACH Museum; Wanapum Heritage Center) as well as used for interpretation at the Manhattan Project National Historical Park's B Reactor (Figure 11-14). The Hanford History Project gave presentations on Hanford Site history and the Hanford Collection at four local and national conferences. These included the Society of American Archivists and the Western History Association. Cataloguing of Hanford Collection artifacts and multimedia will continue during 2018, as will public education and outreach.



Figure 11-14. Several Hanford Collection Materials Incorporated into the WWII: The High Desert Home Front Exhibit at the High Desert Museum, Bend, Oregon.

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2017 Highlight

Quality Assurance and Quality Control Activities

Both field and laboratory quality assurance/quality control (QA/QC) evaluations found no deficiencies in the sample collection, sample handling, analytical methods, or procedures employed to collect data for the Environmental Monitoring and Environmental Surveillance programs.

Subcontracted laboratories used for this effort demonstrated acceptable proficiency and results in independent QC programs such as the Mixed Analyte Performance Evaluation Program and the DOE Consolidated Audit Program.

12.0 Quality Assurance

MW Perrott

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 U.S. Department of Energy (DOE) organizations are involved in and independently conduct environmental monitoring and surveillance activities. Each of these groups are driven by different missions and regulatory requirements but with the same goal in mind. This section describes the Environmental Surveillance program managed by the Environmental Integration Services Group at Mission Support Alliance (MSA). The Environmental Surveillance program includes surveillance and monitoring across multiple media types both on and off the Hanford Site. The program conducts multimedia environmental monitoring to assess on and offsite human health exposures to radionuclides and chemicals. The data collected is used to evaluate the potential impact of current and historic site operations on the environment. This section provides information on specific measures taken in 2017 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 by CH2M Hill Plateau Remediation Company in DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2017*, and are not discussed in this section. However, details of the groundwater monitoring program can be found in Section 8.0.

Quality assurances and QCs of the Hanford on 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 plan specifications. To ensure the highest quality data are obtained, the accredited offsite 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 – DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD)
- *EPA Requirements for Quality Assurance Project Plans* (EPA 2001)
- 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.

12.1.1 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 is accomplished by establishing sitewide policies, procedures, and guidance through training programs. These training programs provide general and specialized training classes using hands-on training facilities dedicated to ensuring personnel are qualified and confident to perform their tasks safely.

The following principles and practices are highlighted in the training programs and 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

DOEO 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

- Ensure that employee training records are current and complete.

12.2 Quality Control Samples

Several types of QC samples are collected during Environmental Surveillance sampling events. The QC procedures ensure the highest quality data possible and are followed both in the field and in the laboratories.

Potential cross-contamination between samples is evaluated using trip blanks and equipment blanks. Field duplicates are collected to evaluate sample matrix heterogeneity, sample collection reproducibility, and analytical variability in conjunction with laboratory QC samples.

Laboratory QC samples are used to ensure the validity of the work done at the laboratory and the resulting data. In order to evaluate the precision and accuracy of laboratory data several types of QC samples are used including laboratory duplicates, matrix spikes, matrix spike duplicates, and method blanks. Table 12-1 summarizes the different types, characteristics, and frequency of QC samples. A QC sample frequency goal of 5% (1 in 20 samples) is used for environmental surveillance activities when feasible.

Table 12-1. Field and Laboratory Quality Control Sample Types, Characteristics, and Frequency.

Sample Type	Primary Characteristics Evaluated	Frequency
Field QC Samples		
Trip blank	VOC cross-contamination during transportation	1 per field trip, if VOCs are collected
Equipment blank	Cross-contamination from non-dedicated equipment	1 per sampling method type per year for selected analytes
Field Duplicate	Sample matrix heterogeneity and sample collection 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 duplicates	Laboratory reproducibility	
Matrix spike	Matrix effect and laboratory accuracy	
Matrix spike duplicate	Laboratory reproducibility/accuracy	
QA = quality assurance		
VOC = volatile organic compound		

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, vegetation, and sediment in accordance with approved schedules, desk instructions, and procedures. Established sampling locations were identified with visible postings or global positioning system readings and documented to ensure data continuity. In 2017, collected environmental samples were submitted to GEL and 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
TestAmerica Richland Laboratory	X	X		X
General Engineering Laboratories, LLC	X	X	X	X

Assessments of field sampling activities are routinely performed and documented by media task leads. In 2017, field duplicate samples were collected and analyzed for air, soil, Columbia River water, natural vegetation, farm products (e.g., milk, wine must, cherries), wildlife, irrigation water, sediment, and seep samples. The accepted method of evaluating the precision or reproducibility of a duplicate sample pair is the calculation of relative percent difference (RPD). RPDs are calculated for individual analytes. The generalized formula for calculating an RPD is as follows:

$$RPD = \left(\frac{|S - D|}{\frac{(S + D)}{2}} \right) \times 100$$

Where “S” and “D” are the sample and duplicate results, respectively.

For the 2017 Environmental Surveillance effort, field duplicate samples were collected at the locations indicated in Table 12-3.

Table 12-3. 2017 Field Duplicate Samples.

Media	Location	Number of Duplicate Sample Pairs
Air	Various	54
Air - Tritium	300 South Gate	13
Soil	Various	7
Natural Vegetation	Various	6
Columbia River Water Transects	Various	2
Columbia River Sediment	100-D-Spring	1
Seeps	100-F Springs – West Lake	2
Wildlife – Walleye/Whitefish	Hanford Townsite 300 Area - 100 Area	2
Wildlife – Upland Game - Goose	Hanford Townsite 300 Area	1
Water - Irrigation	Riverview Canal	1
Cherries	Riverview	1
Milk	Sage Moor Composite	1
Wine	Columbia Basin	2

Sample duplicate pair results for non-detected analytes are considered acceptable. For detected analytes, the RPD of the duplicate sample pair must be less than 30% to be considered acceptable. Duplicate results for 2017 are shown in Table 12-4.

Table 12-4. 2017 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
Air	Alpha (gross)	35 of 54	64
	Beta (gross)	41 of 54	75
	Americium-241	6 of 6	100
	Antimony-125	6 of 6	100
	Cobalt-60	6 of 6	100
	Cesium-134	6 of 6	100
	Cesium-137	6 of 6	100
	Europium-152	6 of 6	100
	Europium-154	6 of 6	100
	Europium-155	6 of 6	100
	Hydrogen-3 (tritium)	14 of 14	100
	Plutonium-238	5 of 5	100
	Plutonium-239/240	6 of 6	100
	Potassium-40	6 of 6	100
	Ruthenium-106	6 of 6	100
	Strontium-90	6 of 6	100
	Uranium-234	6 of 6	100
	Uranium-235	6 of 6	100
	Uranium-238	6 of 6	100
Soil	Antimony-125	8 of 8	100
	Cesium-134	6 of 6	100
	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	5 of 8	62
	Uranium-235	5 of 8	62
	Uranium-238	5 of 8	62
Natural Vegetation	Americium-241	2 of 2	100
	Antimony-125	8 of 8	100
	Cesium-134	8 of 8	100
	Cesium-137	8 of 8	100
	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	7 of 8	87
	Ruthenium-106	8 of 8	100

Table 12-4. 2017 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Strontium-90	8 of 8	100
	Uranium-234	7 of 8	87
	Uranium-235	7 of 7	100
	Uranium-238	8 of 8	100
Irrigation Water	Alpha (gross)	1 of 1	100%
	Beta (gross)	1 of 1	100%
	Strontium-90	1 of 1	100%
	Uranium-234	1 of 1	100%
	Uranium-235	1 of 1	100%
	Tecnetium-99	1 of 1	100%
	Tritium	1 of 1	100%
	Cesium-137	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Cesium-134	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
Columbia River Water Transects	Aluminum	4 of 4	100%
	Iron	4 of 4	100%
	Lead	4 of 4	100%
	Copper	4 of 4	100%
	Magnesium	4 of 4	100%
	Manganese	4 of 4	100%
	Molybdenum	3 of 4	75%
	Nickel	4 of 4	100%
	Potassium	4 of 4	100%
	Silver	4 of 4	100%
	Strontium	4 of 4	100%
	Sodium	4 of 4	100%
	Thallium	4 of 4	100%
	Thorium	4 of 4	100%
	Tin	4 of 4	100%
	Titanium	4 of 4	100%
	Antimony	4 of 4	100%
	Arsenic	4 of 4	100%
	Barium	4 of 4	100%
	Beryllium	4 of 4	100%
	Boron	4 of 4	100%
	Cadmium	4 of 4	100%
	Cesium	4 of 4	100%
	Chromium	4 of 4	100%
	Cobalt	4 of 4	100%
	Uranium	4 of 4	100%
	Vanadium	4 of 4	100%

Table 12-4. 2017 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Zinc	4 of 4	100%
	Zirconium	4 of 4	100%
	Bismuth	4 of 4	100%
	Calcium	4 of 4	100%
	Phosphorus	4 of 4	100%
	Selenium	4 of 4	100%
	Phosphate	2 of 2	100%
	Sulfate	2 of 2	100%
	Chloride	2 of 2	100%
	Fluoride	2 of 2	100%
	Bromide	2 of 2	100%
	Nitrogen in Nitrate	2 of 2	100%
	Nitrogen in Nitrite	2 of 2	100%
	Hexavalent chromium	4 of 4	100%
	Tritium	2 of 2	100%
	Cesium-137	2 of 2	100%
	Cesium-134	2 of 2	100%
	Cobalt-60	2 of 2	100%
	Potassium-40	2 of 2	100%
	Berillium-7	2 of 2	100%
	Ruthenium-106	2 of 2	100%
	Antimony-125	2 of 2	100%
	Europium-152	2 of 2	100%
	Europium-154	2 of 2	100%
	Europium-155	2 of 2	100%
	Strontium-90	2 of 2	100%
	Uranium-234	2 of 2	100%
	Uranium-235	2 of 2	100%
	Uranium-238	2 of 2	100%
Seep	Aluminum	1 of 2	50%
	Iron	1 of 2	50%
	Lead	2 of 2	100%
	Copper	0 of 2	0%
	Magnesium	2 of 2	100%
	Manganese	1 of 2	50%
	Molybdenum	2 of 2	100%
	Nickel	2 of 2	100%
	Potassium	2 of 2	100%
	Silver	2 of 2	100%
	Strontium	2 of 2	100%
	Strontium-90	1 of 1	100%
	Sodium	2 of 2	100%
	Thallium	2 of 2	100%
	Thorium	2 of 2	100%
	Tin	2 of 2	100%
	Titanium	2 of 2	100%
	Antimony	2 of 2	100%

Table 12-4. 2017 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Arsenic	2 of 2	100%
	Barium	2 of 2	100%
	Beryllium	2 of 2	100%
	Boron	2 of 2	100%
	Cadmium	2 of 2	100%
	Cesium	2 of 2	100%
	Chromium	2 of 2	100%
	Cobalt	2 of 2	100%
	Uranium	2 of 2	100%
	Uranium-234	1 of 1	100%
	Uranium-235	1 of 1	100%
	Uranium-238	1 of 1	100%
	Vanadium	2 of 2	100%
	Zinc	1 of 2	50%
	Zirconium	2 of 2	100%
	Bismuth	2 of 2	100%
	Calcium	2 of 2	100%
	Phosphorus	1 of 2	50%
	Selenium	2 of 2	100%
	Tritium	2 of 2	100%
	Phosphate	1 of 1	100%
	Sulfate	1 of 1	100%
	Chloride	1 of 1	100%
	Fluoride	1 of 1	100%
	Bromide	1 of 1	100%
	Bicarbonate	1 of 1	100%
	Hydroxylion	1 of 1	100%
	Alkalinity	1 of 1	100%
	Carbonate Alakalinity	1 of 1	100%
	Nitrogen in Nitrate	2 of 2	100%
	Nitrogen in Nitrite	1 of 1	100%
	Lead	1 of 1	100%
	Copper	1 of 1	100%
	Mercury	0 of 1	0%
	Nickel	1 of 1	100%
	Silver	1 of 1	100%
	Strontium-90	1 of 1	100%
	Thallium	1 of 1	100%
	Antimony	1 of 1	100%
	Antimony-125	1 of 1	100%
	Arsenic	1 of 1	100%
	Beryllium	1 of 1	100%
	Beryllium-7	1 of 1	100%
	Cadmium	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cesium-137	1 of 1	100%
	Chromium	1 of 1	100%

Table 12-4. 2017 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Hexavalent Chromium	0 of 1	0%
	Cobalt-60	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Uranium	1 of 1	100%
	Uranium-234	1 of 1	100%
	Uranium-235	0 of 1	0%
	Uranium-238	1 of 1	100%
	Potassium-40	1 of 1	100%
	Zinc	1 of 1	100%
	Plutonium-238	1 of 1	100%
	Plutonium-239/240	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Selenium	0 of 1	0%
	Phosphate	1 of 1	100%
	Sulfate	1 of 1	100%
	Chloride	1 of 1	100%
	Fluoride	1 of 1	100%
	Bromide	1 of 1	100%
	Nitrogen in Nitrate	1 of 1	100%
	Nitrogen in Nitrite	1 of 1	100%
Wildlife Walleye/Whitefish	Aluminum	1 of 1	100%
	Lead	1 of 1	100%
	Copper	1 of 1	100%
	Manganese	1 of 1	100%
	Mercury	0 of 1	0%
	Nickel	1 of 1	100%
	Silver	1 of 1	100%
	Thallium	1 of 1	100%
	Thorium	1 of 1	100%
	Antimony	1 of 1	100%
	Arsenic	1 of 1	100%
	Barium	1 of 1	100%
	Beryllium	1 of 1	100%
	Cadmium	1 of 1	100%
	Chromium	1 of 1	100%
	Uranium	1 of 1	100%
	Zinc	1 of 1	100%
	Selenium	1 of 1	100%
	Cesium-137	3 of 3	100%
	Cesium-134	3 of 3	100%
	Cobalt-60	3 of 3	100%
	Potassium-40	3 of 3	100%
	Berillium-7	3 of 3	100%
	Plutonium-238	1 of 1	100%
	Plutonium-239/240	1 of 1	100%

Table 12-4. 2017 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Ruthenium-106	3 of 3	100%
	Antimony-125	3 of 3	100%
	Europium-152	3 of 3	100%
	Europium-154	3 of 3	100%
	Europium-155	3 of 3	100%
	Strontium-90	3 of 3	100%
	Uranium-234	1 of 1	100%
	Uranium-235	1 of 1	100%
	Uranium-238	1 of 1	100%
	Tritium	1 of 1	100%
Wildlife Goose	Cesium-137	2 of 2	100%
	Cesium-134	2 of 2	100%
	Cobalt-60	2 of 2	100%
	Potassium-40	2 of 2	100%
	Berillium-7	2 of 2	100%
	Ruthenium-106	2 of 2	100%
	Antimony-125	2 of 2	100%
	Europium-152	2 of 2	100%
	Europium-154	2 of 2	100%
	Europium-155	2 of 2	100%
	Strontium-90	2 of 2	100%
Cherries	Cesium-137	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Berillium-7	1 of 1	100%
	Ruthenium-106	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Strontium-90	1 of 1	100%
Wine	Cesium-137	2 of 2	100%
	Cesium-134	2 of 2	100%
	Cobalt-60	2 of 2	100%
	Potassium-40	2 of 2	100%
	Berillium-7	2 of 2	100%
	Ruthenium-106	2 of 2	100%
	Antimony-125	2 of 2	100%
	Europium-152	2 of 2	100%
	Europium-154	2 of 2	100%
	Europium-155	2 of 2	100%
	Tritium	2 of 2	100%
Milk	Cesium-137	1 of 1	100%
	Cesium-134	1 of 1	100%
	Cobalt-60	1 of 1	100%
	Potassium-40	1 of 1	100%
	Berillium-7	1 of 1	100%

Table 12-4. 2017 Field Duplicate Sample Results. (7 Pages)

Media	Analytes	Number of Results Within Control Limits ^a	Percent of Results within Control Limits
	Ruthenium-106	1 of 1	100%
	Antimony-125	1 of 1	100%
	Europium-152	1 of 1	100%
	Europium-154	1 of 1	100%
	Europium-155	1 of 1	100%
	Tritium	1 of 1	100%
^a Number of reported results within control limits are those with 1) Relative Percent Difference value less than 30% and 2) result 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 Washington State Department of Health (WDOH) for comparative analysis as part of the QA program (DOE/RL-91-50). The WDOH conducts the Hanford Environmental Radiation Oversight Program to independently verify 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 320-115, Hanford Environmental Radiation Oversight Program: 2015 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 2017 included the following:

- Air filters from 14 locations
- Columbia River continuous water from one location
- Columbia River transects from four locations
- Columbia River shoreline springs (seeps) from six locations
- Offsite irrigation water from two locations
- Columbia River Sediment from eight locations
- Melons from three locations
- Cherries from four locations
- Leafy Vegetables from three locations
- Potatoes from three locations
- Corn from four locations
- Wine Must from three locations
- Upland Game Birds from two locations
- Walleye/carp from two locations
- Deer/Elk from one background location
- Soil from six locations
- Vegetation from five locations.

No comparison data for 2017 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 participate in internal and independent QC programs to evaluate analytical precision and accuracy. These laboratories employ chemists and technologists who are qualified 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-source checks, background counts, replicate analysis, matrix spikes, reagent blanks, and maintenance of control charts to identify any analytical deficiencies.

Examples of independent QC programs are the Mixed Analyte Performance Evaluation Program (MAPEP) and the DOE Consolidated Audit Program (DOECAP). MAPEP is conducted twice a year and DOECAP is conducted annually.

In 2017, the GEL and TARL laboratories participated in various independent QA and QC programs including MAPEP and DOECAP. These managed programs use standardized audit methods, processes, and procedures to ensure the validity of the data. MAPEP results for GEL and TARL are presented in Tables 12-5 and 12-6, respectively.

Table 12-5. 2017 DOE Mixed Analyte Performance Evaluation Program Results for General Engineering Laboratories, LLC. (2 Pages)

Environmental Sample Media and Analytes		MAPEP 36 Series June 2017 ^a	MAPEP 37 Series December 2017 ^a
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	Strontium-90 ^b	Strontium-90 ^b
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	Strontium-90 ^b
Soil	Americium-241, cesium-134, cesium-137, cobalt-60, potassium-40, plutonium-238, plutonium-239/240, strontium-90, technetium-99	100% Acceptable	100% Acceptable

**Table 12-5. 2017 DOE Mixed Analyte Performance Evaluation Program Results
for General Engineering Laboratories, LLC. (2 Pages)**

Environmental Sample Media and Analytes		MAPEP 36 Series June 2017 ^a	MAPEP 37 Series December 2017 ^a
<i>Inorganic Compounds</i>			
Water	Antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, thallium, vanadium, zinc	100% Acceptable	Mercury ^b
^a Performance results 100% acceptable for all analytes reported unless otherwise noted. ^b Result is acceptable but was issued a warning for having a bias between 20 and 30%. MAPEP = Mixed Analyte Performance Evaluation Program			

**Table 12-6. DOE Mixed Analyte Performance Evaluation Program Results
for TestAmerica Richland Laboratory.**

Environmental Sample Media and Analytes		MAPEP 36 Series June 2017 ^a	MAPEP 37 Series December 2017 ^a
<i>Radionuclides</i>			
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	Plutonium-238 ^b	Cesium-134 ^c Cesium-137 ^c Cobalt-60 ^c Plutonium-238 ^c Plutonium-239/240 ^c Strontium-90 ^c Uranium-234/233 ^c Uranium-238 ^c
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	Americium-241 ^d Technetium-99 ^d	Technetium-99 ^b Uranium-238 ^c Strontium-90 ^d
Vegetation	Americium-241, cesium-134, cesium-137, cobalt-60, plutonium-238, plutonium-239/240, strontium-90, uranium-234/-233, uranium-238	100% Acceptable	NA
Soil	Americium-241, cesium-134, cesium-137, cobalt-60, potassium-40, plutonium-238, plutonium-239/240, strontium-90, technetium-99	Plutonium-239/240 ^c Technetium-99 ^d	Cesium-137 ^b
^a Performance results 100% acceptable for all analytes reported unless otherwise noted. ^b Result is acceptable but was issued a warning for having a bias between 20 and 30%. ^c Result not acceptable; bias greater than 30%. ^d Result not acceptable; false positive. MAPEP = Mixed Analyte Performance Evaluation Program NA = not available			

12.5.1 Laboratory Performance Evaluation and Proficiency Testing

Participation of Hanford Site analytical laboratories in DOE and U.S. Environmental Protection Agency (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 providing an efficient means for laboratories to demonstrate analytical proficiency. Results to past MAPEP studies can be found on the DOE's MAPEP webpage at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

GEL's MAPEP program radiological results were issued warnings for biased strontium-90 results in the 20 to 30% range; however, these results are considered acceptable. Therefore, GEL's radiological MAPEP results are 100% acceptable for studies 34 and 35 in 2017 for air, water, soil, and vegetation.

GEL's MAPEP results for inorganic compounds in water were issued a warning for mercury in MAPEP study 35; however, this is considered an acceptable result. Therefore, GEL's inorganic MAPEP results are 100% acceptable. Results of MAPEP studies 34 and 35 for GEL are provided in Table 12-5 or at <http://www.id.energy.gov/resl/mapep/mapepreports.html>.

TARL's MAPEP radiological results for studies 34 and 35 in 2017 received warnings for plutonium-238 in air and technetium-99 in water; however, these results are considered acceptable. TARL had unacceptable results for technetium-99, strontium-90, and americium-241 due to false positive results. Additionally, TARL had numerous unacceptable results due to bias greater than 30%. Most of these high bias results were from the air filter sample in study 35 and could be due to an anomaly associated with that specific sample. For additional details of the TARL MAPEP results for studies 34 and 35 please see Table 12-6 or the full reports 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; 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.

12.7 References

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Appendix 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.

biota concentration guide (BCG) – is the limiting concentration of a radionuclide in soil, sediment, or water that would not cause dose limits for protection of populations of aquatic and terrestrial biota to be exceeded

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 high *radiation* levels associated with waste for treatment or residuals which cannot be removed.

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 – 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 stream released from a facility.

emission – Gaseous stream released from a facility.

emission/effluent monitoring – Sampling or measuring specific streams for the presence of pollutants.

exposure – The interaction of an organism with a physical agent (e.g., *radiation*) or a chemical agent (e.g., arsenic) of interest. Also used as a term for quantifying x- and *gamma-radiation* fields. See *roentgen*.

external radiation – *Radiation* originating from a source outside the body.

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 – For nuclides, 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 from 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. (Note: Ion exchange “resin” is frequently applied to inorganic materials {e.g., aluminosilicates and zeolites} which also exhibit ion exchange properties.)

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 – Nuclear waste that does not fit into the categorical definitions for high-level waste, spent nuclear fuel, transuranic waste, or certain byproduct materials such as uranium or thorium mill tailings.

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

offsite locations – Sampling and measurement locations outside the Hanford Site boundary.

onsite locations – Sampling and measurement locations within the Hanford Site boundary.

operable unit – A discrete area for which an incremental step can be taken toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units depending on the complexity of problems associated with the site.

outfall – End of a drain or pipe that discharges wastewater or other *effluent* to the environment (e.g., 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 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 nuclear 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 deviation—A measure of the dispersion of sample values from a population. If the data are from a normal or bell-shaped statistical distribution then about 68% of the values are within one standard deviation of the mean and about 95% of the values are within two standard deviations of the mean.

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 storage tanks used to hold wastes from nuclear fuel reprocessing activities at Hanford.

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 or concentrations determined using chemical analytical techniques .

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.

References

- 40 CFR 761. “Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions.” *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&tpl=/ecfrbrowse/title40/40cfr761_main_02.tpl.

DOE O 458.1, Chg. 3. 2013. *Radiation Protection of the Public and the Environment*. U.S. Department of Energy, The Office of Environment, Safety and Health, Washington, D.C. Online at <https://www.directives.doe.gov/directives-documents/400-series/0458-1-border-admc3>.

Resource Conservation and Recovery Act of 1976, 42 U.S.C. 6901, et seq. Online at <https://www.epa.gov/laws-regulations/summary-resource-conservation-and-recovery-act>.

Toxic Substances Control Act. 1976. Public Law 94-469, as amended, 15 U.S.C. 2601 et seq. Online at <http://www.gpo.gov/fdsys/pkg/STATUTE-90/pdf/STATUTE-90-Pg2003.pdf>.

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B. Background 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 http://www.lib.washington.edu/gmm/collections/govpubs	Portland State University Government Information Branford Price Millar Library 1875 SW Park Ave Portland, OR 97207-1151 (503) 725-4542 https://library.pdx.edu/research/government-information-maps/
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	Gonzaga University, Foley Center East 502 Boone Spokane, WA 99258-0001 (509) 313-3847 https://www.gonzaga.edu/academics/libraries/foley-library
Hanford Health Info Archive (through Washington State Archives): https://www.sos.wa.gov/archives/	

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	Symbol	Name
Temperature		Concentration	
°C	degree Celsius	ppb	parts per billion
°F	degree Fahrenheit	ppm	parts per million
Time		ppmv	parts per million by volume
d	day	Length	
hr	hour	cm	centimeter (1×10^{-2} m)
min	minute	ft	foot
sec	second	in.	inch
yr	year	km	kilometer (1×10^3 m)
Rate		m	meter
cfs (or ft ³ /sec)	cubic feet per second	mi	mile
cpm	counts per minute	mm	millimeter (1×10^{-3} m)
gpm	gallon per minute	μm	micrometer (1×10^{-6} m)
mph	mile per hour	Area	
mR/hr	milliroentgen per hour	ha	hectare (1×10^4 m ²)
mrem/yr	millirem per year	km ²	square kilometer
Volume		mi ²	square mile
cm ³	cubic centimeter	ft ²	square foot
ft ³	cubic foot	Mass	
gal	gallon	g	gram
L	liter	kg	kilogram (1×10^3 g)
m ³	cubic meter	mg	milligram (1×10^{-3} g)
mL	milliliter (1×10^{-3} L)	μg	microgram (1×10^{-6} g)
yd ³	cubic yard	lb	pound

Table B-2. Conversion Table.

Multiply	By	To Obtain	Multiply	By	To Obtain
cm	0.394	in.	in.	2.54	cm
m	3.28	ft	ft	0.305	m
km	0.621	mi	mi	1.61	km
kg	2.205	lb	lb	0.454	kg
L	0.2642	gal	gal	3.785	L
m ²	10.76	ft ²	ft ²	0.093	m ²
ha	2.47	acre	acre	0.405	ha
km ²	0.386	mi ²	mi ²	2.59	km ²
m ³	35.31	ft ³	ft ³	0.0283	m ³
m ³	1.308	yd ³	yd ³	0.7646	m ³
pCi	1,000	nCi	nCi	0.001	pCi
μCi/mL	109	pCi/L	pCi/L	10 ⁻⁹	μCi/mL
Ci/m ³	1012	pCi/m ³	pCi/m ³	10 ⁻¹²	Ci/m ³
mCi/cm ³	1015	pCi/m ³	pCi/m ³	10 ⁻¹⁵	mCi/cm ³
nCi/m ²	1.0	mCi/km ²	mCi/km ²	1.0	nCi/m ²
Ci	3.7×10^{10}	Bq	Bq	2.7×10^{-11}	Ci
pCi	0.037	Bq	Bq	27	pCi
rad	0.01	Gy	Gy	100	rad

Multiply	By	To Obtain
rem	0.01	Sv
ppm	1,000	ppb
°C	$(^{\circ}\text{C} \times 9/5) + 32$	°F
oz	28.349	g
ton	0.9078	tonne

Multiply	By	To Obtain
Sv	100	rem
ppb	0.001	ppm
°F	$(^{\circ}\text{F} - 32) \div 9/5$	°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 becquerels.

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]) ($1 \text{ Ci} = 3.7 \times 10^{10} \text{ dps}$).
1 Becquerel = 1 disintegrations/sec(dps).

Table B-4. Radioactivity Units.

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel ($2.7 \times 10^{-11} \text{ Ci}$)
mCi	millicurie ($1 \times 10^{-3} \text{ Ci}$)	mBq	millibecquerel ($1 \times 10^{-3} \text{ Bq}$)
μCi	microcurie ($1 \times 10^{-6} \text{ Ci}$)	kBq	kilobecquerel ($1 \times 10^3 \text{ Bq}$)
nCi	nanocurie ($1 \times 10^{-9} \text{ Ci}$)	MBq	megabecquerel ($1 \times 10^6 \text{ Bq}$)
pCi	picocurie ($1 \times 10^{-12} \text{ Ci}$)	GBq	gigabecquerel ($1 \times 10^9 \text{ Bq}$)
fCi	femtocurie ($1 \times 10^{-15} \text{ Ci}$)	TBq	terabecquerel ($1 \times 10^{12} \text{ Bq}$)
aCi	attocurie ($1 \times 10^{-18} \text{ Ci}$)		

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 Dose Limits.

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 Limits for Non-human Biota

Regulatory dose limits for non-human biota are set by DOE (Table B-6).

Table B-6. Radioactivity Dose Limits for Non-human Biota.

Daily Radiation Dose Limits	Agency
Aquatic Animal - 1 rad	DOE
Riparian Animal – 0.1 rad	DOE
Terrestrial Plant - 1 rad	DOE
Terrestrial Animal – 0.1 rad.	DOE

B.7 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 (μSv) 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 mrem (10 μSv) 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 mSv) would likely cause temporary radiation sickness in some exposed individuals. An acute dose of over 500 rem (5 mSv) would soon result in death in approximately 50% of those exposed. Exposure to lower amounts of radiation (10 mrem [100 μSv] or less) produces no immediate observable effects, but long-term delayed effects are possible. The average person in the United States receives an annual dose from exposure to naturally produced radiation of approximately 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-7. Radiological Dose Units Conversions.

μSv 0.01	μSv 0.1	μSv 1	μSv 10	μSv 100	mSv 1	mSv 10	mSv 100	Sv 1
1 μrem	10 μrem	100 μrem	1 mrem	10 mrem	100 mrem	1 rem	10 rem	100 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. Dose to non-human biota is calculated in rads and compared to the limits in Table B-6.

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-8. Radiation Dose or Exposure Units.

Symbol	Name
rad	rad (10 milligray [mGy])
mrad	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
μrem	microrem (1×10^{-6} rem)
Sv	sievert (100 rem)
mSv	millisievert (1×10^{-3} Sv)
μSv	microsievert (1×10^{-6} Sv)
nSv	nanosievert (1×10^{-9} Sv)
R	roentgen
mR	milliroentgen (1×10^{-3} R)
μR	microroentgen (1×10^{-6} R)
Gy	gray (100 rad)
mGy	milligray (1×10^{-3} rad)

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-9. 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	^{137m} Ba	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						

NOTE: Natural uranium is a mixture dominated by uranium-238; thus, the half-life is approximately 4.5 × 10⁹ years.

B.8 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-10. 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.9 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.10 Standard Deviation

The standard deviation (SD) of sample data relates to the variation around the mean of a set of individual sample results. If analytical results follow a bell-shaped curve (or a normal statistical distribution), then 95% of the time an independent sample would fall within the mean plus or minus two times the standard deviation (or mean \pm 2 SD).

B.11 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 may be assumed the nominal detection limit.

B.12 Standard Error of the Mean

Just as individual values are accompanied by uncertainty, the mean is accompanied by an associated standard error (SE). The standard error is calculated from the SD and the number of samples. As the number of samples increases the SE decreases, therefore uncertainty in the mean is reduced. The mean plus or minus two times the standard error of the mean would include approximately 95% of the means estimated from that same population.

B.13 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 following 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. 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.

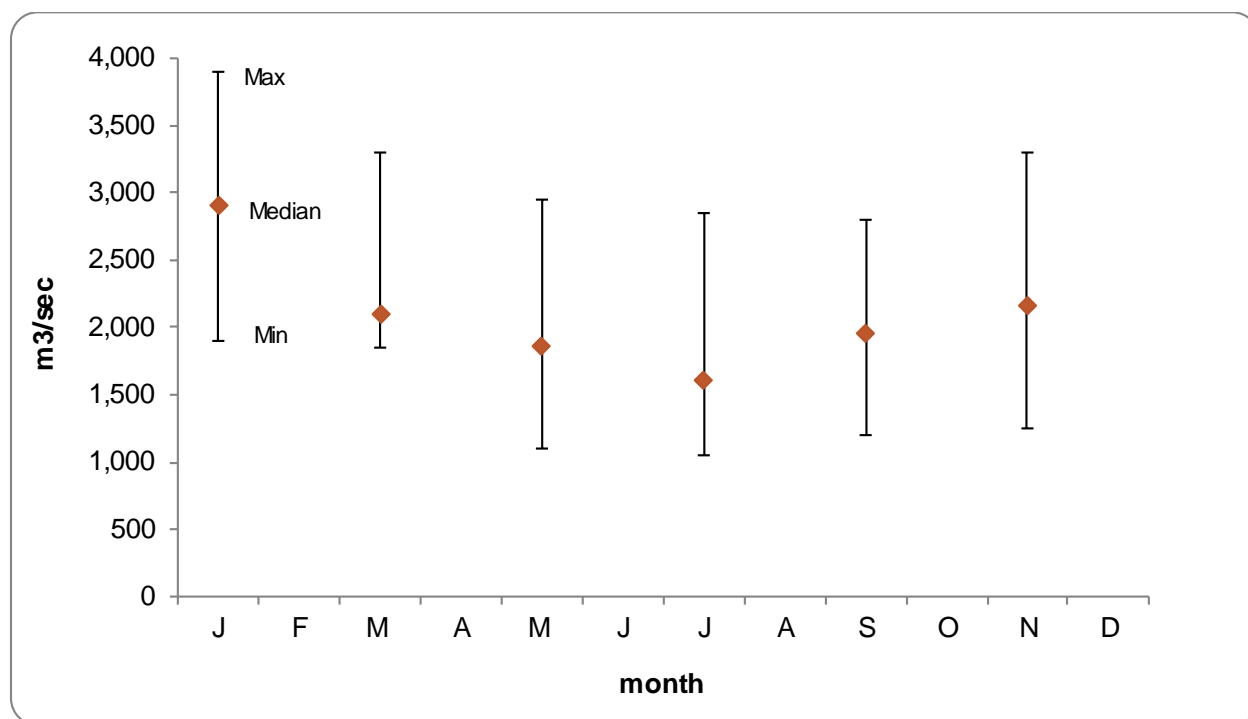


Figure B-1. Maximum, Median, and Minimum Values Graphical Representation.

B.14 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 during sample analysis. Backgrounds are determined with empty detectors and represent an average background decay rate. Because of the randomness of radioactive emissions (including backgrounds), the very low activities of some contaminants, it is possible that the average background value used is larger than the actual contaminant measurement result. 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.15 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.16 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). Each scale has its benefits in presenting information. Note that the linear scale often has a natural minimum value of zero for the y-axis. Zero and negative values cannot be plotted on logarithmic scale plots and the analyst must select an appropriate minimum value for the y-axis.

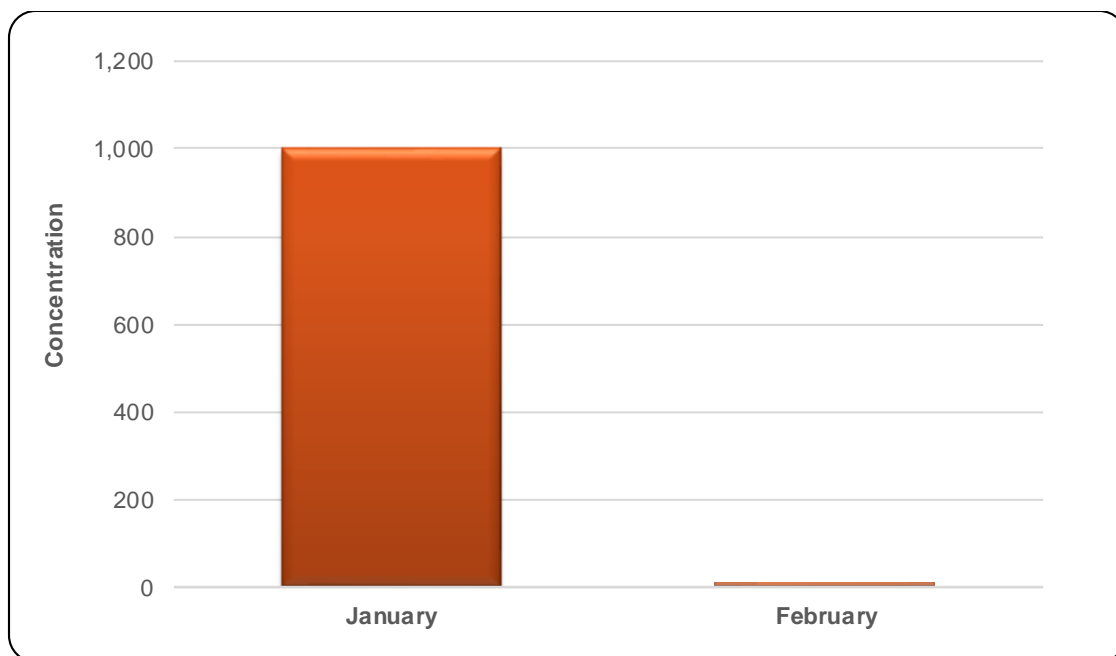


Figure B-2. Data Plotted Using a Linear Scale.

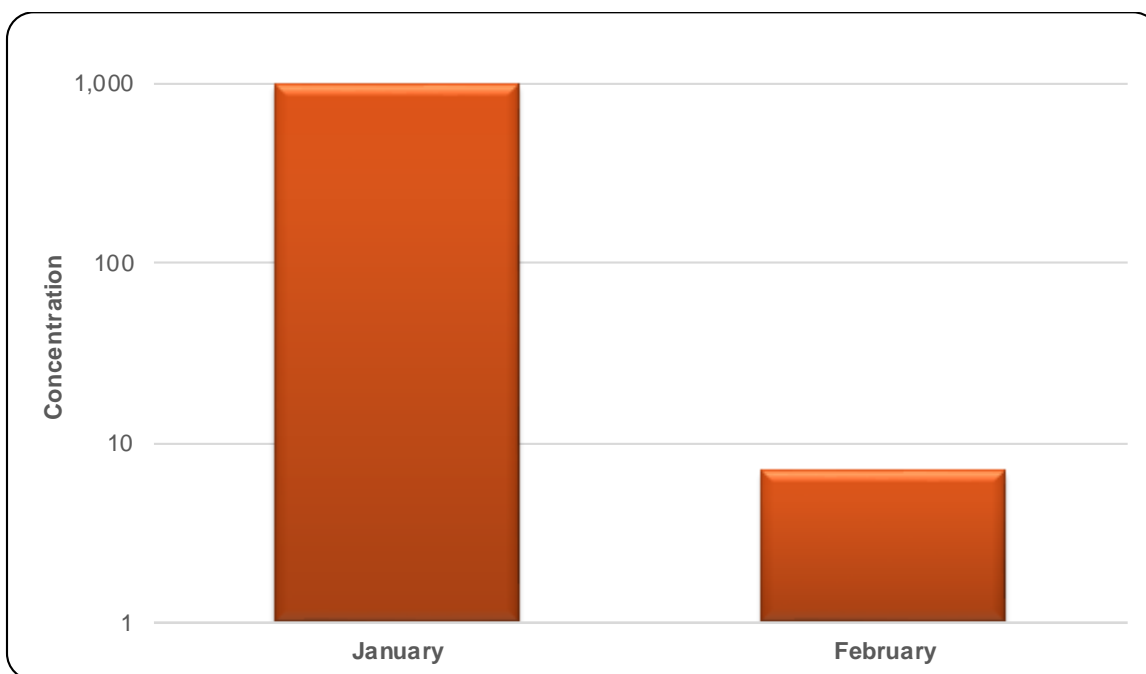


Figure B-3. Data Plotted Using a Logarithmic Scale.

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.¹ 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.

¹ Assuming the data are normally distributed.

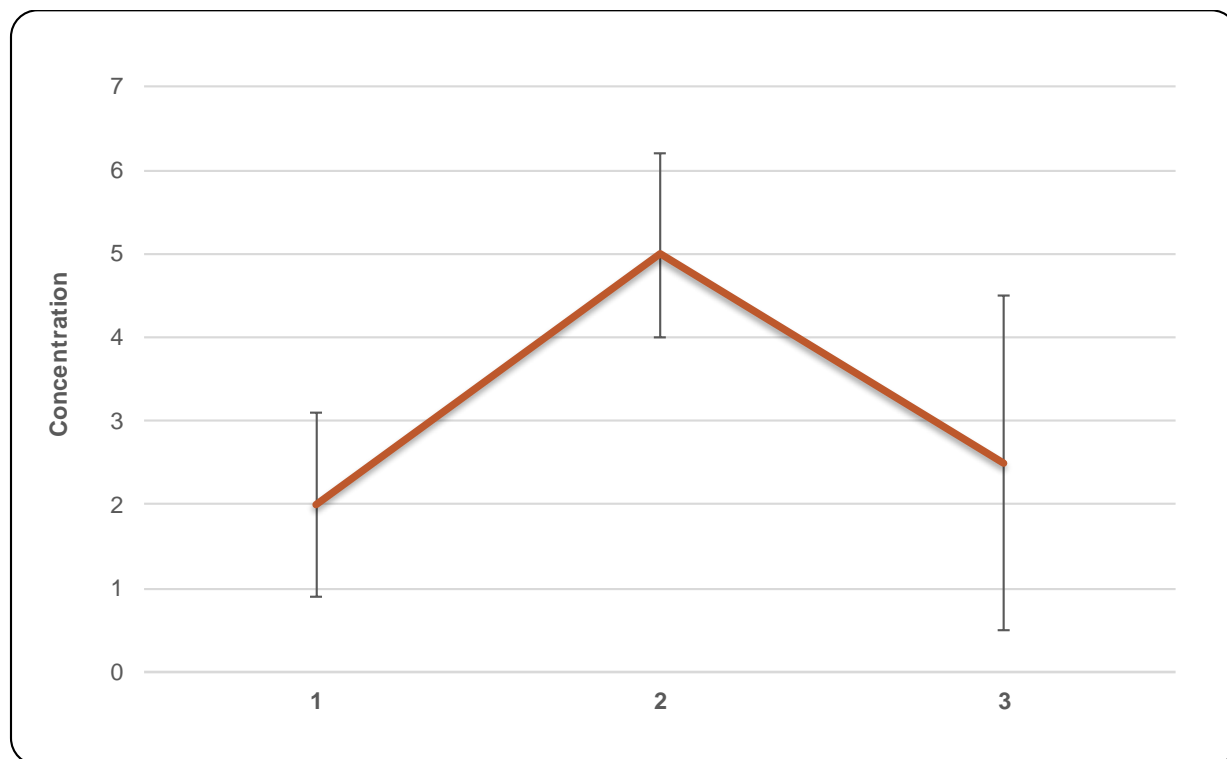


Figure B-4. Data with Error Bars Plotted Using a Linear Scale.

Appendix C. Additional Monitoring Results

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C.0 Additional Monitoring Results

ME Hoefer, CJ Perkins, JE Cranna

This appendix contains additional information on monitoring results and supplements data summarized in the main body of the report.

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C.1 Onsite Pond

Table C-1. Selected Radionuclide Concentrations in West Lake Sediment.

Radionuclide	2017					2012-2016							
	No. of Samples	No. of Detects	Concentration			No. of Samples	No. of Detects	Concentration					
			Maximum ^a					Average ^b		Maximum ^a			
			pCi/g ^c	±	pCi/g ^c			pCi/g ^c	±	pCi/g ^c	pCi/g ^c	±	pCi/g ^c
Cesium-137	7	7	1.3E+00	±	7.1E-02	11	11	6.3E-01	±	9.2E-01	1.6E+00	±	1.6E-01
Gross Alpha	7	6	1.7E+01	±	4.9E+00	11	10	8.7E+00	±	1.1E+01	2.3E+01	±	7.6E+00
Gross Beta	7	7	2.6E+01	±	3.4E+00	11	11	2.3E+01	±	1.2E+01	3.0E+01	±	2.4E+00
Strontium-90	7	7	3.7E-01	±	8.9E-02	11	5	1.5E-01	±	3.5E-01	4.9E-01	±	9.7E-02
Technetium-99	7	0	1.7E-01	±	5.5E-01	11	1	1.2E-01	±	4.8E-01	6.0E-01	±	2.8E-01
Uranium-234	7	7	3.6E+00	±	4.3E-01	11	11	4.2E+00	±	5.5E+00	9.6E+00	±	1.6E+00
Uranium-235	7	6	2.4E-01	±	7.9E-02	11	10	2.4E-01	±	3.2E-01	6.5E-01	±	1.6E-01
Uranium-238	7	7	3.4E+00	±	4.0E-01	11	11	3.9E+00	±	5.2E+00	9.3E+00	±	1.5E+00
^a Result and maximum values are ± total propagated analytical uncertainty. ^b Averages are ±2 standard deviations. ^c 1 pCi = 0.037 Bq.													

Table C-2. Radionuclide Concentrations in West Lake Surface Water.

Radionuclide	2017								2012-2016								DOE-Biota Concentration Guides ^c pCi/L
	No. of samples	No. of detects	Concentration						No. of samples	No. of detects	Concentration						
			Average ^a			Maximum ^b					Average ^a			Maximum ^b			
			pCi/L			pCi/L					pCi/L			pCi/L			
Tritium	8	0	1.7E+01	±	8.9E+01	7.8E+01	±	1.3E+02	16	2	1.1E+02	±	4.5E+02	6.9E+02	±	2.1E+02	2.7E+08
Uranium-234	6	6	4.5E+02	±	4.5E+02	6.6E+02	±	7.7E+01	16	16	1.8E+02	±	2.6E+02	1.1E+04	±	4.4E+03	2.0E+02
Uranium-235	6	6	2.2E+01	±	2.3E+01	3.5E+01	±	5.5E+00	16	15	1.3E+02	±	6.8E+02	1.4E+03	±	1.6E+03	2.2E+02
Uranium-238	6	6	4.2E+02	±	4.3E+02	6.2E+02	±	7.3E+01	16	16	1.7E+03	±	7.0E+03	1.4E+04	±	5.2E+03	2.2E+02

^a Averages ± 2 standard deviations.
^b Maximum values are ± total propagated analytical uncertainty.
^c Biota Concentration Guide value for Aquatic Animal receptor, (DOE/EH-0676)

C.2 Ambient Air

Table C-3. Concentrations of Select Radionuclides (pCi/m³)^a in Onsite Air Samples. (2 Pages)

Radionuclide	Site	2017									2012–2016									EPA
		Number of		Average ^c			Maximum ^d			Sampler	Number of		Average ^c			Maximum ^d			Table 2 ^{e,f}	
		Samples	Detections ^b								Samples	Detections ^b								
gross α	100 K Area	156	152	1.7E-03	±	2.6E-03	7.7E-03	±	1.5E-03	N534	1431	1381	1.2E-03	±	1.8E-03	9.3E-03	±	6.6E-03	2.0E-02	
	200-East	659	627	1.6E-03	±	2.4E-03	9.1E-03	±	2.1E-03	N957	3394	3302	1.3E-03	±	1.9E-03	1.0E-02	±	2.4E-03		
	200-West	665	654	2.5E-03	±	1.1E-02	8.4E-02	±	7.7E-03	N956	3510	3451	1.4E-03	±	1.9E-03	9.9E-03	±	1.4E-03		
	618-10 BG	100	100	1.5E-03	±	1.6E-03	4.3E-03	±	1.0E-03	N579	523	517	1.3E-03	±	1.9E-03	9.9E-03	±	1.1E-03		
	ERDF	130	130	1.6E-03	±	2.5E-03	9.3E-03	±	1.3E-03	N963	655	647	1.2E-03	±	1.5E-03	5.8E-03	±	9.7E-04		
gross β	100 K Area	156	156	1.6E-02	±	2.2E-02	5.4E-02	±	5.1E-03	N927	1431	1431	1.7E-02	±	2.3E-02	1.2E-01	±	1.7E-02		9.0E+00
	200-East	659	659	1.6E-02	±	2.0E-02	7.2E-02	±	6.7E-03	N985	3394	3393	1.7E-02	±	2.5E-02	1.8E-01	±	1.0E-02		
	200-West	665	665	1.6E-02	±	2.0E-02	6.9E-02	±	7.1E-03	N555	3510	3510	1.6E-02	±	2.1E-02	9.1E-02	±	8.0E-03		
	618-10 BG	100	100	1.7E-02	±	2.3E-02	6.4E-02	±	1.1E-02	N549	523	523	1.8E-02	±	2.5E-02	1.1E-01	±	9.0E-03		
	ERDF	130	130	1.6E-02	±	2.1E-02	5.1E-02	±	2.0E-02	N518	655	655	1.5E-02	±	1.9E-02	7.6E-02	±	5.8E-03		
⁹⁰ Sr	100 K Area	12	0	-3.5E-05	±	5.1E-04	3.4E-04	±	4.6E-04	N476	105	10	1.1E-04	±	1.1E-03	4.3E-03	±	6.0E-03	1.9E-02	
	200-East	49	0	-4.8E-05	±	5.2E-04	5.9E-04	±	5.9E-04	N969	249	34	1.3E-04	±	1.3E-03	5.8E-03	±	2.2E-03		
	200-West	50	0	7.6E-05	±	6.0E-04	6.8E-04	±	5.2E-04	N517	261	22	4.8E-06	±	3.9E-04	5.5E-04	±	4.7E-04		
	618-10 BG	8	1	4.4E-04	±	9.7E-04	1.7E-03	±	7.4E-04	N549	40	4	9.6E-05	±	1.9E-04	4.7E-04	±	2.6E-04		
	ERDF	10	0	3.5E-04	±	5.4E-04	6.8E-04	±	5.2E-04	N517	50	4	2.8E-05	±	3.2E-04	4.9E-04	±	3.9E-04		
¹³⁷ Cs	100 K Area	12	0	-3.9E-05	±	2.6E-04	2.1E-04	±	5.3E-04	N534	105	8	6.6E-05	±	1.3E-03	3.8E-03	±	8.2E-03	1.9E-02	
	200-East	48	0	4.8E-05	±	4.1E-04	5.3E-04	±	4.7E-04	N559	264	20	3.5E-04	±	3.3E-03	1.9E-02	±	6.2E-03		
	200-West	50	0	2.0E-05	±	3.2E-04	3.2E-04	±	4.2E-04	N956	273	1	3.8E-05	±	3.5E-04	6.4E-04	±	5.6E-04		
	618-10 BG	8	0	6.0E-05	±	1.0E-04	1.4E-04	±	1.1E-04	N580	40	0	-8.4E-06	±	1.6E-04	1.8E-04	±	1.9E-04		
	ERDF	10	0	4.0E-06	±	2.7E-04	1.7E-04	±	3.2E-04	N963	50	0	3.3E-05	±	2.5E-04	4.0E-04	±	4.5E-04		
²³⁸ Pu	100 K Area	11	0	-3.5E-06	±	1.4E-05	6.5E-06	±	3.4E-05	N927	98	0	2.0E-07	±	1.2E-05	1.8E-05	±	2.0E-05	2.1E-03	
	200-East	48	0	-1.2E-06	±	1.7E-05	2.5E-05	±	3.0E-05	N924	245	3	8.6E-07	±	1.6E-05	1.2E-04	±	3.4E-05		
	200-West	52	9	1.6E-05	±	7.3E-05	1.8E-04	±	7.2E-05	N975	252	1	2.0E-06	±	4.7E-05	3.7E-04	±	1.5E-04		
	618-10 BG	8	0	4.4E-06	±	1.9E-05	2.0E-05	±	3.0E-05	N548	40	2	5.4E-06	±	1.8E-05	4.6E-05	±	2.2E-05		
	ERDF	10	0	6.6E-06	±	1.3E-05	2.0E-05	±	3.1E-05	N482	49	0	7.4E-07	±	6.6E-06	9.9E-06	±	1.2E-05		
^{239/240} Pu	100 K Area	12	0	-5.3E-06	±	1.8E-05	5.4E-06	±	1.2E-05	N576	96	11	8.3E-06	±	6.8E-05	2.4E-04	±	6.0E-04	2.0E-03	
	200-East	49	1	2.7E-06	±	4.0E-05	9.7E-05	±	8.4E-05	N976	252	10	1.3E-06	±	2.1E-05	1.6E-04	±	5.2E-05		
	200-West	52	24	2.8E-04	±	1.3E-03	3.2E-03	±	1.0E-03	N155	266	40	8.9E-06	±	6.0E-05	2.8E-04	±	1.1E-04		
	618-10 BG	8	0	8.3E-06	±	1.7E-05	1.9E-05	±	3.1E-05	N580	40	23	5.8E-05	±	1.8E-04	4.6E-04	±	1.7E-04		
	ERDF	10	4	3.3E-05	±	7.0E-05	1.2E-04	±	7.4E-05	N518	48	9	5.2E-06	±	2.3E-05	6.1E-05	±	2.4E-05		
²³⁴ U	100 K Area	10	4	2.9E-05	±	4.2E-05	8.4E-05	±	8.1E-05	N576	87	38	2.7E-06	±	1.1E-04	1.5E-04	±	5.0E-04	7.7E-03	
	200-East	51	14	3.6E-05	±	6.4E-05	1.7E-04	±	1.4E-04	N929	262	111	1.5E-05	±	3.6E-05	1.7E-04	±	2.0E-04		
	200-West	52	15	2.1E-05	±	5.2E-05	9.9E-05	±	7.9E-05	N901	272	90	1.0E-05	±	2.1E-05	7.5E-05	±	5.3E-05		
	618-10 BG	8	3	5.8E-06	±	1.6E-05	2.3E-05	±	1.2E-05	N548	40	12	1.2E-05	±	3.2E-05	9.2E-05	±	5.2E-05		
	ERDF	10	3	5.4E-06	±	1.1E-05	1.3E-05	±	1.5E-05	N168	49	17	1.1E-05	±	1.6E-05	3.3E-05	±	3.6E-05		

Table C-3. Concentrations of Select Radionuclides (pCi/m³)^a in Onsite Air Samples. (2 Pages)

Radionuclide	Site	2017									2012–2016									EPA
		Number of		Average ^c			Maximum ^d			Sampler	Number of		Average ^c			Maximum ^d			Table 2 ^{e,f}	
		Samples	Detections ^b								Samples	Detections ^b								
²³⁵ U	100 K Area	9	0	1.5E-05	±	3.0E-05	4.5E-05	±	7.3E-05	N575	82	4	4.9E-06	±	5.6E-05	2.5E-04	±	5.0E-04	7.1E-03	
	200-East	50	0	1.1E-05	±	3.1E-05	7.6E-05	±	8.1E-05	N582	238	11	2.8E-06	±	2.0E-05	1.4E-04	±	2.0E-04		
	200-West	47	0	9.3E-06	±	2.7E-05	5.5E-05	±	7.1E-05	N161	248	13	2.8E-06	±	1.2E-05	6.9E-05	±	5.0E-05		
	618-10 BG	7	0	4.5E-07	±	1.3E-06	1.7E-06	±	2.6E-06	N580	31	0	1.1E-06	±	6.9E-06	8.0E-06	±	1.2E-05		
	ERDF	9	0	2.6E-06	±	5.9E-06	7.9E-06	±	4.4E-05	N963	44	3	1.8E-06	±	6.1E-06	1.3E-05	±	2.8E-05		
²³⁸ U	100 K Area	10	0	6.7E-06	±	3.1E-05	3.7E-05	±	4.5E-05	N534	87	30	1.5E-05	±	1.4E-04	6.5E-04	±	1.2E-03	8.3E-03	
	200-East	51	6	2.0E-05	±	4.1E-05	7.4E-05	±	5.3E-05	N929	261	118	1.3E-05	±	3.2E-05	1.5E-04	±	1.8E-04		
	200-West	52	10	9.7E-06	±	2.6E-05	6.6E-05	±	6.1E-05	N901	271	100	8.7E-06	±	2.0E-05	7.8E-05	±	5.0E-05		
	618-10 BG	8	4	3.4E-05	±	1.1E-04	1.6E-04	±	5.4E-05	N548	40	20	5.5E-05	±	3.0E-04	7.6E-04	±	2.6E-04		
	ERDF	10	4	4.5E-06	±	8.0E-06	1.1E-05	±	7.0E-06	N482	49	19	1.1E-05	±	2.0E-05	5.3E-05	±	7.9E-05		
²⁴¹ Am	100 K Area	11	0	1.1E-05	±	3.9E-05	6.3E-05	±	6.3E-04	N927	102	18	-2.6E-05	±	7.8E-04	1.4E-03	±	1.9E-03	1.9E-03	
	200-East	51	0	4.3E-06	±	1.3E-03	1.9E-03	±	2.1E-03	N999	186	0	1.1E-05	±	1.8E-03	4.0E-03	±	3.2E-03		
	200-West	46	17	1.3E-04	±	6.7E-04	9.9E-04	±	3.1E-04	N975	153	5	-1.0E-04	±	1.7E-03	3.0E-03	±	6.0E-03		
	618-10 BG	8	2	7.0E-06	±	1.5E-05	2.0E-05	±	1.1E-05	N548	40	16	2.7E-05	±	7.8E-05	1.8E-04	±	7.4E-05		
	ERDF	4	0	1.6E-05	±	8.0E-04	5.8E-04	±	2.0E-03	N168	12	0	-2.3E-04	±	1.4E-03	1.1E-03	±	1.7E-03		
²⁴¹ Pu	100	10	0	-4.1E-04	±	6.0E-04	8.2E-05	±	8.2E-03	N476	52	2	2.8E-04	±	1.2E-03	2.7E-03	±	3.3E-03	1.9E-01	
	200-E	4	0	-7.1E-04	±	5.0E-04	-3.2E-04	±	5.5E-04	N480	20	0	2.4E-05	±	7.9E-04	7.7E-04	±	1.1E-03		
	200-W	18	5	9.0E-04	±	2.7E-03	4.3E-03	±	1.8E-03	N975	22	0	-4.1E-05	±	1.0E-03	9.8E-04	±	9.8E-03		
^a 1 pCi = 0.037 Bq																				
^b Number of samples with measurable concentrations of contaminant.																				
^c Average ± two standard deviations of all samples analyzed.																				
^d Maximum ± analytical uncertainty																				
^e DOE derived concentration guides are shown for gross alpha and gross beta																				
^f EPA values are based on an effective dose equivalent of 10 mrem/yr (40 CFR 61, Appendix E, Table 2)																				

Table C-4. Concentrations of Selected Radionuclides (pCi/m³)^a in Ambient Air Samples. (3 Pages)

Radionuclide	Site	2017									2012–2016									EPA Table 2 ^{e,f}
		Number of		Average ^c			Maximum ^d			Sampler	Number of		Average ^c			Maximum ^d				
		Samples	Detections ^b								Samples	Detections ^b								
gross α	Onsite	479	399	9.2E-04	±	1.6E-03	5.7E-03	±	1.2E-03	N918	2644	2353	8.6E-04	±	1.5E-03	8.1E-03	±	1.1E-03	2.0E-02	
gross α	Perimeter	292	249	1.0E-03	±	1.8E-03	5.1E-03	±	1.4E-03	N942	1416	1269	8.7E-04	±	1.6E-03	7.7E-03	±	1.2E-03		
gross α	Nearby Communities	184	155	9.5E-04	±	1.7E-03	5.3E-03	±	9.8E-04	N943	599	540	8.8E-04	±	1.4E-03	6.0E-03	±	9.2E-04		
gross α	Distant Community	26	20	9.1E-04	±	1.8E-03	3.8E-03	±	7.0E-04	N909	131	107	7.7E-04	±	1.4E-03	4.2E-03	±	8.5E-04		

Table C-4. Concentrations of Selected Radionuclides (pCi/m³)^a in Ambient Air Samples. (3 Pages)

Radionuclide	Site	2017									2012–2016									EPA Table 2 ^{e,f}
		Number of		Average ^c			Maximum ^d			Sampler	Number of		Average ^c			Maximum ^d				
		Samples	Detections ^b								Samples	Detections ^b								
gross β	Onsite	479	479	1.8E-02	±	2.2E-02	6.3E-02	±	5.3E-03	N903	2646	2646	2.0E-02	±	2.6E-02	1.3E-01	±	1.0E-02	9.0E+00	
gross β	Perimeter	292	292	1.8E-02	±	2.3E-02	5.7E-02	±	4.9E-03	N934	1416	1416	1.9E-02	±	2.5E-02	9.5E-02	±	8.8E-03		
gross β	Nearby Communities	184	184	1.8E-02	±	2.3E-02	5.8E-02	±	5.6E-03	N947	906	906	2.0E-02	±	2.7E-02	1.6E-01	±	1.6E-02		
gross β	Distant Community	26	26	1.6E-02	±	2.1E-02	4.8E-02	±	3.9E-03	N909	131	131	1.7E-02	±	2.4E-02	9.5E-02	±	7.4E-03		
³ H	Onsite	117	24	5.1E+00	±	1.6E+01	3.9E+01	±	1.1E+01	P903	581	289	7.7E+00	±	2.3E+01	1.1E+02	±	1.1E+01		
³ H	Perimeter	96	11	4.5E+00	±	1.8E+01	6.7E+01	±	1.5E+01	P937	452	162	5.0E+00	±	1.8E+01	9.4E+01	±	8.9E+00		
³ H	Nearby Communities	27	7	1.6E+01	±	1.2E+02	3.2E+02	±	6.4E+01	P944	128	45	4.7E+00	±	1.5E+01	5.8E+01	±	1.3E+01	1.5E+03	
³ H	Distant Community	13	0	1.1E+00	±	4.8E+00	6.1E+00	±	4.6E+00	P909	65	17	3.3E+00	±	1.1E+01	2.9E+01	±	6.5E+00		
⁹⁰ Sr	Onsite	30	0	6.5E-06	±	4.6E-04	6.2E-04	±	4.9E-04	N911	155	0	2.6E-06	±	4.6E-04	1.4E-03	±	1.2E-03	1.9E-02	
⁹⁰ Sr	Perimeter	18	0	-4.5E-05	±	6.3E-04	7.8E-04	±	6.6E-04	N941	96	0	-7.8E-07	±	3.8E-04	6.5E-04	±	6.4E-04		
⁹⁰ Sr	Nearby Communities	6	0	-8.1E-05	±	2.0E-04	7.5E-05	±	3.0E-04	N946	34	0	1.0E-05	±	2.5E-04	4.0E-04	±	5.0E-04		
⁹⁰ Sr	Distant Community	2	0	1.8E-05	±	7.4E-05	5.5E-05	±	3.1E-04	N909	12	0	1.1E-05	±	2.5E-04	2.8E-04	±	2.5E-04		
¹³⁷ Cs	Onsite	36	0	5.4E-05	±	2.9E-04	4.0E-04	±	4.6E-04	N905	200	2	6.4E-05	±	4.4E-04	8.0E-04	±	6.4E-04	1.9E-02	
¹³⁷ Cs	Perimeter	22	0	1.1E-05	±	2.5E-04	3.5E-04	±	3.7E-04	N940	120	0	3.2E-05	±	4.8E-04	1.1E-03	±	7.8E-04		
¹³⁷ Cs	Nearby Communities	14	0	2.1E-05	±	2.9E-04	3.6E-04	±	3.1E-04	N945	80	0	5.2E-05	±	4.8E-04	1.0E-03	±	9.2E-04		
¹³⁷ Cs	Distant Community	2	0	1.5E-04	±	2.9E-04	3.0E-04	±	3.0E-04	N909	12	0	-5.2E-05	±	5.0E-04	2.1E-04	±	7.0E-04		
²³⁴ U	Onsite	28	15	7.0E-05	±	6.5E-05	1.7E-04	±	1.4E-04	N929	141	112	4.0E-05	±	3.6E-05	1.3E-04	±	7.6E-05	7.7E-03	
²³⁴ U	Perimeter	8	7	9.5E-05	±	7.9E-05	1.6E-04	±	1.1E-04	N937	48	39	4.3E-05	±	4.0E-05	9.0E-05	±	5.3E-05		
²³⁴ U	Nearby Communities	10	5	8.9E-05	±	4.9E-05	1.5E-04	±	1.4E-04	N943	58	48	4.7E-05	±	3.6E-05	1.1E-04	±	7.0E-05		
²³⁴ U	Distant Community	2	1	5.0E-05	±	1.2E-05	5.6E-05	±	3.7E-05	N909	12	9	4.4E-05	±	4.6E-05	8.8E-05	±	5.6E-05		
²³⁸ U	Onsite	28	13	5.0E-05	±	2.8E-05	7.4E-05	±	5.3E-05	N929	141	126	3.9E-05	±	2.8E-05	9.3E-05	±	6.5E-05	8.3E-03	
²³⁸ U	Perimeter	8	4	6.4E-05	±	8.1E-05	1.7E-04	±	1.0E-04	N935	48	42	4.8E-05	±	3.6E-05	1.2E-04	±	6.4E-05		
²³⁸ U	Nearby Communities	10	4	5.4E-05	±	6.4E-05	1.0E-04	±	9.7E-05	N944	58	54	5.0E-05	±	2.5E-05	8.1E-05	±	5.3E-05		
²³⁸ U	Distant Community	2	1	3.0E-05	±	1.0E-07	3.0E-05	±	4.8E-05	N909	12	9	3.6E-05	±	2.6E-05	6.0E-05	±	2.5E-05		
^{239/240} Pu	Onsite	35	1	3.3E-06	±	4.5E-05	1.1E-04	±	7.6E-05	N901	188	5	8.2E-07	±	2.6E-05	1.6E-04	±	5.2E-05	2.0E-03	
^{239/240} Pu	Perimeter	18	0	-2.1E-06	±	1.7E-05	7.6E-06	±	1.8E-05	N907	93	2	2.6E-07	±	8.1E-06	1.8E-05	±	1.9E-05		

Table C-4. Concentrations of Selected Radionuclides (pCi/m³)^a in Ambient Air Samples. (3 Pages)

Radionuclide	Site	2017									2012–2016									EPA Table 2 ^{e,f}
		Number of		Average ^c			Maximum ^d			Sampler	Number of		Average ^c			Maximum ^d				
		Samples	Detections ^b								Samples	Detections ^b								
^{239/240} Pu	Nearby Communities	8	0	-1.1E-05	±	3.8E-05	1.5E-05	±	2.1E-05	N946	45	2	4.1E-08	±	8.9E-06	1.1E-05	±	2.6E-05		
^{239/240} Pu	Distant Community	2	0	3.6E-06	±	1.8E-05	1.2E-05	±	4.7E-05	N909	12	0	-1.4E-07	±	3.6E-06	2.7E-06	±	2.6E-06		
²⁴¹ Am	Onsite	36	0	5.3E-05	±	9.8E-04	1.5E-03	±	1.6E-03	N918	200	3	-1.2E-05	±	1.8E-03	4.0E-03	±	3.2E-03	1.9E-03	
²⁴¹ Am	Perimeter	22	0	5.5E-05	±	3.4E-04	7.1E-04	±	2.3E-03	N940	120	0	-9.7E-05	±	2.0E-03	2.1E-03	±	2.1E-03		
²⁴¹ Am	Nearby Communities	14	0	-8.6E-05	±	6.3E-04	2.1E-04	±	5.0E-04	N946	80	0	1.6E-05	±	2.3E-03	5.1E-03	±	5.3E-03		
²⁴¹ Am	Distant Community	2	0	-2.1E-06	±	7.7E-06	1.7E-06	±	1.7E-05	N909	12	0	-5.3E-04	±	3.2E-03	1.8E-03	±	2.1E-03		
^a 1 pCi = 0.037 Bq																				
^b 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.																				
^c Average ± two standard deviations of all samples analyzed.																				
^d Maximum ± analytical uncertainty																				
^e DOE derived concentration guides are shown for gross alpha and gross beta																				
^f EPA values are based on an effective dose equivalent of 10 mrem/yr (40 CFR 61, Appendix E, Table 2)																				

C.3 Surface Soil

Table C-5. Concentrations of Select Radionuclides (pCi/g)^a in Hanford Site Soil Samples.

Radionuclide	Hanford Area	2017								2012 - 2016							
		Number of		Average ^c (pCi/g)		Maximum ^d (pCi/g)		Location		Number of		Average ^c (pCi/g)		Maximum ^d (pCi/g)		Location	
		Samples	Detects ^b							Samples	Detects ^b						
²⁴¹ Am	200-W	6	5	1.9E-02	± 2.8E-02	4.2E-02	± 1.3E-02	D031		5	5	8.7E-02	± 1.6E-01	2.5E-01	± 8.3E-02	D032	
¹³⁷ Cs	200-E	24	23	2.9E+00	± 9.0E+00	1.6E+01	± 7.4E-01	D143		64	64	3.2E+00	± 9.4E+00	2.0E+01	± 2.7E+00	D054	
	200-W	23	22	1.2E+00	± 1.7E+00	3.6E+00	± 1.9E-01	D023		85	81	1.2E+00	± 2.4E+00	6.2E+00	± 3.3E-01	D030	
	300	8	5	3.5E-02	± 7.4E-02	1.1E-01	± 3.8E-02	D126		44	24	5.1E-02	± 1.5E-01	4.1E-01	± 6.9E-02	D121	
	400	1	1	3.4E-02 ^e		3.4E-02	± 2.6E-02	D130		5	5	5.8E-02	± 7.2E-02	1.3E-01	± 2.1E-02	D130	
	600	17	17	4.0E-01	± 8.6E-01	2.0E+00	± 1.4E-01	D091		52	51	4.8E-01	± 8.9E-01	2.5E+00	± 2.9E-01	D091	
²³⁸ Pu	200-E	22	0	7.8E-04	± 6.4E-03	1.0E-02	± 1.1E-02	D078		64	18	-9.8E-05	± 7.8E-03	8.0E-03	± 2.9E-03	D058	
	200-W	23	9	1.4E-02	± 5.3E-02	1.3E-01	± 2.8E-02	D039		85	41	5.5E-03	± 3.3E-02	1.4E-01	± 2.3E-02	D039	
	300	8	0	2.7E-04	± 2.8E-03	2.8E-03	± 5.6E-03	D125		44	6	1.2E-03	± 9.8E-03	1.3E-02	± 1.5E-02	D120	
	400	1	0	1.2E-03 ^e		1.2E-03	± 6.0E-03	D130		5	1	2.7E-03	± 8.0E-03	8.0E-03	± 2.8E-03	D130	
	600	15	1	4.3E-03	± 1.4E-02	2.4E-02	± 1.8E-02	D107		51	17	5.0E-04	± 7.3E-03	1.2E-02	± 1.2E-02	D107	
^{239/240} Pu	200-E	24	10	1.5E-02	± 3.8E-02	6.4E-02	± 1.6E-02	D053		64	52	1.5E-02	± 3.3E-02	8.3E-02	± 3.5E-02	D054	
	200-W	24	18	7.5E-02	± 1.5E-01	2.8E-01	± 3.6E-02	D025		85	79	1.1E-01	± 5.2E-01	2.1E+00	± 5.4E-01	D032	
	300	8	1	6.1E-03	± 3.1E-02	4.7E-02	± 1.5E-02	D121		44	19	7.6E-03	± 3.3E-02	9.9E-02	± 3.1E-02	D121	
	400	1	0	1.2E-03 ^e		1.2E-03	± 7.5E-03	D130		5	3	7.1E-03	± 2.1E-02	2.8E-02	± 1.6E-02	D130	
	600	17	8	1.2E-01	± 7.4E-01	1.6E+00	± 1.8E-01	D107		52	44	4.4E-02	± 2.4E-01	8.5E-01	± 1.0E-01	D107	
⁹⁰ Sr	200-E	24	19	2.9E-01	± 8.9E-01	1.9E+00	± 3.5E-01	D063		64	41	3.4E-01	± 9.5E-01	2.2E+00	± 4.1E-01	D457	
	200-W	24	18	1.7E-01	± 3.4E-01	6.0E-01	± 1.3E-01	D051		85	48	1.7E-01	± 4.2E-01	1.1E+00	± 2.6E-01	D321	
	300	8	0	2.9E-03	± 3.7E-02	2.2E-02	± 2.1E-02	D140		44	1	5.7E-02	± 2.8E-01	3.9E-01	± 3.2E-01	D121	
	400	1	0	-1.6E-03 ^e		-1.6E-03	± 1.6E-02	D130		5	0	1.1E-01	± 5.3E-01	6.5E-01	± 4.6E-01	D130	
	600	17	8	6.9E-02	± 1.7E-01	3.4E-01	± 8.6E-02	D107		52	21	1.2E-01	± 3.5E-01	1.0E+00	± 2.0E-01	D091	
²³⁴ U	200-E	24	24	5.3E-01	± 2.2E-01	9.4E-01	± 1.4E-01	D063		64	63	4.6E-01	± 4.0E-01	1.1E+00	± 1.9E-01	D060	
	200-W	24	24	4.7E-01	± 2.5E-01	7.0E-01	± 1.2E-01	D047		85	80	4.2E-01	± 3.6E-01	7.5E-01	± 1.2E-01	D306	
	300	8	8	8.5E-01	± 1.3E+00	2.2E+00	± 2.7E-01	D126		44	44	6.7E-01	± 1.1E+00	2.3E+00	± 3.7E-01	D126	
	400	1	1	4.9E-01 ^e		4.9E-01	± 9.2E-02	D130		5	5	4.5E-01	± 4.2E-01	7.4E-01	± 2.1E-01	D130	
	600	17	17	5.2E-01	± 2.8E-01	9.3E-01	± 1.6E-01	D091		52	51	4.5E-01	± 3.9E-01	9.0E-01	± 1.4E-01	D094	
²³⁵ U	200-E	24	22	5.1E-02	± 4.9E-02	1.1E-01	± 5.0E-02	D059		63	47	4.7E-02	± 6.4E-02	1.1E-01	± 4.3E-02	D071	
	200-W	24	18	4.5E-02	± 4.1E-02	8.6E-02	± 4.5E-02	D039		85	61	3.9E-02	± 5.1E-02	1.1E-01	± 5.0E-02	D026	
	300	8	6	6.5E-02	± 7.8E-02	1.1E-01	± 4.6E-02	D121		44	40	5.6E-02	± 9.7E-02	1.9E-01	± 5.7E-02	D126	
	400	1	1	4.8E-02 ^e		4.8E-02	± 3.3E-02	D130		5	5	4.1E-02	± 4.6E-02	7.7E-02	± 4.0E-02	D130	
	600	17	15	5.0E-02	± 3.7E-02	8.7E-02	± 4.3E-02	D093		52	34	4.5E-02	± 6.0E-02	1.1E-01	± 5.0E-02	D094	
²³⁸ U	200-E	24	24	5.3E-01	± 1.7E-01	8.2E-01	± 1.3E-01	D063		64	63	4.6E-01	± 3.9E-01	1.1E+00	± 1.9E-01	D060	
	200-W	24	24	4.6E-01	± 2.3E-01	6.3E-01	± 1.1E-01	D047		85	80	4.1E-01	± 3.5E-01	6.6E-01	± 1.0E-01	D306	
	300	8	8	7.8E-01	± 1.2E+00	1.9E+00	± 2.5E-01	D126		44	44	6.5E-01	± 1.0E+00	2.2E+00	± 3.5E-01	D126	

Table C-5. Concentrations of Select Radionuclides (pCi/g)^a in Hanford Site Soil Samples.

Radionuclide	Hanford Area	2017									2012 - 2016								
		Number of		Average ^c (pCi/g)			Maximum ^d (pCi/g)			Location	Number of		Average ^c (pCi/g)			Maximum ^d (pCi/g)			Location
		Samples	Detects ^b								Samples	Detects ^b							
	400	1	1	4.8E-01 ^e			4.8E-01	±	9.0E-02	D130	5	5	4.5E-01	±	5.3E-01	9.3E-01	±	2.5E-01	D130
	600	17	17	5.2E-01	±	2.7E-01	9.3E-01	±	1.5E-01	D091	52	51	4.7E-01	±	4.1E-01	9.7E-01	±	1.4E-01	D094
^a 1 pCi = 0.037 Bq																			
^b Number of samples with measurable concentrations of contaminant																			
^c Average ± two standard deviations of all samples analyzed																			
^d Maximum ± analytical uncertainty																			
^e Standard deviation cannot be calculated for one sample.																			

Table C-6. Concentrations of Select Radionuclides (pCi/g)^a in Soil Samples collected from 618-10 Burial Ground.

Project/ Facility	Location ^b	Date	Radionuclide (pCi/g) ^c					
			Strontium-90	Cesium-137	Uranium-234	Uranium-238	Plutonium-239/240	Americium-241
618-10 Burial Ground	D179	12/20/17	8.2E-02 ± 3.4E-02	1.7E-01 ± 2.2E-02	2.1E-01 ± 3.3E-02	2.2E-01 ± 3.4E-02	5.1E-02 ± 1.1E-02	7.2E-03 ± 3.5E-03
	D180	12/20/17	6.0E-02 ± 2.9E-02	6.0E-02 ± 1.3E-02	1.2E-01 ± 3.1E-02	1.4E-01 ± 3.5E-02	1.6E-02 ± 5.4E-03	4.0E-03 ± 2.4E-03
	D181	12/20/17	5.4E-02 ± 2.9E-02	3.5E-02 ± 8.4E-03	3.1E-01 ± 4.6E-02	3.2E-01 ± 4.8E-02	7.5E-02 ± 1.4E-02	3.0E-02 ± 7.5E-03
	D182	12/20/17	1.2E-03 ± 1.2E-02 ^d	3.2E-02 ± 6.1E-03	2.0E-01 ± 3.1E-02	2.2E-01 ± 3.4E-02	2.5E-03 ± 2.7E-03 ^d	4.4E-02 ± 9.4E-03

^a 1 pCi = 0.037 Bq
^b Sample Location Code
^c Result ± analytical uncertainty
^d Value reported is a non-detect

Table C-7. Concentrations of Select Radionuclides (pCi/g)^a in Surface Soil Samples Collected at Vernita Bridge Rest Area.

Location ^b	Date	Radionuclide (pCi/g) ^c						
		Cesium-137	Strontium-90	Plutonium-239/240	Uranium-234	Uranium-235	Uranium-238	Americium-241
D424	12/21/17	4.9E-02 ± 1.6E-02	-7.8E-04 ± 7.8E-03 ^d	1.0E-03 ± 6.2E-03 ^d	7.3E-01 ± 1.3E-01	1.0E-01 ± 5.2E-02	6.4E-01 ± 1.2E-01	4.1E-03 ± 8.8E-03 ^d

^a 1 pCi = 0.037 Bq
^b Sample Location Code
^c Result ± analytical uncertainty
^d Value reported is a non-detect

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Table C-8. Concentrations of Select Radionuclides (pCi/g)^a in Surface Soil Samples Collected Near PFP.

Location ^b	Date	Radionuclide (pCi/g) ^c					
		Cesium-137		Plutonium-239/240		Americium-241	
D002	02/7/18	1.3E-01	± 2.5E-02	5.7E-03	± 5.2E-03 ^d	3.9E-03	± 5.1E-03 ^d
D006	02/6/18	4.4E-02	± 1.2E-02	4.5E-02	± 1.2E-02	1.8E-02	± 8.5E-03
D008	02/6/18	6.8E-02	± 1.8E-02	6.6E-02	± 1.4E-02	1.8E-02	± 1.3E-02
D009	02/6/18	2.2E-01	± 3.6E-02	4.2E-02	± 1.3E-02	2.0E-02	± 1.0E-02
D010	02/6/18	1.5E+00	± 1.4E-01	3.4E-01	± 4.9E-02	6.5E-02	± 1.8E-02
D012	02/6/18	1.8E+00	± 1.5E-01	4.6E-02	± 1.4E-02	1.2E-02	± 6.6E-03
D016	02/6/18	2.3E-01	± 2.9E-02	2.7E-03	± 8.1E-03 ^d	4.2E-03	± 6.7E-03 ^d
D028	02/7/18	3.7E-01	± 4.1E-02	7.3E-02	± 1.6E-02	1.6E-02	± 7.9E-03
D030	02/7/18	7.8E+00	± 6.3E-01	2.0E-01	± 3.1E-02	4.5E-02	± 1.3E-02
D032	02/6/18	3.3E+00	± 2.8E-01	8.3E-01	± 9.1E-02	1.2E-01	± 2.5E-02
D034	02/6/18	1.2E+00	± 1.1E-01	2.4E-01	± 3.2E-02	6.3E-02	± 1.7E-02
D037	02/7/18	1.2E+00	± 1.2E-01	5.1E-02	± 1.5E-02	8.7E-03	± 5.8E-03
D038	02/7/18	7.6E-01	± 6.9E-02	5.3E-02	± 1.4E-02	1.3E-02	± 9.8E-03 ^d
D044	02/6/18	3.2E+00	± 3.4E-01	5.5E-01	± 6.0E-02	1.3E-01	± 3.8E-02
D046	02/7/18	7.3E-01	± 6.9E-02	7.6E-02	± 2.0E-02	1.6E-02	± 9.5E-03
D048	02/7/18	1.5E+00	± 1.3E-01	1.1E-01	± 2.5E-02	2.8E-02	± 1.3E-02
D049	02/7/18	3.8E-01	± 4.9E-02	4.6E-02	± 1.2E-02	1.7E-02	± 1.1E-02
D050	02/7/18	1.8E-01	± 2.9E-02	3.7E-02	± 1.3E-02	1.2E-02	± 6.6E-03
D052	02/7/18	2.0E-01	± 2.8E-02	3.1E-02	± 1.8E-02	1.3E-02	± 9.7E-03 ^d

^a 1 pCi = 0.037 Bq
^b Sample Location Code
^c Result ± analytical uncertainty
^d Value reported is a non-detect

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C.4 Columbia River Water

Table C-9. Radionuclide Concentrations in Columbia River Water (Richland, Washington). (2 Pages)

Radionuclide ^b		2017				2012-2016				WA Ambient Surface Water Quality Standard ^d
		Number of		Concentration ^a		Number of		Concentration ^a		
		Samples	Detects	Maximum	Average	Samples	Detects	Maximum	Average	
				(pCi/L) ^c	(pCi/L) ^c			(pCi/L) ^c	(pCi/L) ^c	
Composite System										
Strontium-90		13	0	3.8E-02 ± 3.5E-02	1.5E-02 ± 3.3E-02	64	0	5.6E-02 ± 3.7E-02	8.3E-03 ± 5.0E-02	8
Tritium		13	13	5.2E+01 ± 1.6E+01	2.5E+01 ± 2.2E+01	64	64	7.0E+01 ± 1.1E+01	2.9E+01 ± 2.3E+01	20000
Technetium-99		13	0	1.2E+00 ± 7.8E-01	1.7E-01 ± 8.8E-01	64	0	6.2E-01 ± 4.5E-01	4.4E-02 ± 4.4E-01	900
Uranium-234		13	13	4.1E-01 ± 7.5E-02	2.9E-01 ± 1.6E-01	64	64	3.4E-01 ± 7.5E-02	2.7E-01 ± 7.7E-02	--
Uranium-235		13	6	7.4E-02 ± 3.4E-02	2.9E-02 ± 3.0E-02	64	15	7.8E-02 ± 3.6E-02	1.6E-02 ± 2.7E-02	--
Uranium-238		13	12	2.9E-01 ± 6.5E-02	2.2E-01 ± 1.3E-01	64	64	2.8E-01 ± 6.3E-02	2.2E-01 ± 5.6E-02	--
Continuous System										
Cesium-137	D ^b	7	0	1.7E-03 ± 2.0E-03	2.1E-04 ± 1.6E-03	59	0	2.4E-03 ± 2.3E-03	-1.7E-04 ± 2.2E-03	200
	P ^b	7	0	6.9E-03 ± 5.2E-03	-1.2E-04 ± 7.3E-03	59	0	6.0E-03 ± 3.5E-03	7.9E-04 ± 4.5E-03	
Plutonium-238*	D ^b	7	0	1.2E-05 ± 8.3E-05	-2.2E-05 ± 5.1E-05	36	0	8.7E-05 ± 7.4E-05	4.5E-06 ± 6.5E-05	600
	P ^b	7	0	1.1E-04 ± 9.4E-05	5.1E-06 ± 1.2E-04	36	3	7.9E-04 ± 3.1E-04	5.2E-05 ± 2.9E-04	
Plutonium-239/240*	D ^b	7	0	9.7E-05 ± 1.9E-04	2.8E-05 ± 9.9E-05	36	0	8.3E-05 ± 7.5E-05	1.0E-05 ± 4.9E-05	--
	P ^b	7	0	1.8E-04 ± 9.8E-05	3.5E-05 ± 1.4E-04	36	0	1.4E-04 ± 1.3E-04	1.7E-05 ± 1.5E-04	

Table C-9. Radionuclide Concentrations in Columbia River Water (Richland, Washington). (2 Pages)

^a Maximum values are \pm total propagated analytical uncertainty (2 sigma). Averages are ± 2 standard deviations of the mean.

^b 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).

^c 1 pCi = 0.037 Bq.

^d WAC 173-201A-250 and EPA-570/9-76-003; WAC 246-290; 40 CFR 141.

*Samples from 2011 were not included as there was no distinguishing characters within the database to differentiate between filter and resin.

Plutonium-238 and Plutonium 239/240 were analyzed quarterly in previous years resulting in fewer samples.

Note: Dashes indicate no concentration guides available.

WA = Washington State.

Table C-10. Radionuclide Concentrations in Columbia River Water (Priest Rapids Dam, Washington). (2 Pages)

Radionuclide ^b		2017				2012-2016				WA Ambient Surface Water Quality Standard ^d
		Number of		Concentration ^a		Number of		Concentration ^a		
		Samples	Detects	Maximum	Average	Samples	Detects	Maximum	Average	
				(pCi/L) ^c	(pCi/L) ^c			(pCi/L) ^c	(pCi/L) ^c	
Composite System										
Strontium-90		13	0	4.0E-02 ± 3.6E-02	5.2E-03 ± 3.7E-02	64	0	5.4E-02 ± 3.7E-02	1.1E-02 ± 4.5E-02	8
Tritium		13	13	2.7E+01 ± 9.7E+00	1.5E+01 ± 8.3E+00	64	62	3.0E+01 ± 1.0E+01	1.7E+01 ± 1.0E+01	20000
Technetium-99		13	0	6.0E-01 ± 7.9E-01	1.2E-01 ± 7.3E-01	64	0	6.0E-01 ± 4.2E-01	1.6E-02 ± 4.9E-01	900
Uranium-234		13	13	3.3E-01 ± 6.3E-02	2.9E-01 ± 6.9E-02	64	64	3.4E-01 ± 6.5E-02	2.4E-01 ± 8.3E-02	--
Uranium-235		13	8	5.5E-02 ± 3.8E-02	2.8E-02 ± 2.6E-02	64	16	7.4E-02 ± 1.4E-02	1.6E-02 ± 3.2E-02	--
Uranium-238		13	13	2.4E-01 ± 5.3E-02	2.1E-01 ± 5.6E-02	64	64	2.7E-01 ± 1.0E-01	1.9E-01 ± 6.2E-02	--
Continuous System										
Cesium-137	D ^b	13	0	4.4E-03± 1.8E-03	6.7E-04 ± 2.5E-03	63	0	4.0E-03 ± 2.7E-03	2.8E-04 ± 1.8E-03	200
	P ^b	13	0	5.0E-03 ± 4.2E-03	1.2E-03 ± 4.7E-03	58	0	5.1E-03 ± 2.9E-03	6.3E-04 ± 4.0E-03	
Plutonium-238*	D ^b	13	0	3.2E-05 ± 5.5E-05	-7.1E-06 ± 4.0E-05	38	0	5.4E-05 ± 7.0E-05	-2.5E-07 ± 4.6E-05	600
	P ^b	13	0	4.6E-05 ± 9.6E-05	-5.1E-06 ± 6.6E-05	36	3	5.2E-04 ± 1.7E-04	3.2E-05 ± 2.8E-04	

Table C-10. Radionuclide Concentrations in Columbia River Water (Priest Rapids Dam, Washington). (2 Pages)

Radionuclide ^b		2017				2012-2016				WA Ambient Surface Water Quality Standard ^d
		Number of		Concentration ^a		Number of		Concentration ^a		
		Samples	Detects	Maximum	Average	Samples	Detects	Maximum	Average	
				(pCi/L) ^c	(pCi/L) ^c			(pCi/L) ^c	(pCi/L) ^c	
Plutonium-239/240*	D ^b	13	1	9.9E-05 ± 7.8E-05	-2.0E-06 ± 6.8E-05	38	0	8.8E-05 ± 7.3E-05	3.6E-06 ± 4.4E-05	--
	P ^b	13	0	6.1E-05 ± 1.2E-04	5.8E-06 ± 7.9E-05	36	1	2.4E-04 ± 2.4E-04	3.4E-05 ± 1.2E-04	
^a Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard deviations of the mean. ^b 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). ^c 1 pCi = 0.037 Bq. ^d WAC 173-201A-250 and EPA-570/9-76-003; WAC 246-290; 40 CFR 141. *Samples from 2011 were not included as there was no distinguishing characters within the database to differentiate between filter and resin. Plutonium-238 and Plutonium 239/240 were analyzed quarterly in previous years resulting in fewer samples. Note: Dashes indicate no concentration guides available. WA = Washington State.										

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Table C-11. 2017 Radionuclide Concentrations in Columbia River Transect Water Samples. (2 Pages)

Transect/Radionuclide	No. of Samples	No. of Detections	Concentration ^a					
			Maximum			Average		
			pCi/L ^b			pCi/L ^b		
Vernita Bridge (HRM 0.3)								
Strontium-90 ^c	8	0	4.0E-02	±	3.6E-02 ^d	1.3E-02	±	4.9E-02
Technitium-99 ^c	8	0	8.6E-01	±	7.0E-01 ^d	2.9E-01	±	8.0E-01
Tritium	8	8	2.0E+01	±	8.5E+00	1.5E+01	±	5.5E+00
Uranium-234	8	8	3.9E-01	±	8.2E-02	3.1E-01	±	1.0E-01
Uranium-235	8	6	7.6E-02	±	3.9E-02	4.4E-02	±	4.5E-02
Uranium-238	8	8	2.7E-01	±	6.4E-02	2.3E-01	±	7.2E-02
100H Area (HRM 15.3)								
Strontium-90 ^c	5	0	5.2E-02	±	3.7E-02 ^d	3.4E-02	±	3.8E-02
Tritium	5	5	4.4E+01	±	1.4E+01	2.1E+01	±	2.3E+01
Uranium-234	5	5	2.9E-01	±	5.7E-02	2.6E-01	±	5.5E-02
Uranium-235	5	2	4.4E-02	±	3.6E-02 ^d	2.8E-02	±	1.8E-02
Uranium-238	5	5	2.1E-01	±	4.6E-02	1.9E-01	±	3.0E-02
100N Area (HRM 9.5)								
Strontium-90 ^c	6	1	2.3E-01	±	5.7E-02	3.7E-02	±	1.7E-01
Tritium	6	6	2.0E+01	±	6.9E+00	1.6E+01	±	4.4E+00
Uranium-234	6	6	3.1E-01	±	6.5E-02	2.7E-01	±	4.7E-02
Uranium-235	6	2	3.1E-02	±	2.3E-02	1.9E-02	±	2.1E-02
Uranium-238	6	6	2.4E-01	±	5.7E-02	2.2E-01	±	2.5E-02
Hanford Townsite (HRM 28.7)								
Strontium-90 ^c	7	0	5.5E-02	±	3.9E-02	2.2E-02	±	4.2E-02
Tritium	7	6	2.9E+02	±	1.3E+02	1.1E+02	±	2.3E+02
Uranium-234	7	7	3.2E-01	±	7.3E-02	2.9E-01	±	4.1E-02
Uranium-235	7	2	6.4E-02	±	3.4E-02	2.2E-02	±	3.9E-02
Uranium-238	7	7	2.3E-01	±	5.8E-02	1.9E-01	±	6.0E-02
300 Area (HRM 43.1)								
Strontium-90 ^c	5	0	3.4E-02	±	2.8E-02 ^d	5.8E-03	±	3.6E-02
Tritium	5	5	4.2E+01	±	1.3E+01	1.9E+01	±	2.3E+01
Uranium-234	5	5	4.4E-01	±	8.8E-02	3.2E-01	±	1.3E-01
Uranium-235	5	1	4.4E-02	±	3.1E-02	2.9E-02	±	2.1E-02
Uranium-238	5	5	3.1E-01	±	7.4E-02	2.4E-01	±	7.3E-02
Richland (HRM 46.4)								
Strontium-90 ^c	10	0	4.2E-02	±	2.6E-02	2.4E-02	±	3.4E-02
Technitium-99	10	0	5.3E-01	±	4.3E-01	6.7E-02	±	5.8E-01
Tritium	10	10	2.6E+01	±	8.3E+00	1.6E+01	±	7.6E+00
Uranium-234	10	10	4.0E-01	±	4.8E-02	3.3E-01	±	8.8E-02
Uranium-235	10	8	6.7E-02	±	1.6E-02	3.5E-02	±	4.0E-02
Uranium-238	10	10	3.1E-01	±	5.6E-02	2.5E-01	±	6.5E-02

Table C-11. 2017 Radionuclide Concentrations in Columbia River Transect Water Samples. (2 Pages)^a Maximum values \pm total propagated analytical uncertainty; Average values \pm 2stdv.^b 1 pCi = 0.037 Bq.^c Less than the laboratory—reported detection limit.^d Maximum value reported in a non-detect

HRM = Hanford river marker.

Table C-12. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. (4 Pages)

Metal	No. of Samples	No. of Detections	Maximum ($\mu\text{g/L}$) ^a	Minimum ($\mu\text{g/L}$) ^a	Average ($\mu\text{g/L}$) ^{a,b}	Minimum Detectable Concentrations ($\mu\text{g/L}$)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^c
Vernita Bridge							
Antimony	8	0	—	—	—	1.0	N/A
Arsenic	8	0	—	—	—	2.0	190
Beryllium	8	0	—	—	—	0.2	N/A
Cadmium	8	0	—	—	—	0.3	N/A
Chromium	8	0	—	—	—	3.0	10
Copper	8	8	0.7	0.6	0.6	0.3	6
Hexavalent Chromium	8	0	—	—	—	1.5	10
Lead	8	0	—	—	—	0.5	1.1
Nickel	8	4	1.2	0.6	0.8	0.6	83
Selenium	8	0	—	—	—	2.0	5
Silver	8	0	—	—	—	0.3	N/A
Thallium	8	0	—	—	—	0.6	N/A
Uranium	8	8	0.7	0.6	0.6	0.1	N/A
Zinc	8	4	13.9	3.3	5.2	3.3	55
100-N Area							
Antimony	6	0	—	—	—	1.0	N/A
Arsenic	6	1	2.1	2.0	—	2.0	190
Beryllium	6	0	—	—	—	0.2	N/A
Cadmium	6	0	—	—	—	0.3	N/A
Chromium	6	0	—	—	—	3.0	10
Copper	6	6	0.7	0.6	0.6	0.3	6
Hexavalent Chromium	6	0	—	—	—	1.5	10
Lead	6	0	—	—	—	0.5	1.1
Nickel	6	1	0.6	0.6	—	0.6	83
Selenium	6	0	—	—	—	2.0	5
Silver	6	0	—	—	—	0.3	N/A

Table C-12. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. (4 Pages)

Metal	No. of Samples	No. of Detections	Maximum (µg/L) ^a	Minimum (µg/L) ^a	Average (µg/L) ^{a,b}	Minimum Detectable Concentrations (µg/L)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^c
Thallium	6	0	—	—	—	0.6	N/A
Uranium	6	6	0.7	0.6	0.6	0.1	N/A
Zinc	6	1	5.9	3.3	—	3.3	55
100-H Area							
Antimony	5	0	—	—	—	1.0	N/A
Arsenic	5	0	—	—	—	2.0	190
Beryllium	5	0	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	0.3	N/A
Chromium	5	0	—	—	—	3.0	10
Copper	5	5	0.6	0.5	0.5	0.3	6
Hexavalent Chromium	5	0	—	—	—	1.5	10
Lead	5	0	—	—	—	0.5	1.1
Nickel	5	0	—	—	—	0.6	83
Selenium	5	0	—	—	—	2.0	5
Silver	5	0	—	—	—	0.3	N/A
Thallium	5	0	—	—	—	0.6	N/A
Uranium	5	5	0.6	0.6	0.6	0.1	N/A
Zinc	5	0	—	—	—	3.3	55
Hanford Townsite							
Antimony	7	0	—	—	—	1.0	N/A
Arsenic	7	0	—	—	—	2.0	190
Beryllium	7	0	—	—	—	0.2	N/A
Cadmium	7	0	—	—	—	0.3	N/A
Chromium	7	0	—	—	—	3.0	10
Copper	7	7	1.0	0.6	0.7	0.3	6
Hexavalent Chromium	7	0	—	—	—	1.5	10
Lead	7	0	—	—	—	0.5	1.1
Nickel	7	0	—	—	—	0.6	83
Selenium	7	0	—	—	—	2.0	5
Silver	7	0	—	—	—	0.3	N/A
Thallium	7	0	—	—	—	0.6	N/A
Uranium	7	7	0.7	0.6	0.6	0.1	N/A
Zinc	7	2	4.6	3.3	3.5	3.3	55

**Table C-12. Dissolved Metal Concentrations in Columbia River Transect
Water Near Hanford Site. (4 Pages)**

Metal	No. of Samples	No. of Detections	Maximum (µg/L) ^a	Minimum (µg/L) ^a	Average (µg/L) ^{a,b}	Minimum Detectable Concentrations (µg/L)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^c
300 Area							
Antimony	5	0	—	—	—	1.0	N/A
Arsenic	5	0	—	—	—	2.0	190
Beryllium	5	0	—	—	—	0.2	N/A
Cadmium	5	0	—	—	—	0.3	N/A
Chromium	5	0	—	—	—	3.0	10
Copper	5	5	0.7	0.7	0.7	0.3	6
Hexavalent Chromium	5	0	—	—	—	1.5	10
Lead	5	0	—	—	—	0.5	1.1
Nickel	5	1	0.6	0.6	—	0.6	83
Selenium	5	0	—	—	—	2.0	5
Silver	5	0	—	—	—	0.3	N/A
Thallium	5	0	—	—	—	0.6	N/A
Uranium	5	5	1.2	0.6	0.8	0.1	N/A
Zinc	5	3	8.0	3.3	4.5	3.3	55
Richland							
Antimony	10	0	—	—	—	1.0	N/A
Arsenic	10	0	—	—	—	2.0	190
Beryllium	10	0	—	—	—	0.2	N/A
Cadmium	10	0	—	—	—	0.3	N/A
Chromium	10	0	—	—	—	3.0	10
Copper	10	10	0.7	0.5	0.6	0.3	6
Hexavalent Chromium	5	0	—	—	—	1.5	10
Lead	10	0	—	—	—	0.5	1.1
Nickel	10	5	1.2	0.6	0.9	0.6	83
Selenium	10	0	—	—	—	2.0	5
Silver	10	0	—	—	—	0.3	N/A
Thallium	10	0	—	—	—	0.6	N/A
Uranium	10	10	1.0	0.7	0.8	0.1	N/A
Zinc	10	7	5.7	3.3	3.8	3.3	55

Table C-12. Dissolved Metal Concentrations in Columbia River Transect Water Near Hanford Site. (4 Pages)

Metal	No. of Samples	No. of Detections	Maximum ($\mu\text{g/L}$) ^a	Minimum ($\mu\text{g/L}$) ^a	Average ($\mu\text{g/L}$) ^{a,b}	Minimum Detectable Concentrations ($\mu\text{g/L}$)	Washington State Ambient Surface Water Quality Chronic Toxicity Level ^c
^a Dashes indicate results at or below minimum detectable concentrations. ^b Average calculated using reporting limit values for all results at or below minimum detectable concentrations. ^c 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, the minimum value of 47 mg CaCO ₃ /L, for 1992 through 2000 water samples collected near Vernita Bridge by the U.S. Geological Survey was used. Parts per million (ppm) values are equivalent to the reported micrograms per liter ($\mu\text{g/L}$) concentrations shown.							

Table C-13. Columbia River Organic Concentrations in Transect Water.

Location	No. of Samples	Trichloroethene	cis-1,2-Dichloroethene	Regulatory Standard ^a
		(mg/L) ^b	(mg/L) ^b	(mg/L)
Richland Pumphouse-1 HRM 46.4	2	0.003	0.003	0.005
Richland Pumphouse-3 HRM 46.4	2	0.003	0.003	0.005
Richland Pumphouse-5 HRM 46.4	2	0.003	0.003	0.005
Richland Pumphouse-7 HRM 46.4	2	0.003	0.003	0.005
Richland Pumphouse-9 HRM 46.4	2	0.003	0.003	0.005
300 Area-1 HRM 43.1	1	0.003	0.003	0.005
300 Area-3 HRM 43.1	1	0.003	0.003	0.005
300 Area-5 HRM 43.1	1	0.003	0.003	0.005
300 Area-7 HRM 43.1	1	0.003	0.003	0.005
300 Area-9 HRM 43.1	1	0.003	0.003	0.005
Vernita-1 HRM 0.3	1	0.003	0.003	0.005
Vernita-2 HRM 0.3	1	0.003	0.003	0.005
Vernita-3 HRM 0.3	1	0.003	0.003	0.005
Vernita-4 HRM 0.3	1	0.003	0.003	0.005
^a EPA Drinking Water Regulation Standard = 0.005 mg/L (both constituents) ^b Maximum concentration reported was a non-detect.				

C.5 Shoreline Seep Water

Table C-14. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/Radionuclide	2017		Concentration pCi/L ^(a) Maximum ^(c)			2012-2016		Concentration pCi/L ^(a) Average ^(d)			Washington State
	No. of Samples	No. of Detects				No. of Samples	No. of Detects				Ambient Surface Water Quality Standard pCi/L ^(a, b)
100B Area (Spring 38-3)											
Strontium-90	1	0	5.0E-02	±	3.2E-02 ^e	5	0	-4.0E-01	±	1.6E+00 ^e	8
Tritium	1	0	2.1E+02	±	1.6E+02 ^e	5	5	8.3E+02	±	5.4E+02	20,000
100B Area (Spring 39-2)											
Strontium-90	1	1	1.9E+00	±	3.0E-01	3	3	2.2E+00	±	6.1E-01	8
Tritium	1	1	1.9E+03	±	4.1E+02	3	3	1.8E+03	±	5.0E+02	20,000
100D Area (Spring 110-1)											
Alpha (gross)	1	0	3.8E+00	±	2.7E+00 ^e	6	1	1.5E+00	±	2.5E+00	15
Beta (gross)	1	1	1.4E+01	±	2.4E+00	6	4	5.9E+00	±	7.5E+00	50
Strontium-90	1	1	2.2E+00	±	3.7E-01	6	3	1.3E+00	±	2.4E+00	8
Technetium-99	1	0	4.2E-01	±	4.9E-01 ^e	6	0	-5.3E-01	±	3.4E+00 ^e	900
Tritium	1	1	2.1E+03	±	4.5E+02	6	6	1.4E+03	±	2.1E+03	20,000
Uranium-234	1	1	1.1E+00	±	1.4E-01	6	6	6.9E-01	±	8.7E-01	–
Uranium-235	1	1	1.0E-01	±	3.5E-02	6	3	4.4E-02	±	6.1E-02	–
Uranium-238	1	1	8.6E-01	±	1.1E-01	6	6	6.6E-01	±	9.7E-01	–
100F Area (100F Spring 207-1 and 100F Spring 211-1)											
Strontium-90	4	0	3.4E-02	±	3.6E-02 ^e	9	0	-1.3E-01	±	7.0E-01 ^e	8
Tritium	4	1	3.5E+02	±	1.3E+02	9	8	3.7E+02	±	2.4E+02	900
100H Area (Spring 152-2)											
Strontium-90	1	1	3.7E+00	±	5.9E-01	1	1	5.4E+00	±	9.5E-01	8

Table C-14. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/Radionuclide	2017		Concentration pCi/L ^(a) Maximum ^(d)			2012-2016		Concentration pCi/L ^(a) Average ^(d)			Washington State
	No. of Samples	No. of Detects				No. of Samples	No. of Detects				Ambient Surface Water Quality Standard pCi/L ^(a, b)
Tritium	1	0	1.3E+02	±	1.3E+02 ^e	2	1	3.7E+02	±	4.0E+02	900
100K Area (Spring 63-1)											
Alpha (gross)	1	0	2.4E+00	±	2.5E+00 ^e	4	1	1.4E+00	±	2.8E+00	15
Beta (gross)	1	1	6.9E+00	±	2.5E+00	4	4	7.9E+00	±	1.3E+01	50
Carbon-14	1	1	2.2E+02	±	4.2E+01	19	9	1.9E+02	±	9.6E+02	2,000
Strontium-90	1	0	-3.7E-03	±	3.0E-02 ^e	4	0	-2.1E-01	±	7.4E-01 ^e	8
Technetium-99	1	1	8.5E+00	±	1.1E+00	4	3	7.0E+00	±	1.6E+01	–
Tritium	1	0	1.8E+02	±	1.4E+02 ^e	4	1	2.8E+02	±	7.7E+02	20,000
100N Area (Spring 8-13)											
Alpha (gross)	1	0	6.1E-01	±	2.0E+00 ^e	5	0	1.0E+00	±	1.9E+00 ^e	15
Beta (gross)	1	1	2.2E+00	±	1.4E+00	5	3	3.3E+00	±	3.1E+00	50
Strontium-90	1	0	9.9E-03	±	3.1E-02 ^e	5	0	-1.2E-01	±	5.6E-01 ^e	8
Tritium	1	1	3.4E+03	±	6.9E+02	5	5	3.7E+03	±	3.0E+03	20,000
100N Area (Spring 89-1)											
Strontium-90	1	1	2.2E+01	±	4.0E+00	5	5	2.6E+01	±	3.7E+01	8
Tritium	1	0	7.8E+01	±	1.6E+02 ^e	5	4	8.5E+02	±	1.2E+03	20,000
Hanford Townsite (Hanford Spring 25-4)											
Alpha (gross)	1	0	8.2E-01	±	1.1E+00 ^e	3	0	2.5E-01	±	9.7E-01 ^e	15
Beta (gross)	1	0	1.4E+00	±	1.4E+00 ^e	3	1	3.8E+00	±	3.3E+00	50
Strontium-90	1	0	-3.2E-03	±	3.1E-02 ^e	3	0	-8.5E-02	±	1.9E-01 ^e	8
Technetium-99	1	0	7.2E-01	±	4.1E-01 ^e	3	0	3.7E-01	±	1.5E-01 ^e	–
Tritium	1	0	-1.2E+02	±	1.5E+02 ^e	3	0	-7.5E+00	±	4.2E+01 ^e	20,000

Table C-14. Radionuclide Concentrations in Columbia River Shoreline Seep Water. (3 Pages)

Location/Radionuclide	2017		Concentration pCi/L ^(a) Maximum ^(c)			2012-2016		Concentration pCi/L ^(a) Average ^(d)			Washington State
	No. of Samples	No. of Detects				No. of Samples	No. of Detects				Ambient Surface Water Quality Standard pCi/L ^(a, b)
Hanford Townsite (Hanford Spring 28-2)											
Alpha (gross)	1	1	4.2E+00	±	2.6E+00	5	2	3.4E+00	±	3.5E+00	15
Beta (gross)	1	1	3.6E+01	±	4.0E+00	5	5	3.0E+01	±	2.6E+01	50
Tritium	1	1	1.6E+04	±	3.1E+03	5	5	2.0E+04	±	1.7E+04	20,000
Iodine	1	0	2.3E-01	±	4.8E-01 ^e	5	0	-1.4E-02	±	4.8E-01 ^e	–
300 Area (300 Area Spring 42-2 and 300 Area Spring DR 42-2)											
Alpha (gross)	2	2	3.4E+01	±	3.8E+00	12	12	3.7E+01	±	4.9E+01	15
Beta (gross)	2	2	2.3E+01	±	3.4E+00	12	12	2.1E+01	±	1.7E+01	50
Tritium	2	2	4.6E+03	±	9.2E+01	12	12	4.1E+03	±	1.3E+03	20,000
Uranium-234	2	2	2.7E+01	±	6.5E+00	12	12	2.1E+01	±	2.5E+01	–
Uranium-235	2	2	2.7E+00	±	9.0E-01	12	12	1.7E+00	±	2.0E+00	–
Uranium-238	2	2	2.5E+01	±	6.1E+00	12	12	2.1E+01	±	2.5E+01	–
^a 1 pCi = 0.037 Bq. ^b WAC 246-290, 40 CFR 141; WAC 173-201A-250; EPA-570/9-76-003; Appendix Table D.4 ^c Maximum values are ± total propagated analytical uncertainty. ^d Averages are ± 2 standard deviations of the mean. ^e Maximum value reported is a non-detect. Note: Dashes indicate no concentration guides available.											

Table C-15. Metals and Anions in Columbia River Water Shoreline Seep Water. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c
100B (39-2 and 38-3)	Metals								
	Antimony	2	1	Filtered	1.00E+00	-	1.08E+00	µg/L	N/A
	Arsenic	2	1	Filtered	2.00E+00	-	2.72E+00	µg/L	190
	Cadmium	2	0	Filtered	3.00E-01			µg/L	0.59
	Chromium	2	2	Filtered	4.36E+00	-	5.65E+00	µg/L	10 ^d
	Chromium	2	2	Unfiltered	5.95E+00	-	1.22E+01	µg/L	96 ^e
	Copper	2	2	Filtered	4.12E-01	-	8.19E-01	µg/L	6
	Hexavalent Chromium	2	2	Filtered	4.70E+00	-	1.20E+01	µg/L	10
	Hexavalent Chromium	2	1	Unfiltered	1.50E+00	-	1.20E+01	µg/L	10
	Lead	2	0	Filtered	5.00E-01			µg/L	1.1
	Nickel	2	1	Filtered	6.00E-01	-	6.10E-01	µg/L	83
	Selenium	2	0	Unfiltered	2.00E+00			µg/L	5
	Thallium	2	0	Filtered	6.00E-01			µg/L	N/A
	Zinc	2	0	Filtered	3.30E+00			µg/L	55
	Anions								
	Nitrate	2	2	Unfiltered	4.05E+03	-	6.06E+03	µg/L	10 ^f
100D (110-1)	Metals								
	Antimony	1	0	Filtered	1.00E+00			µg/L	N/A
	Arsenic	1	1	Filtered	2.14E+00			µg/L	190
	Cadmium	1	0	Filtered	3.00E-01			µg/L	0.59
	Chromium	1	1	Filtered	1.22E+01			µg/L	10 ^d
	Chromium	1	1	Unfiltered	1.20E+01			µg/L	96 ^e
	Copper	1	1	Filtered	6.12E-01			µg/L	6
	Hexavalent Chromium	1	1	Filtered	1.10E+01			µg/L	10

Table C-15. Metals and Anions in Columbia River Water Shoreline Seep Water. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b	Unit	Regulatory limit ^c
	Hexavalent Chromium	1	1	Unfiltered	1.20E+01	µg/L	10
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	1	1	Filtered	7.93E-01	µg/L	83
	Selenium	1	0	Unfiltered	2.00E+00	µg/L	5
	Thallium	1	0	Filtered	6.00E-01	µg/L	N/A
	Zinc	1	1	Filtered	4.77E+00	µg/L	55
	Anions						
	Nitrate	1	1	Unfiltered	2.13E+04	µg/L	10 ^f
100F (207-1, 211-1)	Metals						
	Antimony	4	0	Filtered	1.00E+00 - 2.00E+00	µg/L	N/A
	Arsenic	4	2	Filtered	2.25E+00 - 4.00E+00	µg/L	190
	Cadmium	4	0	Filtered	3.00E-01	µg/L	0.59
	Chromium	4	4	Filtered	3.81E+00 - 5.67E+00	µg/L	10 ^d
	Chromium	4	4	Unfiltered	4.15E+00 - 7.44E+00	µg/L	96 ^e
	Copper	4	3	Filtered	4.00E-01 - 3.03E+01	µg/L	6
	Hexavalent Chromium	3	3	Filtered	2.20E+00 - 3.70E+00	µg/L	10
	Hexavalent Chromium	3	2	Unfiltered	1.50E+00 - 3.20E+00	µg/L	10
	Lead	4	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	4	1	Filtered	6.00E-01 - 2.00E+00	µg/L	83
	Selenium	4	0	Unfiltered	2.00E+00	µg/L	5
	Thallium	4	0	Filtered	6.00E-01	µg/L	N/A
	Zinc	4	2	Filtered	3.30E+00 - 2.24E+01	µg/L	55
	Anions						
	Nitrate	4	4	Unfiltered	1.12E+04 - 1.28E+04	µg/L	10 ^f

Table C-15. Metals and Anions in Columbia River Water Shoreline Seep Water. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b	Unit	Regulatory limit ^c
100H (152-2)	Metals						
	Antimony	1	0	Filtered	1.00E+00	µg/L	N/A
	Arsenic	1	1	Filtered	2.66E+00	µg/L	190
	Cadmium	1	0	Filtered	3.00E-01	µg/L	0.59
	Chromium	1	1	Filtered	4.74E+00	µg/L	10 ^d
	Chromium	1	1	Unfiltered	5.60E+00	µg/L	96 ^e
	Copper	1	1	Filtered	5.71E-01	µg/L	6
	Hexavalent Chromium	1	1	Filtered	2.90E+00	µg/L	10
	Hexavalent Chromium	1	1	Unfiltered	2.40E+00	µg/L	10
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	1	0	Filtered	6.00E-01	µg/L	83
	Selenium	1	0	Unfiltered	2.00E+00	µg/L	5
	Thallium	1	0	Filtered	6.00E-01	µg/L	N/A
	Zinc	1	0	Filtered	3.30E+00	µg/L	55
	Anions						
	Nitrate	1	1	Unfiltered	7.88E+03	µg/L	10 ^f
100K (63-1)	Metals						
	Antimony	1	0	Filtered	1.00E+00	µg/L	N/A
	Arsenic	1	0	Filtered	2.00E+00	µg/L	190
	Cadmium	1	0	Filtered	3.00E-01	µg/L	0.59
	Chromium	1	0	Filtered	3.00E+00	µg/L	10 ^d
	Chromium	1	0	Unfiltered	3.00E+00	µg/L	96 ^e
	Copper	1	1	Filtered	5.51E-01	µg/L	6
	Hexavalent Chromium	1	1	Filtered	2.00E+00	µg/L	10

Table C-15. Metals and Anions in Columbia River Water Shoreline Seep Water. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b			Unit	Regulatory limit ^c
	Hexavalent Chromium	1	1	Unfiltered	2.00E+00			µg/L	10
	Lead	1	0	Filtered	5.00E-01			µg/L	1.1
	Nickel	1	0	Filtered	6.00E-01			µg/L	83
	Selenium	1	0	Unfiltered	2.00E+00			µg/L	5
	Thallium	1	0	Filtered	6.00E-01			µg/L	N/A
	Zinc	1	1	Filtered	4.58E+00			µg/L	55
	Anions								
	Nitrate	1	1	Unfiltered	3.96E+03			µg/L	10 ^f
100N (8-13, 89-1)	Metals								
	Antimony	2	0	Filtered	1.00E+00			µg/L	N/A
	Arsenic	2	2	Filtered	2.22E+00	-	4.12E+00	µg/L	190
	Cadmium	2	0	Filtered	3.00E-01			µg/L	0.59
	Chromium	2	1	Filtered	3.00E+00	-	4.43E+00	µg/L	10 ^d
	Chromium	2	1	Unfiltered	3.00E+00	-	4.25E+00	µg/L	96 ^e
	Copper	2	2	Filtered	4.81E-01	-	6.60E-01	µg/L	6
	Hexavalent Chromium	2	1	Filtered	1.50E+00	-	3.20E+00	µg/L	10
	Hexavalent Chromium	2	1	Unfiltered	1.50E+00	-	3.50E+00	µg/L	10
	Lead	2	0	Filtered	5.00E-01			µg/L	1.1
	Nickel	2	1	Filtered	6.00E-01	-	6.68E-01	µg/L	83
	Selenium	2	0	Unfiltered	2.00E+00			µg/L	5
	Thallium	2	0	Filtered	6.00E-01			µg/L	N/A
	Zinc	2	1	Filtered	3.30E+00	-	2.00E+01	µg/L	55
	Anions								
	Nitrate	2	2	Unfiltered	3.30E+03	-	2.01E+04	µg/L	10 ^f

Table C-15. Metals and Anions in Columbia River Water Shoreline Seep Water. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b	Unit	Regulatory limit ^c
Hanford Townsite (25-4)	Metals						
	Antimony	1	0	Filtered	1.00E+00	µg/L	N/A
	Arsenic	1	0	Filtered	2.00E+00	µg/L	190
	Cadmium	1	0	Filtered	3.00E-01	µg/L	0.59
	Chromium	1	0	Filtered	3.00E+00	µg/L	10 ^d
	Chromium	1	0	Unfiltered	3.00E+00	µg/L	96 ^e
	Copper	1	1	Filtered	6.64E-01	µg/L	6
	Hexavalent Chromium	1	0	Filtered	1.50E+00	µg/L	10
	Hexavalent Chromium	1	0	Unfiltered	1.50E+00	µg/L	10
	Lead	1	0	Filtered	5.00E-01	µg/L	1.1
	Nickel	1	1	Filtered	7.99E-01	µg/L	83
	Selenium	1	0	Unfiltered	2.00E+00	µg/L	5
	Thallium	1	0	Filtered	6.00E-01	µg/L	N/A
	Zinc	1	0	Filtered	3.30E+00	µg/L	55
	Anions						
	Nitrate	1	1	Unfiltered	2.89E+03	µg/L	10 ^f
Hanford Spring (28-2)	Metals						
	Hexavalent Chromium	1	0	Filtered	1.50E+00	µg/L	10
	Hexavalent Chromium	1	0	Unfiltered	1.50E+00	µg/L	10
	Anions						
	Nitrate	1	1	Unfiltered	1.36E+04	µg/L	10 ^f
300 Area (42-2, DR 42-2)	Metals						
	Hexavalent Chromium	2	0	Filtered	1.50E+00	µg/L	10

Table C-15. Metals and Anions in Columbia River Water Shoreline Seep Water. (6 Pages)

Location	Analyte	# of samples	Detects	Filtered/Unfiltered ^a	Range (min-max) ^b	Unit	Regulatory limit ^c
	Hexavalent Chromium	2	1	Unfiltered	1.50E+00	µg/L	10
	Anions						
	Nitrate	2	1	Unfiltered	0.00E+00	µg/L	10 ^f

^aDissolved concentrations are associated with filtered samples; Recoverable concentrations are associated with unfiltered samples.

^bFor non-detects, one value is shown for the method detection limit (MDL); Multiple values are shown on non-detects if the laboratory method detection limit differed during the analyses process.

^cAmbient water quality criteria values or chronic toxicity unless otherwise noted (WAC 173-201A-240).

^dValue for hexavalent chromium.

^eValue for trivalent chromium.

^fWashington State drinking water standard utilized (WAC 246-290).

Table C-16. Columbia River Organic Concentrations in Shoreline Seep Water.

Location	No. of Samples	Trichloroethene	cis-1,2-Dichloroethene	Regulatory Standard ^a
		(mg/L) ^b	(mg/L) ^c	(mg/L)
300 Area Spring DR 42-2	1	0.004 ^d	0.003	0.005
300 Area Spring 42-2	1	0.003	0.003	0.005
Hanford Townsite 25-4	1	0.003	0.003	0.005
100K Spring 63-1	1	0.0045 ^d	0.003	0.005

^aEPA Drinking Water Regulation Standard = 0.005 mg/L (both constituents)

^bMaximum concentration reported was a non-detect.

^cMaximum concentration reported was a non-detect.

^dMaximum concentration reported was estimated by the analytical laboratory.

Table C-17. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site). (2 Pages)

Sediment Location	Radionuclide	2017		2012-2016			
		No. of Samples	No. of Detects	Maximum Concentration ^a	No. of Samples	No. of Detects	Average Concentration ^a
				<i>pCi/g</i>			<i>pCi/g</i>
Adjacent to Locke Island	Cesium-137	1	0	1.3E-02 ± 1.3E-02 ^b	4	0	9.5E-03 ± 1.7E-02
	Plutonium-239/240	1	0	-2.3E-03 ± 9.5E-03 ^b	4	0	8.5E-04 ± 4.7E-03
	Uranium-234	1	1	1.2E+00 ± 1.6E-01	4	4	1.3E+00 ± 2.5E-01
	Uranium-235	1	1	1.0E-01 ± 4.2E-02	4	4	9.5E-02 ± 1.8E-02
	Uranium-238	1	1	1.0E+00 ± 1.5E-01	4	4	1.3E+00 ± 1.9E-01
Adjacent to Savage Island	Cesium-137	1	1	5.2E-02 ± 3.5E-02	4	4	3.8E-02 ± 1.3E-02
	Plutonium-239/240	1	0	-7.1E-03 ± 5.5E-03 ^b	4	0	1.9E-03 ± 3.6E-03
	Uranium-234	1	1	7.4E-01 ± 1.4E-01	4	4	7.7E-01 ± 3.3E-01
	Uranium-235	1	1	8.6E-02 ± 5.0E-02	4	4	6.4E-02 ± 2.9E-02
	Uranium-238	1	1	6.8E-01 ± 1.3E-01	4	4	7.3E-01 ± 2.3E-01
100-D Spring 102-1	Cesium-137	3	3	1.0E-01 ± 1.9E-02	7	7	1.3E-01 ± 6.9E-02
	Plutonium-239/240	3	1	2.6E-03 ± 9.8E-03	7	3	3.4E-03 ± 1.1E-02
	Uranium-234	3	3	5.9E-01 ± 1.0E-01	7	7	4.9E-01 ± 1.2E-01
	Uranium-235	3	3	8.8E-02 ± 4.1E-02	7	7	4.9E-02 ± 2.8E-02
	Uranium-238	3	3	4.8E-01 ± 9.4E-02	7	7	5.1E-01 ± 8.2E-02
100F Slough	Cesium-137	1	1	1.8E-01 ± 2.1E-02	5	5	1.8E-01 ± 5.2E-02
	Plutonium-239/240	1	0	-1.3E-03 ± 8.3E-03 ^b	5	2	1.9E-03 ± 3.0E-03
	Uranium-234	1	1	4.9E-01 ± 9.1E-02	5	5	5.7E-01 ± 2.1E-01
	Uranium-235	1	1	4.2E-02 ± 2.9E-02	5	5	6.1E-02 ± 2.0E-02
	Uranium-238	1	1	5.0E-01 ± 9.2E-02	5	5	5.3E-01 ± 1.9E-01
100-K Spring 63-1	Cesium-137	1	1	5.7E-02 ± 1.7E-02	3	3	1.1E-01 ± 3.7E-02
	Plutonium-239/240	1	0	4.1E-03 ± 8.0E-03 ^b	3	1	4.2E-03 ± 5.9E-03
	Uranium-234	1	1	1.1E+00 ± 1.5E-01	3	3	1.2E+00 ± 2.3E-01
	Uranium-235	1	0	4.4E-02 ± 3.6E-02 ^b	3	3	6.6E-02 ± 1.9E-02
	Uranium-238	1	1	9.3E-01 ± 1.4E-01	3	3	1.1E+00 ± 2.6E-01
Hanford Slough	Cesium-137	1	1	2.1E-01 ± 6.4E-02	7	7	2.4E-01 ± 3.7E-02
	Plutonium-239/240	1	0	-3.1E-03 ± 5.3E-03 ^b	7	3	2.9E-03 ± 1.8E-03
	Uranium-234	1	1	6.9E-01 ± 1.1E-01	7	7	1.2E+00 ± 2.3E+00
	Uranium-235	1	1	1.1E-01 ± 4.5E-02	7	6	8.7E-02 ± 1.5E-01
	Uranium-238	1	1	7.8E-01 ± 1.2E-01	7	7	7.6E-01 ± 3.7E-01
McNary Dam	Cesium-137	2	2	2.4E-01 ± 4.1E-02	10	10	2.2E-01 ± 5.7E-02
	Plutonium-239/240	2	0	7.7E-03 ± 9.4E-03 ^b	10	6	9.8E-03 ± 9.1E-03
	Uranium-234	2	2	1.7E+00 ± 2.7E-01	10	10	1.4E+00 ± 1.7E-01
	Uranium-235	2	2	1.8E-01 ± 9.0E-02	10	10	8.7E-02 ± 2.5E-02

Table C-17. Radionuclide Concentrations in Columbia River and Shoreline Sediment (Near Hanford Site). (2 Pages)

Sediment Location	Radionuclide	2017				2012-2016		
		No. of Samples	No. of Detects	Maximum Concentration ^a		No. of Samples	No. of Detects	Average Concentration ^a
				<i>pCi/g</i>				<i>pCi/g</i>
	Uranium-238	2	2	1.3E+00 ± 2.4E-01		10	10	1.2E+00 ± 1.5E-01
Priest Rapids Dam	Cesium-137	2	2	2.9E-01 ± 7.8E-02		10	10	2.5E-01 ± 7.5E-02
	Plutonium-239/240	2	1	1.3E-02 ± 1.5E-02		10	10	1.1E-02 ± 3.4E-03
	Uranium-234	2	2	1.6E+00 ± 2.7E-01		10	10	1.2E+00 ± 3.2E-01
	Uranium-235	2	2	1.3E-01 ± 7.2E-02		10	10	8.5E-02 ± 3.7E-02
	Uranium-238	2	2	1.4E+00 ± 2.5E-01		10	10	1.1E+00 ± 2.6E-01
White Bluffs Slough	Cesium-137	1	1	2.8E-01 ± 5.2E-02		5	5	3.4E-01 ± 9.7E-02
	Plutonium-239/240	1	0	4.3E-04 ± 4.3E-03 ^b		5	2	4.4E-03 ± 4.3E-03
	Uranium-234	1	1	1.0E+00 ± 1.6E-01		5	5	9.5E-01 ± 3.2E-01
	Uranium-235	1	1	9.6E-02 ± 4.8E-02		5	5	7.4E-02 ± 7.2E-02
	Uranium-238	1	1	9.3E-01 ± 1.5E-01		5	5	9.2E-01 ± 3.3E-01
^a Maximum Concentrations ± Analytical Uncertainty; Average Concentrations ± 2stdv. ^b Maximum value reported as a non-detect. N/A = Not applicable								

Table C-18. Dissolved Metal Concentration Ranges in Columbia River Sediment (Near Hanford Site).

Metal	Priest Rapids Dam	Hanford Reach ^a	McNary Dam
	(mg/kg dry weight)	(mg/kg dry weight)	(mg/kg dry weight)
Antimony	8.3 - 11	0.43 - 5.3	0.65 - 0.75
Arsenic	9.2 - 11	3.2 - 13.3	4.8 - 5.5
Beryllium	1.7 - 1.9	0.16 - 1.4	0.44 - 0.60
Cadmium	3.9 - 4.4	0.14 - 1.5	1.3 - 1.6
Chromium	43 - 46	7.6 - 57	21 - 23
Copper	53 - 59	9.3 - 31	20 - 25
Lead	41 - 42	4.1 - 62	35 - 39
Mercury	0.15 - 0.17	.005 - .054	0.12 - 0.26
Nickel	45 - 47	6.1 - 18	20 - 23
Selenium	2.1 - 2.3	0.69 - 2.2	0.98 - 1.1
Silver	0.25 - 0.33	0.11 - 0.27	0.20 - 0.23
Thallium	13 - 17	0.46 - 28	4.0 - 4.1
Zinc	422 - 446	73 - 445	180 - 182
No. of Samples	2	11	2
^a 100-F Slough (n=1), Hanford Slough (n=1), White Bluffs Slough (n=1), Adjacent to Locke Island (n=1), Adjacent to Savage Island (n=1), 100-H 145-1 (n=1), 100-D Spring 102-1 (n=3), 100-K 63-1 (n=1), 300 Area (n=1); where n = number of samples.			

Table C-19. Columbia River Hexavalent Chromium in Sediment Samples.

Location	No. of Samples	No. of Detects	2017 Max Concentration	No. of Samples	No. of Detects	2012-2016 Max Concentration
			(ug/Kg)			(ug/Kg)
300 Area Spring DR 42-2 (shoreline)	1	0	176	2	0	195
Adjacent to Savage Island (shoreline)	1	0	154	4	2	424
Hanford Slough	1	0	257	7	0	341
White Bluffs Slough	1	0	210	6	1	1700
100F Slough	1	0	196	1	0	190
100H Spring 145-1 (shoreline)	1	0	166	2	1	611
Adjacent to Locke Island (shoreline)	1	0	227	4	2	643
100D 102-1	3	2	1290	7	5	5850
100K Spring 63-1 (shoreline)	1	1	2430	3	2	1880
Priest Rapids Dam (Grant Side)	1	0	366	5	1	2010
Priest Rapids Dam (Yakima Side)	1	0	1550	5	1	2870
McNary Dam (WA Side)	1	0	943	5	1	1250
McNary Dam (OR Side)	1	0	1330	5	1	2470

Table C-20. Total Organic Carbon in Columbia River Sediment. (2 Pages)

Sediment Location	2017			2012-2016		
	No. of Samples	Concentration ^a		No. of Samples	Concentration ^a	
		Minimum	Maximum		Minimum	Maximum
		mg/kg	mg/kg		mg/kg	mg/kg
Adjacent to Locke Island ^b	0	N/A	N/A	1	N/A	1.2E+03
Adjacent to Savage Island ^b	0	N/A	N/A	1	N/A	2.2E+03
100-D Spring 102-1	3	1.9E+03	3.1E+03	7	1.6E+03	5.9E+03
100-F Slough	1	N/A	1.5E+03	1	N/A	1.4E+03

Table C-20. Total Organic Carbon in Columbia River Sediment. (2 Pages)

Sediment Location	2017			2012-2016		
	No. of	Concentration ^a		No. of	Concentration ^a	
	Samples	Minimum	Maximum	Samples	Minimum	Maximum
		mg/kg	mg/kg		mg/kg	mg/kg
100-H Spring 145-1	1	N/A	8.6E+03	2	7.3E+03	8.7E+03
100-K Spring 63-1	1	N/A	1.4E+03	3	5.9E+03	1.8E+04
Hanford Slough	1	N/A	1.4E+04	7	5.3E+03	1.7E+04
McNary Dam	2	1.3E+04	1.7E+04	10	4.5E+03	2.5E+04
Priest Rapids Dam	2	1.9E+03	3.3E+04	10	1.5E+04	4.0E+04
White Bluffs Slough	1	N/A	8.4E+03	6	5.3E+03	1.7E+04
^a 1 mg/kg = ug/kg divided by 1000						
^b Adjacent to Locke and Savage Island sediment was analyzed for TOC in 2013 only.						

Table C-21. Irrigation Water Sample Results. (2 Pages)

Isotope	2017				2012 - 2016			
	Number of		Average ^a (pCi/l)	Maximum ^b (pCi/l)	Number of		Average ^a (pCi/l)	Maximum ^b (pCi/l)
	Samples	Detects			Samples	Detects		
⁶⁰ Co	7	0	-8.5E-02 ± 1.4E+00	1.3E+00 ± 2.1E+00	30	0	-4.7E-03 ± 2.5E+00	3.8E+00 ± 3.1E+00
¹³⁴ Cs	7	0	-2.2E-01 ± 1.8E+00	1.6E+00 ± 1.7E+00	30	0	4.1E-01 ± 2.7E+00	2.7E+00 ± 3.2E+00
¹³⁷ Cs	7	0	2.2E-01 ± 1.6E+00	1.9E+00 ± 2.5E+00	30	0	5.8E-02 ± 2.1E+00	2.4E+00 ± 2.4E+00
¹⁵² Eu	7	0	-1.4E+00 ± 4.2E+00	1.3E+00 ± 4.9E+00	30	0	1.0E-01 ± 6.8E+00	5.1E+00 ± 6.9E+00
¹⁵⁴ Eu	7	0	2.9E-01 ± 3.2E+00	2.4E+00 ± 5.3E+00	30	0	-2.8E-01 ± 7.1E+00	5.4E+00 ± 6.9E+00
¹⁵⁵ Eu	7	0	2.3E+00 ± 9.2E+00	8.1E+00 ± 8.0E+00	30	0	-7.1E-02 ± 7.3E+00	5.7E+00 ± 1.1E+01
³ H	7	7	1.6E+01 ± 5.0E+00	2.1E+01 ± 8.0E+00	29	29	2.0E+01 ± 1.1E+01	3.4E+01 ± 6.5E+00

Table C-21. Irrigation Water Sample Results. (2 Pages)

Isotope	2017				2012 - 2016			
	Number of		Average ^a (pCi/l)	Maximum ^b (pCi/l)	Number of		Average ^a (pCi/l)	Maximum ^b (pCi/l)
	Samples	Detects			Samples	Detects		
¹⁰⁶ Ru	7	0	-2.8E+00 ± 1.3E+01	9.6E+00 ± 1.9E+01	30	0	-1.6E+00 ± 2.0E+01	1.7E+01 ± 1.9E+01
¹²⁵ Sb	7	0	7.9E-02 ± 5.6E+00	4.5E+00 ± 5.1E+00	30	0	3.7E-01 ± 5.1E+00	6.0E+00 ± 5.8E+00
⁹⁰ Sr	7	0	1.8E-02 ± 4.1E-02	4.8E-02 ± 3.7E-02	30	0	1.2E-02 ± 4.9E-02	5.4E-02 ± 3.8E-02
^a Average ± two standard deviations ^b Maximum ± analytical uncertainty								

C.6 Vegetation Monitoring

Table C-22. Concentrations of Select Radionuclides (pCi/g)^a in Hanford Site Vegetation Samples. (2 Pages)

Radionuclide	Hanford Area	2017									2012 - 2016									
		Number of		Average ^c			Maximum ^d			Location	Number of		Average ^c			Maximum ^d			Location	
		Samples	Detects ^b								Samples	Detects ^b								
²⁴¹ Am	200-W	5	0	5.3E-03	±	6.6E-03	9.1E-03	±	7.9E-03	V007	0	0	8.0E-03	±	4.2E-02	5.1E-02	±	6.9E-02	n/a	
¹³⁷ Cs	100	2	0	1.5E-02	±	8.5E-03	2.0E-02	±	2.6E-02	Y719	12	0	4.8E-02	±	9.5E-02	2.4E-01	±	2.6E-02	Y724	
	200-E	12	1	8.1E-02	±	4.4E-01	8.0E-01	±	5.9E-02	V076	37	15	2.2E-02	±	4.9E-02	1.3E-01	±	3.4E-02	V054	
	200-W	16	1	1.1E-02	±	4.1E-02	5.7E-02	±	2.8E-02	V047	65	11	9.2E-03	±	4.4E-02	4.7E-02	±	4.4E-02	V301	
	300	2	0	7.1E-03	±	2.2E-02	1.8E-02	±	2.6E-02	V132	17	1	2.0E-02	±	6.2E-02	7.7E-02	±	5.9E-02	V123	
	400	1	0	-1.7E-02 ^e			-1.7E-02	±	4.4E-02	V130	5	0	1.7E-02	±	5.4E-02	1.3E-01	±	3.5E-02	V130	
	600	15	0	6.7E-03	±	3.0E-02	3.1E-02	±	2.3E-02	V089	43	5	-8.7E-04	±	3.6E-03	1.0E-03	±	9.6E-03	V086	
²³⁸ Pu	100	1	0	-3.3E-04 ^e			-3.3E-04	±	4.8E-04	Y719	11	0	-4.1E-05	±	3.9E-03	3.3E-03	±	5.8E-03	Y719	
	200-E	12	0	4.0E-05	±	2.7E-04	3.0E-04	±	5.6E-04	V078	34	1	-5.9E-05	±	1.9E-03	1.9E-03	±	5.5E-03	V314	
	200-W	16	1	4.0E-04	±	1.7E-03	3.6E-03	±	2.5E-03	V139	64	4	1.9E-03	±	7.9E-03	1.5E-02	±	9.1E-03	V032	
	300	2	0	5.3E-04	±	1.7E-04	6.2E-04	±	7.5E-04	V123	17	1	3.6E-05	±	2.8E-03	5.4E-03	±	5.3E-03	V122	
	600	16	0	1.6E-04	±	6.8E-04	8.1E-04	±	6.8E-04	V105	41	0	2.3E-04	±	2.3E-03	2.1E-03	±	1.0E-03	V084	
^{239/240} Pu	100	1	0	5.4E-04 ^e			5.4E-04	±	7.7E-04	Y719	10	1	1.3E-03	±	3.4E-03	5.7E-03	±	5.6E-03	Y719	
	200-E	12	2	2.3E-04	±	3.5E-04	5.6E-04	±	3.7E-04	V079	36	7	3.2E-03	±	9.3E-03	2.1E-02	±	2.0E-03	V058	
	200-W	17	11	1.1E-03	±	3.2E-03	6.1E-03	±	1.3E-03	V007	65	41	9.5E-04	±	3.0E-03	4.4E-03	±	5.5E-03	V048	
	300	2	0	-1.6E-04	±	6.1E-04	1.5E-04	±	7.7E-04	V132	17	0	6.8E-04	±	3.2E-03	3.7E-03	±	4.3E-03	V123	
	400	1	0	1.4E-04 ^e			1.4E-04	±	2.3E-04	V130	5	0	4.0E-04	±	2.4E-03	3.0E-03	±	3.0E-02	V130	
	600	15	3	4.3E-04	±	9.8E-04	1.7E-03	±	6.2E-04	V107	43	9	1.3E+00	±	3.7E+00	7.1E+00	±	1.2E+00	V319	
⁹⁰ Sr	100	2	2	4.1E-01	±	3.7E-01	5.9E-01	±	1.3E-01	Y724	12	11	1.8E-01	±	4.3E-01	8.2E-01	±	1.8E-01	Y724	
	200-E	12	6	8.6E-02	±	2.5E-01	4.8E-01	±	1.0E-01	V076	37	16	8.4E-02	±	2.9E-01	7.4E-01	±	2.0E-01	V063	
	200-W	17	1	1.4E-02	±	8.1E-02	1.7E-01	±	4.9E-02	V045	65	12	1.4E-01	±	4.3E-01	8.4E-01	±	1.9E-01	V302	
	300	2	0	-2.9E-03	±	2.4E-03	-1.7E-03	±	1.7E-02	V123	17	3	3.4E-02	±	1.2E-01	1.5E-01	±	1.7E-01	V123	
	400	1	0	-1.5E-02 ^e			-1.5E-02	±	2.8E-02	V130	5	0	4.9E-02	±	1.9E-01	4.2E-01	±	1.8E-01	V130	
	600	16	1	1.0E-02	±	4.7E-02	7.3E-02	±	3.6E-02	V091	43	7	3.9E-02	±	1.0E-01	1.8E-01	±	1.4E-01	V081	
²³⁴ U	100	2	2	3.4E-02	±	5.4E-03	3.6E-02	±	1.2E-02	Y719	12	8	5.8E-02	±	1.8E-01	3.6E-01	±	1.8E-01	Y724	
	200-E	12	12	3.0E-02	±	1.6E-02	4.7E-02	±	1.4E-02	V055	37	24	3.3E-02	±	1.3E-01	3.4E-01	±	1.7E-01	V315	
	200-W	17	8	8.5E-03	±	1.1E-02	1.8E-02	±	7.8E-03	V031	65	46	2.9E-02	±	3.7E-02	7.9E-02	±	9.5E-02	V305	
	300	2	2	2.0E-02	±	3.3E-03	2.2E-02	±	1.0E-02	V132	17	15	2.0E-02	±	2.0E-02	3.6E-02	±	1.2E-01	V123	
	400	1	1	1.9E-02 ^e			1.9E-02	±	9.1E-03	V130	5	4	3.0E-02	±	1.0E-01	1.4E-01	±	4.7E-02	V130	
	600	16	11	1.4E-02	±	1.1E-02	2.5E-02	±	1.0E-02	V091	43	30	1.3E-02	±	2.4E-02	4.4E-02	±	1.1E-01	V108	
²³⁵ U	100	2	0	1.1E-02	±	1.2E-03	1.2E-02	±	9.6E-03	Y724	12	4	2.8E-02	±	8.9E-02	1.6E-01	±	1.3E-01	Y724	
	200-E	12	10	1.4E-02	±	1.1E-02	2.1E-02	±	1.1E-02	V053	37	16	1.2E-02	±	9.9E-02	1.6E-01	±	1.2E-01	V062	
	200-W	12	0	1.7E-03	±	4.8E-03	7.6E-03	±	1.0E-02	V019	64	21	4.2E-03	±	1.9E-02	2.3E-02	±	1.2E-02	V304	

Table C-22. Concentrations of Select Radionuclides (pCi/g)^a in Hanford Site Vegetation Samples. (2 Pages)

Radionuclide	Hanford Area	2017									2012 - 2016								
		Number of		Average ^c			Maximum ^d			Location	Number of		Average ^c			Maximum ^d			Location
		Samples	Detects ^b								Samples	Detects ^b							
	300	2	0	4.6E-03	±	1.4E-03	5.3E-03	±	5.5E-03	V123	17	5	2.2E-02	±	6.7E-02	8.9E-02	±	1.1E-01	V123
	400	1	0	8.4E-03 ^e			8.4E-03	±	7.8E-03	V130	5	1	1.0E-02	±	7.5E-02	7.7E-02	±	3.9E-02	V130
	600	15	5	6.2E-03	±	7.0E-03	1.2E-02	±	8.4E-03	V087	43	15	3.1E-02	±	6.0E-02	1.0E-01	±	1.2E-01	V108
²³⁸ U	100	2	2	1.3E-02	±	1.0E-03	1.4E-02	±	8.1E-03	Y719	12	7	3.6E-02	±	7.9E-02	1.4E-01	±	1.3E-01	Y724
	200-E	12	11	2.2E-02	±	1.2E-02	3.1E-02	±	1.1E-02	V141	37	19	1.8E-02	±	7.5E-02	1.4E-01	±	1.1E-01	V312
	200-W	17	10	8.4E-03	±	7.3E-03	1.7E-02	±	8.2E-03	V047	65	37	3.3E-02	±	5.1E-02	1.2E-01	±	1.1E-01	V304
	300	2	2	1.0E-02	±	2.2E-03	1.2E-02	±	8.0E-03	V132	17	16	1.1E-02	±	8.0E-03	1.8E-02	±	7.9E-02	V123
	400	1	0	7.5E-03 ^e			7.5E-03	±	7.2E-03	V130	5	3	2.1E-02	±	1.1E-01	1.6E-01	±	2.5E-01	V130
	600	15	8	8.8E-03	±	9.5E-03	1.9E-02	±	9.6E-03	V091	43	28	8.0E-03	±	4.2E-02	5.1E-02	±	6.9E-02	V308
^a 1 pCi = 0.037 Bq ^b Number of samples with measurable concentrations of contaminant ^c Average ± two standard deviations of all samples analyzed ^d Maximum ± analytical uncertainty ^e Standard deviation cannot be calculated for one sample.																			

C.7 References

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Appendix D. Dose Calculations

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D.0 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.

The total annual dose to a hypothetical, maximally exposed individual (MEI) in 2017 at the offsite location where projected doses were highest (Horn Rapids Road) was 0.22 mrem (2.2 μ Sv). This dose is 0.22% of the 100 mrem (1000 μ Sv)/yr public dose limit specified in [DOE O 458.1, *Radiation Protection of the Public and the Environment*](#). For context, a 2009 National Council on Radiation Protection and Measurements report estimated that the overall annual exposure to ionizing radiation for the average American is 620 mrem (6,200 μ Sv), approximately half of which is related to natural sources and the other half attributable primarily to medical procedures.

D.1 Supporting Information for Calculation of Public Doses

The radiological dose that the public could have received in 2017 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 [10 CFR 835, “Occupational Radiation Protection Program.”](#) 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)¹ 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 years) internal exposure from radionuclides absorbed into the body during the current year. The committed effective dose equivalent is the sum of individual committed (50 years) organ doses multiplied by tissue weighting factors (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 offsite 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

¹ 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

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 offsite locations. Long-lived radionuclides deposited 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 2.10.1* ([PNNL-14583](#); [PNNL-14584](#); [PNNL-19168](#)), which employs the internal dosimetry methodology described in ICRP 60 (ICRP 1991) and external dose coefficients described in Federal Guidance Report 12 ([EPA 1993](#)). GENII Version 1.485 ([PNL-6584](#)), 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. GENII Version 2.10.1 was used for dose calculations starting with 2016 data. 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 CAP-88PC (also known as CAP-88) was used to calculate an air pathway dose to an MEI for compliance with *Clean Air Act* standards, as required by the U.S. Environmental Protection Agency (EPA) through [40 CFR 61, "National Emission Standards for Hazardous Air Pollutants,"](#) Subpart H, from airborne radionuclide effluents (other than radon-220 and radon-222) released at the U.S. Department of Energy (DOE) facilities. Air pathway calculations performed with the CAP-88PC computer code differ slightly from those performed in GENII. Technical details of the CAP-88PC calculations are provided in [DOE/RL-2017-17, Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2016](#).

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 (1,000-μSv) 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 and off DOE sites
- 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/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 offsite 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 offsite 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 the following:

- The relative contributions of the different operational areas to radioactive emissions released to the air
- The contribution of radionuclide releases to the Columbia River from Hanford Site facilities
- 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 (e.g., fishing, hunting, boating, swimming, and exposure to sediments during shoreline activities).

D.1.1.1 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 2016 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 pathway receptor locations: at Ringold (200 Area air emissions sources), Sagemoor (300 Area air emissions sources), Horn Rapids Road (300 Area air emissions sources, plus drinking water pathway dose), and Riverview (300 Area air emissions sources, plus drinking water pathway dose).

For 2017, air pathway radiological dose calculations conducted using CAP-88PC in support of the *Clean Air Act* requirements and GENII Version 2.10.1 have identified the Horn Rapids Road as the location with the highest MEI dose. Air pathway calculations performed with the GENII computer code indicate that Sagemoor and Horn Rapids Road air pathway MEI doses in 2017 are almost identical (0.21 mrem at Sagemoor and 0.22 mrem at Horn Rapids Road). Unlike the Sagemoor receptor, the MEI at Horn Rapids Road receives additional dose from the drinking water pathway, but the contribution of water pathway doses in 2017 (0.0011 mrem) was negligible. A comparison of Sagemoor and Horn Rapids Road MEI GENII results are shown in Section 4.0, Figure 4.4.

MEI location coordinates relative to Hanford Site operating areas are entered in the GENII computer code to specify the location for the air pathway 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 Areas: 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 Areas: 22.6 km Easting, -22.6 km Northing	400 Area: 7.92 km Easting, -7.92 km Northing

D.1.1.2 Water and Air Release Inputs Used In GENII Version 2.10.1. As discussed in Section 4.2, the environmental data needed to perform the GENII Version 2.10.1 dose calculations for the water pathway are the measured upstream and downstream radionuclide concentrations in the Columbia River. As discussed below, radionuclide releases to the Columbia River that are calculated as the difference between annual-average downstream and upstream concentrations. 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 pathway dose calculations. These air and water pathway data must be processed for input to the GENII computer code. GENII accepts inputs for environmental releases using dimensions of activity (e.g., curie or becquerel) per time for both water and air pathways.

Direct liquid effluent releases from outfalls in the 100 Area were historically used to characterize contributions from the 100 Area. 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 Area in 2017. 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 riverwater radionuclide concentrations downstream of the Hanford Site (samples collected at the Richland Pumphouse, sampling location label RICH.PMPHSHRM46.4) and upstream of the Hanford Site (samples collected at a location below the Priest Rapids Dam, sampling location label PRIEST RAPIDS-RIVER). Radionuclides are measured in both filtered samples (in solution) and in samples that capture suspended particulates (adhered to a resin). These data for dissolved and particle-bound radionuclides were evaluated both separately and summed.

The river water samples used in the GENII dose assessment are based on continuous sampling of river water. A continuous sampler collects 55-mL water samples at 1-hr intervals. These samples are composited bimonthly and then combined for a single monthly composite that is submitted for laboratory analysis (DOE/RL-2017-24). In August 2017, the Richland Pumphouse sampling station continuous water sampler failed, and these samples were not collected. In their stead, 0.5-gal (2-L) grab water samples were collected once per month for the period of August through December 2017. River flow varies seasonally and in response to operations of upstream dams, which can produce a change of up to 10 ft (3 m) in Hanford Reach river elevation within a few hours (DOE/RL-2017-24). Changes in river flow and elevation can lead to changes in river water concentrations of Hanford-related radionuclides. Ideally, downstream and upstream water would be sampled using the same method to eliminate artificial differences related to sample collection method. The continuous (hourly) increments better represent the full range of monthly water quality conditions. Therefore, the substitution of once a month grab samples for continuous (hourly) samples at RICH.PMPHSHRM46.4 in the latter part of the year affected the ability to accurately measure monthly average downstream concentrations.

Specifically, as discussed in Section 4.2.1.1, it is possible that dose from the water pathways has been underestimated in 2017 when, unlike in previous years, neither uranium-234 nor uranium-238 were identified at higher levels in Columbia River samples downgradient of the Hanford Site relative to upstream levels. The difference in downstream versus upstream contaminant concentrations is commonly larger during the fall when river flow is lowest and effluent discharges from the Hanford Site are less diluted. A single grab sample cannot be representative of an entire month. If, for example, the grab was collected at a time with relatively high river flow or elevation, then this would have inadvertently created a low result in the measured downstream concentrations. As shown in Figure 4-5,

from 2002 through 2016 annual-average downstream concentrations of uranium have generally been larger than upstream concentrations, but there is also an increasing trend in uranium concentrations from 2012 through 2017 at both upstream and downstream locations. The change to grab samples at the Richland Pumpouse beginning August 2017, and/or the trend of increasing uranium concentrations at both upstream and downstream locations, could be factors in explaining why uranium releases to the Columbia River were not identified in 2017.

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 as a potentially Hanford-related contaminant to include in the 2017 water pathway dose assessment using a p-value of 0.05. As discussed above, concentrations of uranium isotopes in downstream samples were not greater than upstream concentrations in 2017. Statistical tests could not be conducted for gamma-emitting radionuclides and isotopic plutonium, analytes that are commonly present in forms that are relatively insoluble (antimony-125, beryllium-7, cesium-134, cesium-137, cobalt-60, isotopic europium, isotopic plutonium, potassium-40, and ruthenium-106). With the continuous flow sampler, these radionuclides are sampled by passing water through a filter to trap particulates and subsequently through a resin column to trap radionuclides in solution. The minimum detectable activity of plutonium isotopes in the grab samples was about 100-times larger than that of the continuous samples; for the gamma-emitting analytes this difference ranged from several hundred to approximately 1,000-times larger. However, with the exception of beryllium-7 and potassium-40, these radionuclides were not measured at levels above minimum detectable activities in any sample including those collected with the continuous sampler at the Richland Pumpouse through July 2017. Beryllium-7 is a naturally occurring radionuclide of cosmogenic origin with a half-life of approximately 53 days. Because of its short half-life, it is not plausibly present today due to historical Hanford operations. Potassium-40 is a primordial radionuclide (half-life of approximately 1.25×10^9 years) that is naturally occurring and has no known Hanford-related sources.

Table D-1 summarizes the mean annual differences in downstream and upstream concentrations, and calculated annual releases for the 2017 GENII water pathway dose calculations.

Table D-1. Liquid Effluent Radionuclide Releases for GENII Dose Calculations.

Radionuclide	Upstream	Downstream	Difference
<i>Columbia River Annual-Average Radionuclide Concentrations (pCi/L)^a</i>			
Tritium	1.5E+01	2.4E+01	9.6E+00
<i>Calculated Radionuclide Releases (Ci/year)^b</i>			
Tritium	NA ^d	NA ^d	1.18E+03
^a 1 pCi=0.037 Bq ^b Calculated as the product of the difference in downstream and upstream radionuclide concentrations and the 2017 annual-average riverflow rate of 1.24E+14 L/yr at Priest Rapids Dam. ^d Radionuclide releases calculated based on difference between annual -average downstream and upstream concentrations. NA = not applicable			

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 pathway 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 offsite 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 hours 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 were also made on emissions from each operating area. Following the precedent of DOE/RL-2018-5, 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 were incorporated in the estimated doses. These specific radionuclides were selected based on their historical association with releases in these operating areas and because air pathway 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 pathway dose calculations are summarized in Table D-2.

Table D-2. Air Pathway Radionuclide Stack Emissions for GENII Modeling. (3 Pages)

Radionuclide	100 Area	200 Areas	300 Area	400 Area
	(Curies)			
Hydrogen-3 (elemental tritium)	NA ^a	NA ^a	16	NA ^a
Hydrogen-3 (tritiated water vapor)	NA ^a	NA ^a	160	0.016
Carbon-14	NA ^a	NA ^a	1.2E-04	NA ^a
Sodium-22	NA ^a	NA ^a	NA	2.1E-10

Table D-2. Air Pathway Radionuclide Stack Emissions for GENII Modeling. (3 Pages)

Radionuclide	100 Area	200 Areas	300 Area	400 Area
	(Curies)			
Cobalt-60	NA ^a	NA ^a	7.7E-08	NA ^a
Krypton-85	NA ^a	NA ^a	5.2E-07	NA ^a
Stontium-90	5.5E-06	5.9E-06	1.9E-07	NA ^a
Yttrium-90 ^a	8.2E-07	8.8E-06	2.8E-08	NA ^a
Technetium-99	NA ^a	NA ^a	4.1E-06	NA ^a
Ruthenium-106	NA ^a	NA ^a	1.3E-09	NA ^a
Iodine-129	NA ^a	9.3E-04	NA ^a	NA ^a
Cesium-134	NA ^a	NA ^a	NA ^a	NA ^a
Cesium-137 ^b	2.0E-05	2.2E-05	1.4E-05	1.9E-06
Barium-137m ^{b, c}	2.0E-05	2.2E-05	1.4E-05	1.9E-06
Europium-152	NA ^a	NA ^a	2.2E-09	NA ^a
Europium-154	NA ^a	NA ^a	1.1E-08	NA ^a
Gadolinium-153	NA ^a	NA ^a	9.0E-11	NA ^a
Radon-219	NA ^a	NA ^a	3560	NA ^a
Lead-211 ^c	NA ^a	NA ^a	6.4	NA ^a
Bismuth-211 ^c	NA ^a	NA ^a	1.1	NA ^a
Thallium-207 ^c	NA ^a	NA ^a	5.0E-02	NA ^a
Radon-220	NA ^a	NA ^a	885	NA ^a
Lead-212 ^c	-- ^d	-- ^d	1.3E+00	NA ^a
Bismuth-212 ^c	-- ^d	-- ^d	1.1E+00	NA ^a
Radon-222	NA ^a	NA ^a	3.6E-05	NA ^a
Polonium-218 ^c	NA ^a	NA ^a	3.6E-05	NA ^a
Lead-214 ^c	NA ^a	NA ^a	3.4E-05	NA ^a
Bismuth-214 ^c	NA ^a	NA ^a	3.2E-05	NA ^a
Radium-226	NA ^a	NA ^a	3.7E-10	NA ^a
Actinium-227	NA ^a	NA ^a	3.1E-10	NA ^a
Uranium-232	NA ^a	NA ^a	8.6E-09	NA ^a
Uranium-233	NA ^a	NA ^a	2.3E-08	NA ^a
Neptunium-237	NA ^a	NA ^a	1.4E-08	NA ^a
Plutonium-238	4.1E-07	1.8E-07	3.6E-08	NA ^a
Plutonium-239/240 ^e	1.1E-05	3.1E-05	4.6E-06	2.9E-07
Plutonium-241	1.4E-05	3.3E-06	NA	NA ^a
Americium-241	3.9E-06	2.2E-06	1.6E-08	NA ^a
Americium-243	NA ^a	NA ^a	4.3E-08	NA ^a
Neptunium-239 ^e	-- ^d	-- ^d	7.3E-09	NA ^a
(gross alpha)	8.2E-06	2.1E-05	4.6E-06	2.9E-07
(gross beta)	1.5E-05	1.9E-05	1.4E-05	1.9E-06

Table D-2. Air Pathway Radionuclide Stack Emissions for GENII Modeling. (3 Pages)

Radionuclide	100 Area	200 Areas	300 Area	400 Area
	(Curies)			
^a No stack emissions reported for this radionuclide.				
^b Values include the addition of gross beta activity.				
^c These short-lived radionuclides will ingrow during air dispersion to offsite locations and contribute to inhalation dose. Values are the highest activity calculated within an upperbound 15-hr dispersion time period to any exposure point within a 50-mi (80-km) distance.				
^d Separate stack emission estimates were not reported for this short-lived radionuclide.				
^e Values include the addition of gross alpha activity.				
-- = Not included;				
NA = Not available or not detected.				

D.1.1.3 Exposure Parameter Values Used in GENII Version 2.10.1. GENII Version 2.10.1 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 offsite 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.

D.1.1.4 Meteorological Data Used in GENII Version 2.10.1. GENII Version 2.10.1 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 2017 meteorological data used in the GENII air dispersion modeling were gathered at monitoring stations in the 100 Area (station 29 100-K), 200 Areas (station 21; Hanford Meteorological Station), 300 Area (Station 11; 300 Area), and 400 Area (station 9; Fast Flux Test Facility). With the exception of the 100 and 200 Areas, all meteorological data were obtained at a height of 33 ft (10 m). In the 100-K Area, the temporary tower was implemented at 10 ft (3 m) in height. In the 200 Areas, 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		Fruit s	Cereal s	Eggs	Poultr y	Beef	Milk	Hay (beef cattle, milk cows)	Pasture (milk cows)	Grains (beef cattle, poultry)
	Leafy	Root									
Holdup time ^a ; day (MEI)	1	5	5	180	1	1	15	1	100	0	180
Holdup time ^a ; 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 ^b	1.5	4	2	0.8	NA	NA	NA	NA	2	1.5	0.8
Irrigation rate; cm/yr	77	88	77	NA ^c	NA	NA	NA	NA	103	103	NA ^c
Irrigation period; month	6	6	6	NA ^c	NA	NA	NA	NA	6	6	NA ^c
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 ^d	55/55 ^e	NA	NA	NA
Contaminated fraction of diet ^b	NA	NA	NA	NA	1.0	1.0	0.25/0.75 ^d	0.25/0.75 ^e	NA	NA	NA
Livestock soil intake; kg/day	NA	NA	NA	NA	0.0	0.0	0.0	0.375 ^f	NA	NA	NA
^a Holdup time is the time between harvest and consumption ^b Pertains to animal feed; 100% of animal water is assumed contaminated surface water. ^c No irrigation is assumed to occur for cereal crops or grains. ^d First value pertains to grains, and second value pertains to hay. ^e First value pertains to hay, and second value pertains to pasture grass. ^f Calculated as 0.5 kg soil/day while grazing × 0.75 diet fraction of pasture grass. MEI=maximally exposed individual NA=not applicable											

Table D-4. Consumption Parameters for Hanford Site Dose Calculations.

Medium	Consumption Rate ^a	
	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 ^b	88 lbs (40 kg)/yr	-- ^c
Drinking water ^d	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 A transit time of 11 hours from the release to receptor locations is assumed.

^b A holdup time of 1 day is used for both MEI and population calculations.

^c Average individual consumption not identified; see text of Section D.1.2.

^d A holdup time of 1 day is used for the Riverview calculations for identification of the location of the MEI.

MEI = maximally exposed individual

Table D-5. Residency Parameters for Hanford Site Dose Calculations.

Pathway	Exposure	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Air: Inhalation ^{a, b}	24 hrs/day, 365 days/yr	24 hrs/day, 365 days/yr
Air: external (submersion) ^b	24 hrs/day, 365 days/yr	24 hrs/day, 365 days/yr
Soil: external (groundshine)	12 hrs/day, 365 days/yr	8 hrs/day, 365 days/yr

^a Inhalation rate, adult 1.0 m³/hr (35 ft³/hr).

^b Dispersion time of 15 hours is protectively assumed for ingrowth of short-lived progeny during transport (50 mi [80 km]) population dose radius and 4.9 ft/sec (1.5 m/sec) wind speed.

Table D-6. Columbia River Parameters for Hanford Site Dose Calculations.

Activity and Pathway	Exposure ^a	
	Maximally Exposed Individual	Average Individual (Collective Dose)
Shoreline: sediment; external	5.0 hrs/day, 100 days/yr ^b	1.7 hrs/day, 10 days/yr ^b
Boating: river water; external	2.0 hrs/day, 50 days/yr ^c	0.1 hr/day, 50 days/yr ^c
Swimming: river water; inadvertent ingestion ^d , external	2.0 hrs/day, 50 days/yr	0.2 hr/day, 50 days/yr

^a A transit time of 11 hours from the release to receptor locations is assumed.

^b A shoreline width factor of 0.2 is used.

^c No shielding by the boat is assumed.

^d Ingestion rate of 0.68 oz (0.02 L)/hr.

Hourly meteorological data from the monitoring stations described above were formatted for use in the GENII computer code. Four meteorological files were created, one for each of the Hanford Site operating areas and stations described above. 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 in Section D.1.1.1. 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 operation areas was calculated to conform to DOE environmental protection policies and to 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, 200, 300, and 400 Areas).

The same exposure pathways evaluated for the MEI (Section D.1.1) were used to calculate doses to the offsite 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 offsite 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.

D.1.2.1 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-Cities² are assumed to obtain all of their drinking water directly from the Columbia River or from impacted wells near the river that are assumed to have the same radionuclide concentrations as were measured in near-shore river water. Annual drinking water dose for an average individual is multiplied by the Tri-Cities population to calculate the collective drinking water dose.

D.1.2.2 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 the Columbia River 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. An annual irrigated foods dose for an average individual is protectively multiplied by the estimate population of 2,000 individuals to calculate the collective irrigated foods dose.

² The Cities of Pasco, Kennewick, and Richland—known as the Tri-Cities—are located in southeastern Washington State. Population estimates are based on the 2010 census, from <https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>.

D.1.2.3 Columbia River Recreation. As described in Section 4.2 and Section D.1.1, recreational activities on the Columbia River 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.

D.1.2.4 Fish Consumption. Population doses from consuming fish obtained locally from the Columbia River were calculated from an estimated total annual catch of 33,000 lb (15,000 kg)/yr. It was protectively assumed that 100% of the annual catch was consumed by individuals in the Tri-Cities area and that tissue concentrations in the fish were in equilibrium with concentrations of radionuclides in river water, which is likely to introduce a protective bias for anadromous fish such as salmon and steelhead. Population dose related to fish consumption was calculated as follows:

$$\text{Population dose (person-rem)} = \text{MEI dose (mrem)} \times 0.001 \text{ rem/mrem} \times (\text{annual catch [kg/yr]}/\text{IR}_{\text{fish}} [\text{kg/yr/person}]), \text{ where MEI dose} = \text{fish ingestion dose for the MEI; annual catch} = 15,000 \text{ kg fish/yr; IR}_{\text{fish}} = \text{individual fish ingestion rate used in the MEI calculation (40 kg/yr/person)}$$

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 ([PNNL-20631, Hanford Site Regional Population—2010 Census](#)). These distributions are based on 2010 United States Census Bureau 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 pathway 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 4 cardinal, 4 ordinal, and 8 cross-wind directions (e.g., N, NNE, NE, ENE). These sectors were transformed into grids using concentric circles with radii of 1, 2, 3, 4, 5, 10, 20, 30, 40, and 50 mi (1.6, 3.2, 4.8, 6.4, 8, 16, 32.1, 48.2, 64.3 and 80.4 km). 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 RESidual RADioactivity (RESRAD)-BIOTA 1.8 computer code was used to screen the 2017 radionuclide concentrations in water, sediment, soil, and tissues to see if they exceeded the established biota concentration guides. Biota concentration guides (BCGs) are concentrations published in [DOE-STD-1153-2002, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota](#), that could result in a dose rate of 1 rad/day for aquatic biota or 0.1 rad/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 Distribution Coefficients.

Radionuclide	Water (pCi/L) ^a	Limiting Organism	Sediment (pCi/g) ^a	Limiting Organism	Default K _d (mL/g) ^b
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
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

^a 1 pCi=0.037 Bq. Biota concentration guides (pCi/g or pCi/L) from RESRAD-BIOTA v1.8.
^b K_d=Sediment to Water Distribution Coefficients (mL/g) from RESRAD-BIOTA v1.8.
 RESRAD = RESidual RADioactivity

Table D-8. Tier 1 Soil Biota Concentration Guides.

Radionuclide	Soil (pCi/g) ^a	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
Uranium-234	5.13E+03	Terrestrial animal
Uranium-235	2.77E+03	Terrestrial animal
Uranium-238	1.58E+03	Terrestrial animal
Americium-241	3.89E+03	Terrestrial animal

^a 1 pCi=0.037 Bq.
 Biota concentration guides (pCi/g) from RESRAD-BIOTA v1.8.
 RESRAD = RESidual RADioactivity

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 sediment to water distribution coefficient. These coefficients are tabulated in Table D-7.

The sites for the aquatic biota dose assessment were grouped into the following:

- Upstream (Vernita sediment and Priest Rapids Dam river water samples)
- The 100 Area (sediments from 100-K, 100-D, 100-H, 100-F and White Bluff; river water from 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)
- The 300 Area (river water and springs)
- Downstream (sediments from McNary Dam and river water from the Richland Pump house station).

Table D-9. Maximum Detected Concentrations Evaluated for Aquatic Biota Dose Assessment. (2 Pages)

Location Group	Radionuclide	Maximum Sediment (pCi/g) ^a	Maximum Water (pCi/L) ^a
Upstream	Hydrogen-3	—	20.2
	Cesium-137	0.295	—
	Plutonium-239/240	0.0117	—
	Uranium-234	1.63	0.393
	Uranium-235	0.127	0.0765
	Uranium-238	1.43	0.267
100 Area	Hydrogen-3	—	3370
	Carbon-14	—	216
	Strontium-90	—	22.5
	Technetium-99	—	8.54
	Cesium-137	0.285	—
	Plutonium-238	0.00064	—
	Plutonium-239/240	0.00218	—
	Uranium-234	1.07	1.09
	Uranium-235	0.0958	0.101
	Uranium-238	0.932	0.859
Hanford Townsite	Hydrogen-3	—	15900
	Cesium-137	0.21	—
	Plutonium-238	0.0458	—
	Uranium-234	1.19	0.323
	Uranium-235	0.11	0.0644
	Uranium-238	1.03	0.232
300 Area	Hydrogen-3	—	4590
	Cesium-137	0.163	—
	Uranium-234	0.886	26.7
	Uranium-235	0.125	3.14 ^b
	Uranium-238	0.958	24.8
Downstream	Hydrogen-3	—	26.5
	Cesium-137	0.239	—
	Uranium-234	1.69	0.404
	Uranium-235	0.18	0.0671
	Uranium-238	1.29	0.313

Table D-9. Maximum Detected Concentrations Evaluated for Aquatic Biota Dose Assessment. (2 Pages)

^a	1 pCi = 0.037 Bq
^b	Uranium-236 was added to the uranium-235 value due to the lack of available BCGs for uranium-236 in RESRAD-BIOTA v1.8. These radionuclides have similar K_d values and emissions and thus would have similar calculated BCGs.
—	= Not detected or not measured
K_d	= Water to Sediment Distribution Coefficients (mL/g) from RESRAD-BIOTA v1.8
BCG	= Biota Concentration Guide
RESRAD	= RESidual RADioactivity

Radionuclides were selected for the aquatic biota dose assessment based primarily on their detection in sediment or water. 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; however, due to relatively high soil-water distribution coefficients, these radionuclides would most likely be associated with sediments instead of water. Cesium-137 and isotopic plutonium were detected in sediments and may have sources from DOE operations. Although the magnitude of the sediment concentrations onsite is sometimes 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 has no groundwater plumes or other known DOE sources; 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, sediment, and soils (onsite and offsite). 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 DOE-STD-1153-2002.

Table D-10. West Lake 2017 Water and Sediment Samples.

Radionuclide	Water Concentration (pCi/L) ^a		Sediment Concentration (pCi/g) ^a	
	Maximum	Average	Maximum	Average
Hydrogen-3	305	305	—	
Strontium-90	—	—	0.368	0.182
Cesium-137	—	—	1.34	0.637
Uranium-234	658	447	3.62	1.29
Uranium-235	34.7	22.1	0.241	0.116
Uranium-238	623	421	3.38	1.23
^a pCi=0.037 Bq				
— = Not detected or not measured.				

The Tier 1 and 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. The isotopic ratios of uranium indicate a natural source (granitic erratics from the Missoula floods) and no uranium-236 was detected, albeit some minor amounts of depleted uranium may be present (PNL-7662). 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 [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 in annual reports since that date. 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 v1.8.

Radionuclide	Water BCG (pCi/L) ^a		Sediment BCG (pCi/g) ^a	
	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
^a 1 pCi=0.037 Bq				
RESRAD = RESidual RADioactivity				

Dose to terrestrial biota were evaluated using the onsite soil sample results. Note that offsite soil samples are collected every 3 to 5 years and are scheduled for collection in 2018. Table D-12 lists the maximum concentrations of strontium-90, cesium-137, plutonium-238, plutonium-239/240, uranium-234, uranium-235, uranium-238, and americium-241. These radionuclides were selected for the terrestrial biota dose assessment based on their detection in soil. 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.

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. Maxima were used in the supplemental internal dose calculations, which is more protective than the mean recommended by DOE guidance for these Tier 3 dose calculations. However, the detections were infrequent for tissues and, therefore, the maximum detected values and mean detected values would be similar.

Table D-12. Maximum Detected Concentrations Evaluated for Terrestrial Biota Dose Assessment.

Location Group	Radionuclide	Maximum Soil Concentration (pCi/g) ^a
Onsite	Strontium-90	1.87
	Cesium-137	16
	Uranium-234	2.23
	Uranium-235	0.114
	Uranium-238	1.93
	Plutonium-238	0.127
	Plutonium-239/240	1.6
	Americium-241	0.042
^a 1 pCi=0.037 Bq.		

D.3 References

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