PNNL-30262

Pacific Northwest National Laboratory Annual Site Environmental Report for Calendar Year 2019

Final Report

September 2020

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

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PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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Pacific Northwest National Laboratory
Richland, Washington 99352

Pacific Northwest National Laboratory
Annual Site Environmental Report for 2019
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Executive Summary

Pacific Northwest National Laboratory (PNNL), one of the U.S. Department of Energy (DOE) Office of Science's 10 national laboratories, provides innovative science and technology development in the areas of energy and the environment, fundamental and computational science, and national security. DOE's Pacific Northwest Site Office is responsible for oversight of PNNL.

PNNL prepares this annual site environmental report to meet the requirements of DOE Order 231.1B, *Environmental, Safety and Health Reporting*, and DOE Order 458.1, *Radiation Protection of the Public and the Environment*, assuring that the public is informed of any PNNL Richland Campus or PNNL Sequim Campus event that could adversely affect the health and safety of the public, site staff, or the environment. The report provides a synopsis of ongoing environmental management performance and compliance activities for operations that occur on the PNNL Richland Campus in Richland, Washington, and at the PNNL Sequim Campus near Sequim, Washington. It describes the location of and background for each facility; addresses compliance with applicable DOE, federal, state, and local regulations and site-specific permits; documents environmental monitoring efforts and their status; presents potential radiation doses to staff and the public in the surrounding areas; and describes DOE-required data quality assurance methods used for data verification.

Compliance with Federal, State, and Local Laws and Regulations in 2019

PNNL is subject to many federal, state, and local environmental laws, regulations, guidance decrees, DOE requirements, and Executive Orders, as well as numerous site-specific permits. Detailed requirements are integrated into all PNNL projects by means of environmental compliance representatives assigned to assess and assist with each project. PNNL continued to exhibit an excellent compliance record in 2019; required reports were submitted, necessary reviews and permits for research and support activities were obtained, all sitewide permits were current, and authorized emission and discharge levels were not exceeded.

Environmental Sustainability Performance

PNNL's environmental management system (EMS) has been certified to meet the requirements of the International Standards Organization (ISO) 14001 standards since 2002, demonstrating commitment to safe and sustainable operations, and satisfying the requirements of DOE Order 436.1, *Departmental Sustainability*. The EMS is integrated into PNNL's Integrated Safety Management Program, which assures that staff are aware of project scope, risks/hazards, and controls available to address functions, processes, and procedures used to plan and perform work safely. PNNL is dedicated to responsible planning for and management of resources that could be affected by facility operations and exhibits excellent environmental sustainability performance in disciplines including energy and water conservation, waste diversion, alternative fuel use, reduction of greenhouse gas emissions, and sustainable building design.

Environmental Monitoring and Dose Assessment

PNNL monitors air and water quality to assure compliance with federal, state, and local regulatory requirements and permits.

Air Emissions. Airborne emissions from PNNL facilities are monitored to assess the effectiveness of emission treatment and control systems, as well as pollution management practices. The Benton Clean Air Agency implements and enforces most federal and state requirements on the PNNL Richland Campus, and the Olympic Region Clean Air Agency implements and enforces most federal and state

requirements at the PNNL Sequim Campus. There were no unplanned releases of regulated substances or substances of concern from PNNL facilities in 2019.

Liquid Effluent Monitoring. Liquid effluent discharges from PNNL Richland Campus operations are monitored under permits issued by the City of Richland. Process wastewater from the PNNL Sequim Campus is treated at an onsite wastewater treatment plant prior to being discharged to Sequim Bay under a permit issued by the Washington State Department of Ecology. In 2019, there were no unplanned releases of regulated pollutants or contaminated wastewater from PNNL facilities and effluent discharges were within permitted limits.

Radiological Release of Property. PNNL uses the pre-approved guideline limits derived from guidance in DOE Order 458.1, Chg 3, *Radiation Protection of the Public and the Environment*, when releasing property potentially contaminated with residual radioactive material. No property with detectable residual radioactivity above authorized levels was released from PNNL in 2019.

Radiation Protection of Biota. PNNL models environmental concentrations for air, soil, sediment, and water to consider impacts on biota from PNNL particulate radioactive releases to ambient air. The 2019 dose rate estimates for aquatic, terrestrial, and riparian animals and plants were well below the dose rate limits of DOE Order 458.1, Chg 3, guidance for both the PNNL Richland Campus and PNNL Sequim Campus.

Environmental Radiological Monitoring. No radiological releases to the environment exceeded permitted limits in 2019.

Radioactive particulates in ambient air are monitored using a particulate air-sampling network located at the PNNL Richland Campus. In 2019, there was no indication that any PNNL activities increased the ambient air concentrations at the air-sampling locations. The maximum exposed individual (MEI) exposure to radionuclide air emissions resulted in a dose estimate of 1.5×10^{-5} mrem (1.5×10^{-7} mSv).

In 2019, within the 80 km (50 mi) radius of the PNNL Richland Campus, the collective dose from radionuclide air emissions that originated from the campus was 8.4×10^{-5} person-rem (8.4×10^{-7} person-Sv). The PNNL Richland Campus MEI location was 0.67 km (0.42 mi) south-southeast of the Physical Sciences Facility 3410 Building.

The PNNL Sequim Campus MEI location was 0.23 km (0.15 mi) west of the central emission location. The dose to the MEI from site emissions was 2.8×10^{-4} mrem (2.8×10^{-6} mSv). The 80 km (50 mi) collective dose for PNNL Sequim Campus emissions was 3.1×10^{-4} person-rem (3.1×10^{-6} person-Sv).

The total dose to either the PNNL Richland Campus or PNNL Sequim Campus MEI is well below the federal and state standard of 10 mrem/yr (0.1 mSv/yr).

Environmental Nonradiological Program Information. PNNL nonradiological air emissions are below levels that require stack monitoring; compliance is achieved by conforming to permit conditions. There were no nonradiological air emission permit exceedances or noncompliances at either the PNNL Richland Campus or PNNL Sequim Campus in 2019.

Natural and Cultural Resource Management

Protection and management of cultural and biological resources on PNNL lands is implemented through internal cultural and biological resource protection procedures, which are updated annually to reflect relevant changes in applicable laws and regulations and compliance methods. The *Pacific Northwest Site Office Cultural and Biological Resources Management Plan* provides guidance related to protecting and managing biological and cultural resources at PNNL. Environmental permits required for PNNL research activities were obtained and adhered to in accordance with requirements of associated federal and state statutes and regulations.

Groundwater Protection

Groundwater under the PNNL Richland Campus is monitored routinely through seven groundwater monitoring wells and four heat pump production wells. Results are reported monthly to the Washington State Department of Ecology. PNNL complies with all permit sampling requirements.

Quality Assurance

The comprehensive quality assurance programs at PNNL, which include various quality control procedures and method verification, assure reported data are reliable and meet all quality control and quality assurance objectives.

Acknowledgments

Compilation of the Pacific Northwest National Laboratory Annual Site Environmental Report involved the collaboration and expertise of numerous PNNL staff. Principal contributors and their subject matter specialties included the following:

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Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	microgram(s) per liter
µS/cm	microsiemen(s) per centimeter
µSv	microsievert(s)

A

ac	acre(s)
ALARA	as low as reasonably achievable
AQSS	Acquisition Quality Support Services
ASME	American Society of Mechanical Engineers
ASO	Analytical Support Operations (laboratory)

B

Battelle	Battelle Memorial Institute
BCAA	Benton Clean Air Agency
BP	Before Present
BPA	Bonneville Power Administration
Bq	bequerel(s)
BSF	Biological Sciences Facility
Btu	British thermal unit(s)

C

C&D	construction and demolition
CAA	*Clean Air Act*
CBRMP	Cultural and Biological Resources Management Plan
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	Code of Federal Regulations
Ci	curie(s)
cm	centimeter(s)
CSF	Computational Sciences Facility
CWA	*Clean Water Act*
CY	calendar year
CZMA	*Coastal Zone Management Act of 1972*

D

d	day(s)
DOE	U.S. Department of Energy
DOECAP	DOE Consolidated Audit Program
DOE-RL	DOE-Richland Operations Office
DOE-SC	DOE Office of Science
dpm	disintegrations per minute
DQO	data quality objective

E

ECM	energy and water conservation measure
ED	effective dose
EDE	effective dose equivalent
EDL	Engineering Development Laboratory
EISA	*Energy Independence and Security Act of 2007*
EM	Effluent Management

P	effluent management quality assurance plan
EMP	Environmental Management Plan
EMS	environmental management system
EMSL	William R. Wiley Environmental Molecular Sciences Laboratory
EO	Executive Order
EPEAT	Electronic Product Environmental Assessment Tool
EPA	U.S. Environmental Protection Agency
EPCRA	*Emergency Planning and Community Right-to-Know Act of 1986*
ERP	Environmental Research Permitting
ESA	*Endangered Species Act of 1973*

F

FEMA	Federal Emergency Management Agency
FR	*Federal Register*
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
FY	fiscal year

G

g	g-force
g	gram(s)
gal	gallon(s)
GBq	gigabecquerel(s)
GEL	General Engineering Laboratories
GHG	greenhouse gas
gpd	gallon(s) per day
gpm	gallon(s) per minute
GSA	General Services Administration
Gy	gray(s)

H

ha	hectare(s)
HDI	How Do I….?
HPSB	high-performance sustainable building

I

in.	inch(es)
ISO	International Organization for Standardization
ISO/IEC	International Organization for Standardization/ International Electrotechnical Commission

K

kBtu	kilo-Btu(s) (1,000 British thermal units)
kg	kilogram(s) (1,000 grams)
kgal	kilo-gallon(s) (1,000 gallons)
km	kilometer(s)
km^2	square kilometer(s)
kW	kilowatt(s)

L

L	liter(s)
L/min	liter(s) per minute
lb	pound(s)
LNM	Local Notice to Mariners
LSL2	Life Sciences Laboratory 2

M

m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
m/s	meter(s) per second
MAPEP	Mixed-Analyte Performance Evaluation Program
MDL	method detection limit
MEI	maximum exposed individual
mg	milligram(s)
mg/L	milligram(s) per liter
mGy/d	milligray(s) per day
mi	mile(s)
mi^2	square mile(s)
min	minute(s)
MMPA	*Marine Mammal Protection Act of 1972*
MoU	Memorandum of Understanding
mph	mile(s) per hour

mrem	millirem
mrem/yr	millirem per year
MSFCMA	*Magnuson–Stevens Fishery Conservation and Management Act*
mSv	millisievert(s)
mSv/yr	millisievert(s) per year

N

NA	not applicable
ND	nondetectable
NELAP	National Environmental Laboratory Accreditation Program
NEPA	*National Environmental Policy Act of 1969*
NESHAP	National Emission Standards for Hazardous Air Pollutants
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NQA	nuclear quality assurance
NRHP	National Register of Historic Places

O

OAR	Oregon Administrative Rules
ORCAA	Olympic Region Clean Air Agency
OSL	Optically stimulated luminescence

P

PATON	permit and/or private aid to navigation
PCB	polychlorinated biphenyl
pCi/m^3	picocurie(s) per cubic meter
pCi/mL	picocurie(s) per milliliter
PIC-5	Potential Impact Category 5
PNL	Pacific Northwest Laboratory
PNNL	Pacific Northwest National Laboratory
PNSO	Pacific Northwest Site Office
PSF	Physical Sciences Facility
PSL	Physical Sciences Laboratory

Q

QC	quality control
QA	quality assurance

R

R&D	research and development
RAEL	radioactive air emission license
RCRA	*Resource Conservation and Recovery Act of 1976*
RESL	Radiological and Environmental Sciences Laboratory
RHA	*Rivers and Harbors Appropriations Act of 1899*
RTL	Research Technology Laboratory
RCW	Revised Code of Washington
RPL Laboratory	Radiochemical Processing

S

s	second(s)
SEPA	*State Environmental Policy Act*
SHPO	State Historic Preservation Officer
SMA	*Shoreline Management Act of 1971*
Sv	sievert(s)

T

TNI	The NELAC Institute

U

USACE	U.S. Army Corps of Engineers
U.S.C.	U.S. Code
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service

W

WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington State Department of Health

Y

yr	year(s)

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1.0 Introduction

The U.S. Department of Energy (DOE) requires that all its site facilities develop an annual site environmental report to comply with DOE Order 231.1B, Chg 1, *Environment, Safety and Health Reporting*, and DOE Order 458.1, Admin Chg 3, *Radiation Protection of the Public and the Environment*. This report provides a synopsis of calendar year (CY) 2019 information related to environmental management performance and compliance efforts at Pacific Northwest National Laboratory (PNNL). It summarizes site compliance with federal, state, and local environmental laws, regulations, policies, directives, permits, and Orders, and provides environmental management performance benchmarks and their status to the public, regulatory agencies, community officials, Native American tribes, and public interest groups.

PNNL—one of 10 DOE Office of Science (DOE-SC) national laboratories—provides innovative science and technology solutions in energy and the environment, fundamental and computational science, and national security disciplines. Operated by Battelle Memorial Institute (Battelle) under contract to DOE-SC's Pacific Northwest Site Office (PNSO), PNNL performs work for a diverse set of clients, including the National Nuclear Security Administration, U.S. Department of Homeland Security, U.S. Nuclear Regulatory Commission, U.S. Environmental Protection Agency (EPA), DOE Office of Environmental Management, and other federal agencies, as well as private industry. PNSO is responsible for program implementation, acquisition management, and laboratory stewardship at PNNL. Through its oversight role, PNSO manages the safe and efficient operation of PNNL while enabling the pursuit of visionary research and development (R&D) in support of complex national energy and environmental missions.

As part of PNNL's commitment to environmental stewardship, staff members conduct surveillance and monitoring tasks to confirm compliance with established standards and specific permit limits, as well as to provide information regarding any impacts on the environment from operations.

1.1 Location

PNNL has facilities on the PNNL Richland Campus in Richland, Washington, and on the PNNL Sequim Campus near Sequim, Washington (Figure 1.1). Environmental activities at other locations also fall under PNNL's responsibility (e.g., a permitted waste storage and treatment unit on the Hanford Site). In addition, PNNL conducts research at satellite offices in various other locations, including Seattle, Washington, and Portland, Oregon, as well as at various offsite field locations.

Figure 1.1. PNNL Office Locations

1.1.1 PNNL Richland Campus

The PNNL Richland Campus covers approximately 269 ha (664 ac) and is located in Benton County in southeastern Washington State, 275 km (170 mi) east-northeast of Portland, Oregon, 270 km (170 mi) southeast of Seattle, Washington, and 200 km (125 mi) southwest of Spokane, Washington. It is located at the northern boundary of the City of Richland and south of the DOE-Richland Operations Office's (DOE-RL's) Hanford Site 300 Area (Figure 1.2). Adjacent to the Columbia River, the PNNL Richland Campus encompasses DOE-SC federally owned land, land owned by Battelle, and leased facilities in the Richland area. PNNL also leases facilities located on private land and on the campus of Washington State University–Tri-Cities, located just south of the PNNL Richland Campus.

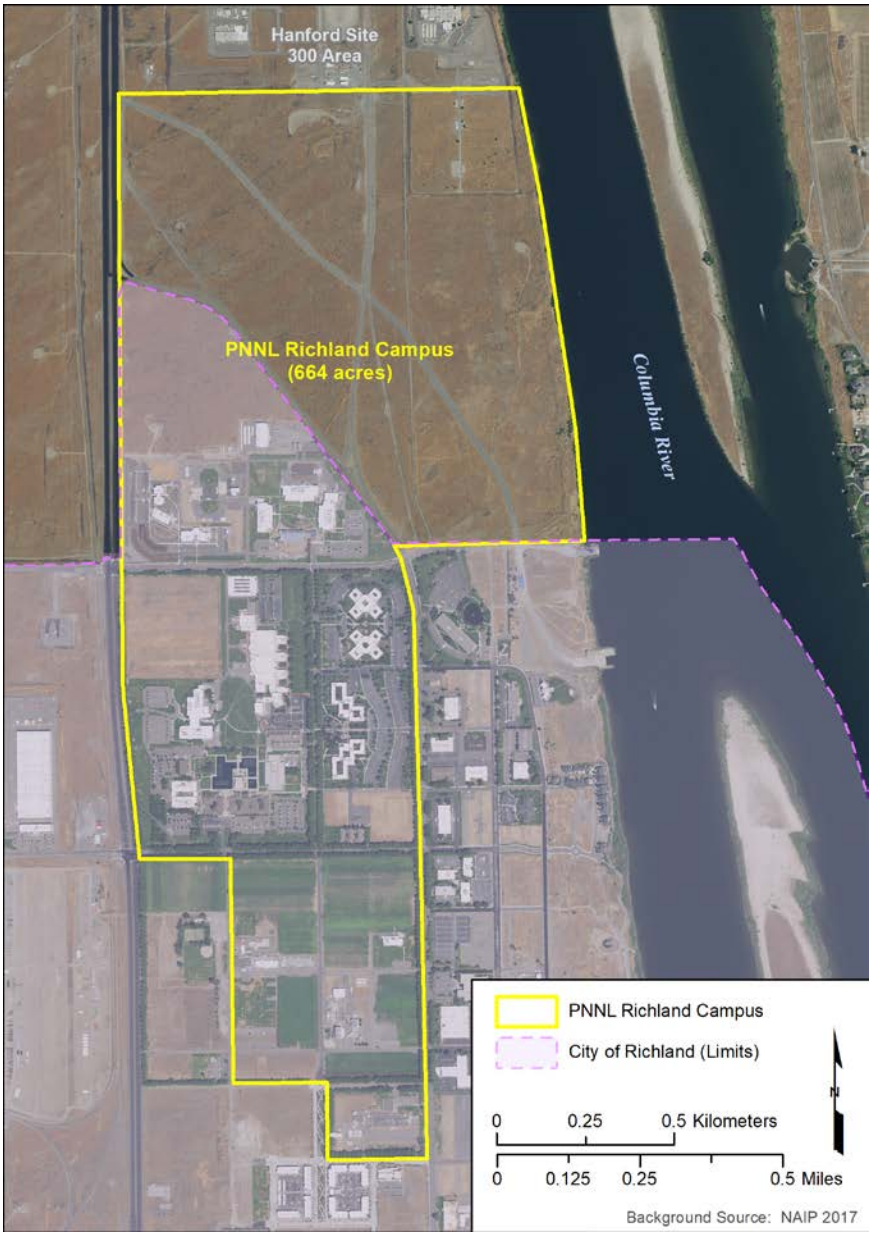

Figure 1.2. PNNL Richland Campus

1.1.2 PNNL Sequim Campus

The PNNL Sequim Campus is located at the mouth of Sequim Bay, near the town of Sequim on the northern portion of the Olympic Peninsula in Clallam County, Washington, 74 km (46 mi) northwest of Seattle, Washington, and 47 km (29 mi) southwest of Victoria, British Columbia. The PNNL Sequim Campus area encompasses 47 ha (117 ac), including the main portion on the west shore of Sequim Bay, most of Travis Spit, which forms the northern boundary of Sequim Bay, and a shoal in the bay called The Middle Ground (Figure 1.3).

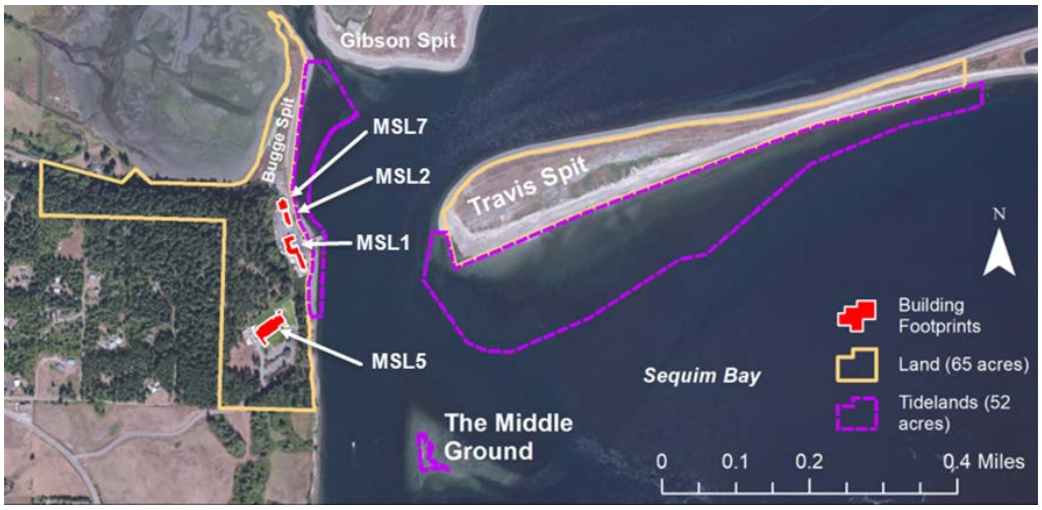

Figure 1.3. PNNL Sequim Campus and Nearby Environment

1.2 Background and Mission

The following sections provide a short synopsis of the history and mission of PNNL.

1.2.1 PNNL Richland Campus

In January 1965, Battelle was awarded the Pacific Northwest Laboratory (PNL) contract to operate the Hanford Site laboratories. In addition, Battelle invested its own funds to construct facilities to conduct non-Hanford Site research to promote R&D in the Pacific Northwest. In the late 1970s, research expanded to include energy, health, environment, and national security ventures. PNL contributed to areas including robotics, environmental monitoring, material coatings, veterinary medicine, and the formation of new plastics.

In 1995, PNL was renamed Pacific Northwest National Laboratory. Over the years, PNNL researchers have developed versatile technologies, and received numerous R&D 100 awards, Federal Laboratory Consortium awards, Innovation awards, and patents for their R&D work and contributions.

PNNL is operated by Battelle for DOE-SC's PNSO, which was established in 2003. PNSO is responsible for overseeing all PNNL activities, and for monitoring the Laboratory's compliance with applicable laws, policies, and DOE Orders. Research efforts on the PNNL Richland Campus include the development and analysis of high-performance materials for energy, construction, and transportation technologies and systems; national security-related radiation detection methodologies, including optics/infrared spectroscopy, electromagnetics/radiography, and acoustics/ultrasonics; systems biology research, which develops comprehensive monitoring programs and performs environmental and biotechnology research; visual analytics technologies; cyber analytics; and critical infrastructure assessment and protection.

1.2.2 PNNL Sequim Campus

In 1967, Battelle acquired acreage on Sequim Bay on the Strait of Juan de Fuca in Washington's Puget Sound near the City of Sequim. As part of Battelle's commitment to developing research facilities to benefit the region and serve the environment, the Marine Research Laboratory near Sequim was constructed to provide laboratories for marine-related work involving biology, physiology, histology, chemistry, physics, and engineering. In 1973, the Marine Research Laboratory opened; it was later renamed Marine Research Operations and is now referred to as the PNNL Sequim Campus.

In October 2012, the PNNL operating contract was revised, giving DOE exclusive use of the PNNL Sequim Campus, consolidating operations under PNSO oversight. Currently, researchers at the PNNL Sequim Campus provide innovative science and technology solutions critical to the nation's energy, environmental, and security future. Capabilities are based on expertise in biotechnology, biogeochemistry, ecosystems science, toxicology, and earth systems modeling. In addition, a scientific dive team supports in-water research and analysis. The research laboratories encompass more than 1,400 m^2 (15,000 ft^2) of area, which includes an innovative seawater treatment system that treats up to 909 L (200 gal) per minute of seawater to remove chemical and biological impurities before returning the water to Sequim Bay. Research efforts include studying algal biofuels, biofouling/biocorrosion, climate change, environmental monitoring; quantifying the transport, fate, and effects of chemicals in marine environments; predicting and analyzing coastal risks/hazards; and developing detection and signatures against threats.

1.3 Demographics

The PNNL Richland Campus is located in Benton County, Washington, south of the Hanford Site, in an area that is primarily flat, semi-arid, and restricted from public access. Residents north and east of the Hanford Site generally live on farms or in farming communities. Residents south, southwest, and west of the PNNL Richland Campus live in the urban communities of Richland, Kennewick, Pasco, and West Richland.

In 2019, an estimated 204,390 people lived in Benton County and 95,222 people lived in adjacent Franklin County, increases of 16.7% and 21.8%, respectively, over 2010 figures (USCB 2020). During 2019, Benton and Franklin Counties accounted for 3.9% of Washington's population. Based on U.S. Census population data, the population within an 80 km (50 mi) radius of the PNNL Richland Campus is estimated to be about 432,000. This population estimate is used to calculate the radiation dose to the general public (see Section 4.2 of this report).

The PNNL Sequim Campus is located in Clallam County, Washington, an area of approximately 4,500 km^2 (1,740 mi^2) on the Olympic Peninsula in the northwestern corner of Washington State. An estimated 77,331 people lived in Clallam County in 2019, an increase of approximately 8.3% over 2010 figures and equivalent to approximately 1% of Washington's population (USCB 2020). The City of Sequim, the nearest population center to the PNNL Sequim Campus, had a population of 7,640 people in 2019 (USCB 2020).

1.4 Environmental Setting – PNNL Richland Campus

The lands composing the PNNL Richland Campus have experienced varying degrees of previous disturbance. Upland areas affected by lower levels of prior disturbance principally support native shrub-steppe vegetation, while more heavily disturbed uplands support more invasive, non-native vegetation. Other areas have undergone complete habitat conversion and contain facilities bordered by landscaping or xeriscaping. The Columbia River riparian zone bordering the PNNL Richland Campus is largely undisturbed and supports both native and non-native vegetation.

The PNNL Richland Campus is located in the Columbia Basin, an intermontane region between the Cascade Range and the Rocky Mountains. The campus lies above a gentle syncline formed by the intersection of the Yakima Fold Belt, a series of anticlinal ridges and synclinal valleys, and the gently west-dipping Palouse Slope, which contains few faults and low-amplitude, long wavelength folds. The uppermost basalt flow is part of the Ice Harbor Member of the Saddle Mountains Basalt Formation, and the relatively thin overlying sediment layers consist of Ringold Formation and Hanford formation sediments. These sediment layers are predominantly coarse sandy alluvial deposits mantled by windblown sand. A generalized suprabasalt stratigraphic column showing what underlies the PNNL Richland Campus is shown in Figure 1.4. The stratigraphic column for the upper Ringold Formation and the Hanford formation is based on information obtained from the drilling of 11 boreholes within the footprint of the Biological Sciences Facility/Computational Sciences Facility (BSF/CSF) on the PNNL Richland Campus (Freedman et al. 2010).

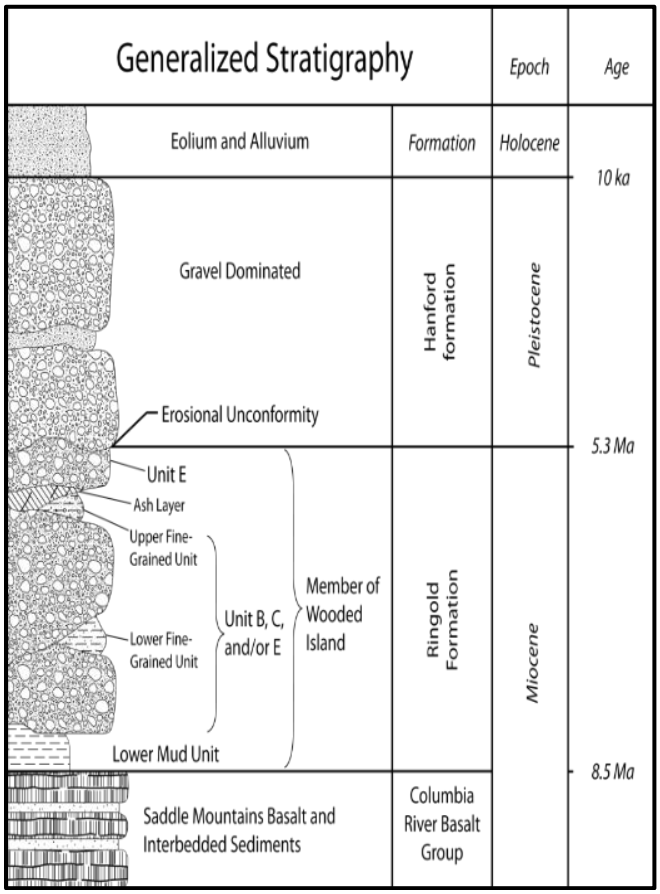

Figure 1.4. Generalized Stratigraphic Column Depicting the Stratigraphy Underlying the PNNL Richland Campus (modified from Reidel et al. 1992; Thorne et al. 1993; Lindsey 1995; Williams et al. 2000; DOE-RL 2002; and Williams et al. 2007)

The Hanford formation, a highly permeable mixture of sand and gravel deposited by Ice Age floods during the late Pleistocene period, comprises unconsolidated sediments that range in size from boulder-sized gravel to sand, silt, and clay. Late Miocene- to Pliocene-age sediments of the Ringold Formation underlie the Hanford formation. The Ringold Formation displays lower hydraulic conductivity and is texturally and structurally distinct from the overlying Hanford formation. Ringold Formation sediments contain sands, gravels, and muds that are typically more consolidated and less permeable than those in the Hanford formation. The basalt underlying the Ringold Formation has a very low vertical hydraulic conductivity and forms an aquitard between the base of the unconfined aquifer and the confined aquifers within the basalt formations.

The general direction of groundwater flow under the PNNL Richland Campus is toward the east-northeast toward the Columbia River (Figure 1.5). The unconfined aquifer beneath the PNNL Richland Campus is predominantly in the Ringold Formation; however, depending on the water table elevation, the aquifer may inundate portions of the Hanford formation. The vadose zone below the PNNL Richland Campus, is about 15 m (49 ft) thick; its thickness generally decreases with proximity to the Columbia River, as the ground surface slopes toward the river. This zone consists of unsaturated sediments between the ground surface and the water table, predominantly within the Hanford formation (Newcomer 2007).

While large Columbia River floods have occurred in the past, the likelihood of recurrence of large-scale flooding has been reduced by the construction of dams upstream on the Columbia River. The largest flood on record for the Columbia River occurred in 1894 and had an estimated peak discharge of 21,000 m^3/s (742,000 ft^3/s) at the Hanford Site; the largest recent flood took place in 1948 and had an estimated peak discharge of 20,000 m^3/s (700,000 ft^3/s) (Duncan 2007). Exceptionally high runoff during the spring of 1996 resulted in a maximum discharge of nearly 11,750 m^3/s (415,000 ft^3/s) (Duncan 2007). The floodplain associated with the 1894 flood has been modeled based on topographic cross sections of the river; no portion of the PNNL Richland Campus was within this area.

The probable maximum flood has an unspecified, but very large return period (generally greater than 500 years). Based on modeling conducted in 1976, the Hanford Site would be unaffected by the probable maximum flood on the Columbia River, a discharge of about 40,000 m^3/s (1.4 million ft^3/s) (Duncan 2007). A flood of this magnitude would result in a water-surface elevation of 119 m (390 ft) at the Columbia Generating Station, located about 12 km (7.5 mi) north of the PNNL Richland Campus (Energy Northwest 2011). The standard project flood, a flood that would occur during the combination of the harshest meteorological and hydrological conditions, has an unspecified return period, usually greater than several hundred years (Linsley et al. 1992). The regulated standard project flood used by the U.S. Army Corps of Engineers for the Columbia Generating Station is 16,100 m^3/s (570,000 ft^3/s) (Energy Northwest 2011). The 100-year regulated flood discharge for the Columbia River along the northern boundary of the Hanford Site is estimated to be 12,500 m^3/s (440,000 ft^3/s) (Duncan 2007); corresponding discharge at the PNNL Richland Campus would be somewhat larger. The Federal Emergency Management Agency (FEMA) floodplain maps extend only to the southern boundary of the PNNL Richland Campus (FEMA 1984). However, FEMA maps suggest that the PNNL Richland Campus, with a ground-surface elevation of about 122 m (400 ft), would be unaffected by a 100-year flood.

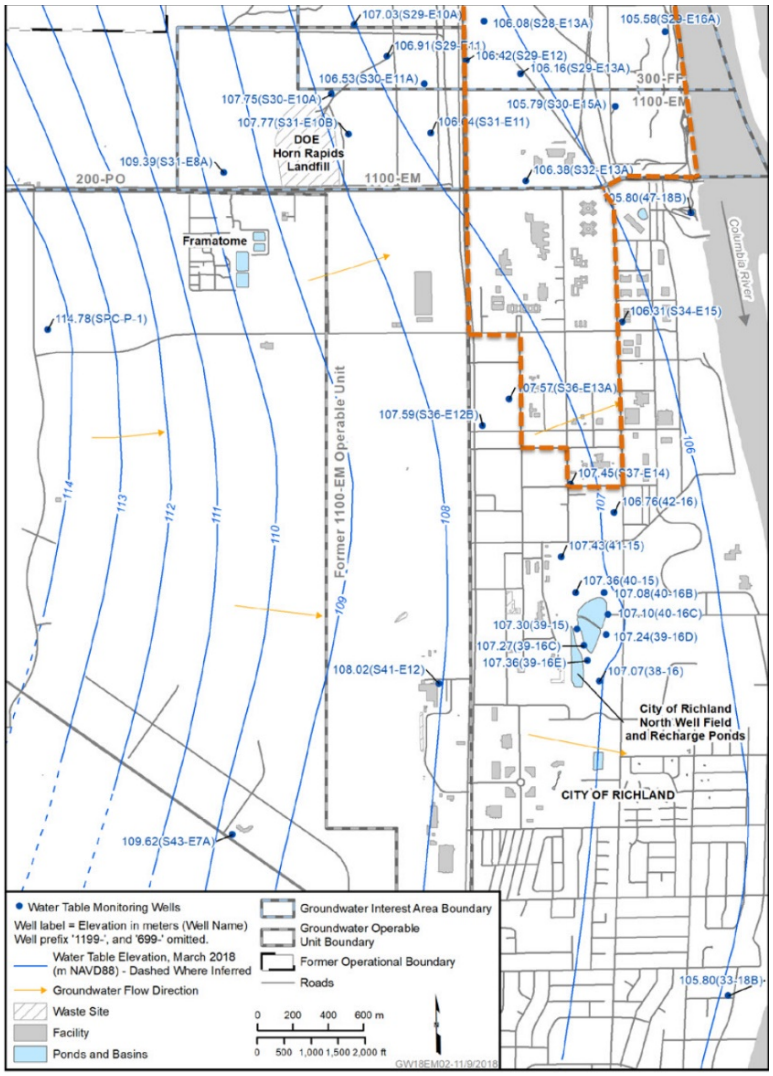

Figure 1.5. Water Table Elevations (m) in March 2018 (modified from DOE-RL 2019a). Groundwater flow direction is normal to the water table contour lines. The approximate PNNL Richland Campus is outlined in orange (northern portion not shown).

The seismicity of the PNNL Richland Campus vicinity is relatively low compared to other regions of the Pacific Northwest, as determined by the rate and magnitude of historical events. The largest known earthquake in the region occurred in 1936 near Milton-Freewater, Oregon, approximately 103 km (64 mi) from the PNNL Richland Campus (Duncan 2007). This earthquake had a Richter magnitude of 5.75 and a maximum Modified Mercalli Intensity (MMI) of VII (very strong shaking). Susceptibility to liquefaction is rated as very low or low for the entire PNNL Richland Campus (WDNR 2020). The U.S. Geological Survey has identified ash as the only volcanic hazard in the vicinity of the PNNL Richland Campus (WDNR 2020).

The rain-shadow effect of the Cascade Range, west of Yakima, influences the climate at the PNNL Richland Campus. North of the PNNL Richland Campus, the Rocky Mountains and ranges in southern British Columbia protect the region from severe, cold polar air masses moving southward across Canada and the winter storms associated with them. Daily meteorological data are collected at an automated weather station maintained by AgWeatherNet on the campus of Washington State University–Tri-Cities (WSU 2020), located just south of the PNNL Richland Campus. Normal monthly average temperatures

range from a low of –2.9°C (26.7°F) in February to a high of 24.7°C (76.4°F) in August. The maximum high temperature in 2019 was 39.8°C (103.6°F); the minimum was -15.5°C (4.1°F). The average annual temperature near the PNNL Richland Campus in 2019 was 11.8°C (53.2°F), 0.8°C (1.4°F) above the 19-year average (2001–2019) of 12.6°C (54.6°F). The annual relative humidity near the PNNL Richland Campus was 63.1% in 2019; humidity was highest during winter, when it averaged approximately 82%, and lowest during summer, when it averaged 44.7%. Precipitation for 2019 was 12.9 cm (5.09 in.), 7.2% below average (13.9 cm [5.47 in.]). According to Hanford Site meteorological records, March 2019 was a historic cold and snowy month. March 21 marked the end of a 45-day streak (February 4–March 20), where the daily mean temperature was below normal. The 2018–2019 winter was the fourth snowiest on record, 81.5 cm (32.1 in), whereas normal rates are 38.6 cm (15.2 in.) (DOE 2020).

Regional winds are primarily from the south and southwest at the PNNL Richland Campus. Monthly average wind speeds were lowest during the fall and winter months, averaging about 1.7 m/s (3.8 mph) in 2019, and highest during spring, averaging about 2 m/s (5 mph). The maximum wind gust recorded during 2019 was 16.5 m/s (36.8 mph); the maximum for the period of record (2001–2019) was 27.7 m/s (62 mph) (WSU 2020).

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 at the Hanford Site during summer (Poston et al. 2011). During winter, moderate to extremely stable stratification exists (approximately 66% of the time).

Fog has been recorded during every month of the year at the Hanford Meteorology Station; however, fog occurs mostly from November through February. Additional visibility reductions can occur in the form of windblown dust; the region has averaged four dust storms per year for the entire period of record (1945–2019); however, no dust storms were reported in 2019 (DOE 2020).

1.4.1 Ecology

The PNNL Richland Campus is located in the lowest and most arid portion of the Columbia Plateau Ecoregion (LandScope Washington 2020; EPA 2013). The portion of the PNNL Richland Campus north of Horn Rapids Road (Figure 1.6) was previously part of the Hanford Site, and has been protected from agricultural use and development since 1943. It is still mostly dominated by native shrub-steppe vegetation, and thus retains much of its native biodiversity and community structure (Figure 1.6). These areas are dominated by climax shrubs such as big sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*), with a noticeable component of native perennial bunchgrasses within an introduced annual grass understory. The portion of the PNNL Richland Campus south of Horn Rapids Road has been developed to various extents and consists of a mosaic of maintained landscapes, abandoned agricultural fields, and previously disturbed, early successional habitats dominated by introduced annual grasses or subclimax shrubs, such as common rabbitbrush (*Ericameria nauseosa*) (Figure 1.6). The more mature and undisturbed shrub-steppe communities generally support greater plant species diversity. Approximately 161 plant species, 38 bird species, and 9 other wildlife species have been observed in upland portions of the PNNL Richland Campus (Appendix A).

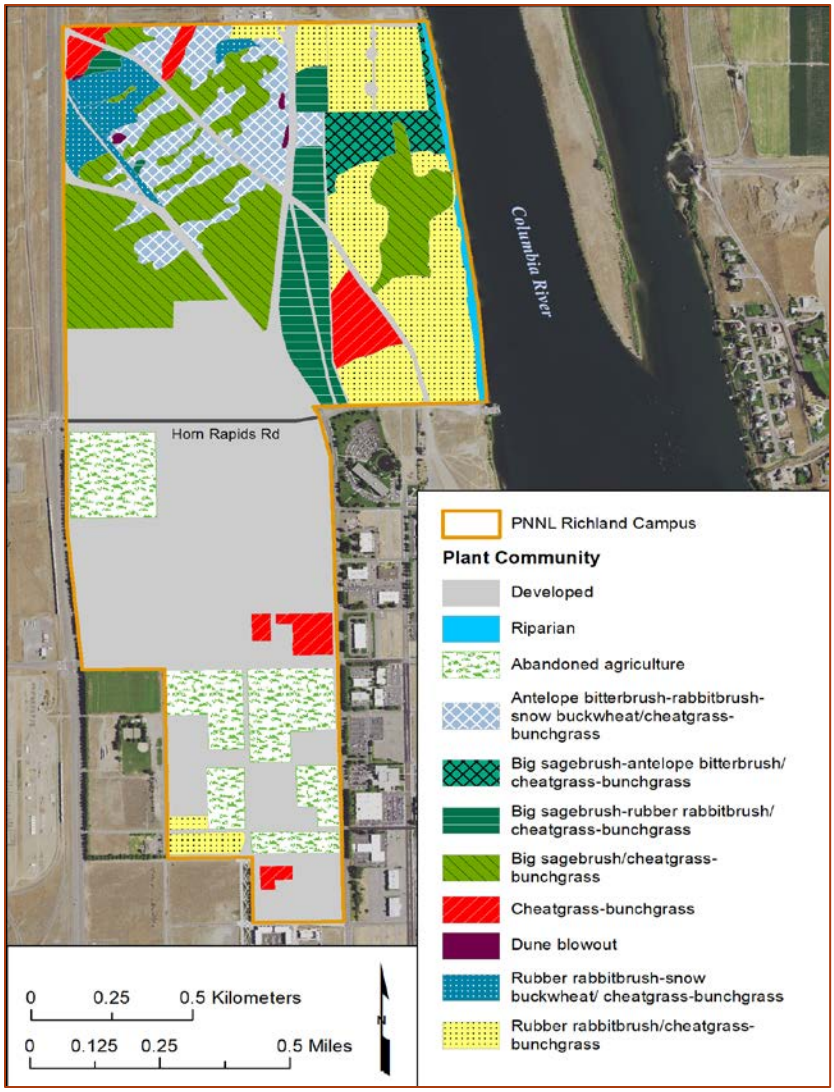

Figure 1.6. Habitat Polygons on the PNNL Richland Campus

A relatively undisturbed riparian community exists along the Columbia River shoreline north of Horn Rapids Road (Figure 1.6). The riparian community is limited to a narrow band of multilayered trees, including Siberian elm (*Ulmus pumila*), white mulberry (*Morus alba*), and poplars (*Populus* spp.); shrubs such as coyote willow (*Salix exigua*) and rose (*Rosa woodsii*); and herbaceous and grass species. Species diversity is high in the riparian zone given its relatively small area. Approximately 87 plant species, 29 bird species, and 5 other wildlife species have been observed in the riparian zone of the PNNL Richland Campus (Appendix A).

Priority habitats are those habitat types or elements that have unique or significant value to a diverse assemblage of species. Both the shrub-steppe and riparian habitats are listed by the Washington Department of Fish and Wildlife (WDFW) as priority habitats for the state and are considered to be priorities for management and conservation (WDFW 2020a).

The Hanford Reach of the Columbia River is adjacent to the eastern edge of the PNNL Richland Campus. This river supports a diverse fish and invertebrate community including three species listed under the *Endangered Species Act* (ESA) (Table 1.1). The Columbia River is designated as critical habitat for these species under the ESA (70 FR 52630, 75 FR 63898).

Federal and state-listed wildlife and plant species known to occur or that potentially occur on or near the PNNL Richland Campus were identified using sources from the WDFW (2020b) and Washington Natural Heritage Program (WNHP 2019), and are listed in Table 1.1. Of these, the American white pelican (*Pelecanus erythrorhynchos*), sagebrush sparrow (*Artemisiospiza nevadensis*), loggerhead shrike (*Lanius ludovicianus*), and black-tailed jackrabbit (*Lepus californicus*) have been observed on the upland portions of the PNNL Richland Campus (see Appendix A).

Table 1.1. Wildlife, Fish, and Plant Species of Conservation Concern Known to Occur or That Potentially Occur near the PNNL Richland Campus

Common Name	Genus and Species	Federal Status[(a)]	State Status[(b)]
Wildlife			
American white pelican	*Pelecanus erythrorhynchos*		Threatened
Black-tailed jackrabbit	*Lepus californicus*		Candidate
Burrowing owl	*Athene cunicularia*		Candidate
Loggerhead shrike	*Lanius ludovicianus*		Candidate
Northern sagebrush lizard	*Sceloporus graciosus*		Candidate
Sagebrush sparrow	*Artemisiospiza nevadensis*		Candidate
Striped whipsnake	*Masticophis taeniatus*		Candidate
Townsend ground squirrel	*Urocitellus townsendii*		Candidate
Fish			
Bull trout	*Salvelinus confluentus*	Threatened	Candidate
Upper Columbia River spring Chinook salmon	*Oncorhynchus tshawytscha*	Endangered	Candidate
Upper Columbia River steelhead	*Oncorhynchus mykiss*	Threatened	Candidate
Plants			
Awned halfchaff sedge	*Lipocarpha aristulata*		Threatened
Beaked spike-rush	*Eleocharis rostellata*		Sensitive
Canadian St. Johnswort	*Hypericum majus*		Sensitive
Columbian yellowcress	*Rorippa columbiae*		Threatened
Grand redstem	*Ammania robusta*		Threatened
Great Basin gilia	*Aliciella leptomeria*		Threatened
Loeflingia	*Loeflingia squarrosa*		Threatened
Lowland toothcup	*Rotala ramosior*		Sensitive
Rosy pussypaws	*Calyptridium roseum*		Threatened
Suksdorf monkeyflower	*Erythranthe suksdorfii*		Sensitive

Sources: WDFW (2020b) and WNHP (2019)

(a) Federally threatened species are likely to become an endangered species within the foreseeable future throughout all or a significant portion of their range. Federally endangered species are in danger of extinction within the foreseeable future throughout all or a significant portion of their range (USFWS 2019).

(b) State candidate animal species are those fish and wildlife species that the Washington Department of Fish and Wildlife will review for possible listing as endangered, threatened, or sensitive (WDFW 2020b). State threatened animal species are native to the state of Washington and are likely to become endangered within the foreseeable future throughout a significant portion of their range within the state without cooperative management or removal of threats (WDFW 2020b). State threatened plant species are those that are likely to become endangered within the near future in Washington if the factors contributing to their population decline or habitat loss continue. State sensitive plant species are those that are vulnerable or declining and could become endangered or threatened in the state without active management or removal of threats (WNHP 2019).

1.5 Environmental Setting – PNNL Sequim Campus Vicinity

The PNNL Sequim Campus is located on Sequim Bay in Puget Sound and consists of forests, sandy beach shoreline, a bluff line, and developed areas with roads and structures, as well as The Middle Ground, a sandy shoal that is submerged except during low tide, and Travis Spit (Figure 1.3). PNNL Sequim Campus facilities include buildings on the shoreline, as well as structures on an approximately 27 m (89 ft) high bluff overlooking the ocean.

In the vicinity below the PNNL Sequim Campus are Quaternary-age unconsolidated glacial and interglacial deposits to depths greater than 366 m (1200 ft) (Thomas et al. 1999). The upland portion of the PNNL Sequim Campus has surficial deposits of glacial till 14,500 to 17,500 years old, designated as unstratified, poorly sorted, clayey, sandy silt up to 45.7 m (150 ft) thick, and averaging 9.1 m (30 ft) thick throughout the greater region (Schasse and Logan 1998). Beneath the surficial deposits are undifferentiated deposits from older glacial events and interglacial periods. Water-bearing units of coarse-grained sands and gravels are found in the unconsolidated deposits throughout the region, including in the vicinity of the PNNL Sequim Campus site (Thomas et al. 1999). Tertiary-age sedimentary rock (primarily siltstone, sandstone, and mudstone) and volcanic rock (primarily basalt and basalt breccia) are beneath the unconsolidated deposits (Schasse and Logan 1998).

Earthquakes have been recorded in the vicinity of the PNNL Sequim Campus, and seismically active faults are located within 8 km (5 mi), with the nearest fault trace about 3.2 km (2 mi) to the southwest (WDNR 2020). The region is subject to significant seismic hazards, as evidenced by the estimated peak ground acceleration of 3.92 to 7.85 m/s^2 (0.4 to 0.8 *g*) with a two-percent probability of exceedance in 50 years (Peterson et al. 2014). Washington State has evaluated several earthquake scenarios, including modeling a magnitude 9.0 earthquake on the Cascadia Subduction Zone. An earthquake of this magnitude would result in a MMI of VII (very strong shaking) in the PNNL Sequim Campus region (WDNR 2013). Susceptibility to liquefaction is rated as very low or low for both the uplands and shoreline areas of the PNNL Sequim Campus, with the exception of Travis Spit and Bugge Spit north of the shoreline parking area, which are rated as moderate to high for liquefaction susceptibility (WDNR 2020). The shoreline area of the PNNL Sequim Campus and Travis Spit are subject to tsunami hazard (inundation) for the Cascadia Subduction Zone scenario (WDNR 2020). Although the glacial deposits at the PNNL Sequim Campus support the near-vertical slopes along the bluff at the site, a number of landslides have been mapped in the region (WDNR 2020), suggesting a potential landslide hazard at the site. No volcanic hazard has been identified in the PNNL Sequim Campus region (WDNR 2020).

Daily meteorological data are collected at an automated weather station near Sequim, Washington, maintained by AgWeatherNet, an affiliate of Washington State University (WSU 2020). The region around the PNNL Sequim Campus is positioned in the rain shadow of the Olympic Mountains, so it generally receives less than 38 cm (15 in.) of rainfall annually despite its

coastal location; average rainfall in 2019 was 37.3 cm (14.67 in.). The region experiences cool, wet winters and warm, dry summers; average monthly temperatures in 2019 ranged from 1.2°C to 17.4°C (34.2°F to 63.4°F). For the period of record, January 2009 to January 2020, average monthly temperatures ranged from 3.9°C to 16.5°C (39.1°F to 61.7°F). The annual average temperature in 2019 was 9.89°C (49.8°F); maximum temperature was 28.8°C (83.9°F) and minimum was -15.1°C (4.9°F). The lowest temperature for the period of record was -17.9°C (-0.3°F); the highest was 33.1°C (91.6°F). The annual relative humidity at the PNNL Sequim Campus was 82.0% in 2019; humidity was highest during fall, when it averaged approximately 85.3%, and lowest during spring, when it averaged 77.5%. Regional winds are primarily from the northwest. Wind speed averaged 1.2 m/s (2.7 mph) in 2019; peak wind speed, 14.8 m/s (33.2 mph), occurred in December.

1.5.1 Ecology

The PNNL Sequim Campus (Figure 1.3) lies in the Olympic Rain Shadow subdivision of the Puget Lowland Ecoregion, a north-south depression between the Olympic Peninsula and western slopes of the Cascade Mountains that flank the coastline of Puget Sound (LandScope Washington 2020; EPA 2013). The PNNL Sequim Campus is located within one of the driest areas in the region, owing to the rain-shadow effects of the Olympic Mountains. Timber harvesting and cultivation have removed and fragmented the original coniferous forest and prairie-oak woodland (WWF 2020). Today, the region consists mostly of second-growth coniferous forest and agricultural fields; little of the original forest habitat remains (EPA 2013; LandScope Washington 2020).

The PNNL Sequim Campus includes 26 ha (65 ac) of land and 21 ha (52 ac) of tidelands (Figure 1.3). Tideland habitat includes shoals, intertidal wetlands, and subtidal wetlands. The Middle Ground (Figure 1.3 and Figure 1.7) is a sandy shoal, which is submerged except during lower tides, and does not support vegetation (DOE-PNSO 2020). Estuarine intertidal wetlands occur in a narrow band that circumscribes the shoreline of Sequim Bay, while adjacent estuarine subtidal wetlands occur in deeper water and make up the interior portion of Sequim Bay (Figure 1.7). Seagrass meadows consisting of eelgrass (*Zostera* spp.) occur in intertidal wetlands (Figure 1.7) (DOE-PNSO 2020), and serve as forage for birds, snails, and crab species. Some fish species use eelgrass for spawning, while other anadromous and forage fish use eelgrass beds for cover or to find food. Common aquatic species include fish species such as sole (*Paraphrys vetulus*), sculpin (*Artedius fenestralis*), Pacific tomcod (*Mircogadus proximus*), striped perch (*Embiotca lateralis*), Pacific herring (*Clupea pallasii*), sand lance (*Ammodytes hexapterus*), and spiny dogfish (*Squalus acanthias*) (DOE-PNSO 2020).

Land habitat includes spits, beaches, and uplands. Travis Spit and Bugge Spit (Figure 1.3 and Figure 1.7) are located slightly above sea level and consist of sediments deposited during higher tides. They support mostly herbaceous vegetation consisting of forbs, including silver bursage (*Ambrosia chamissonis*), common yarrow (*Achillea millefolium*), Puget Sound gumweed (*Grindelia integrifolia*), bare-stemmed biscuitroot (*Lomatium nudicaule*), low glasswort (*Salicornia depressa*), and yellow sand verbena (*Abronia latifolia*); and grasses such as blue wildrye (*Elymus glaucus*) (DOE-PNSO 2020). A sandy beach lies at the base of an approximately 7.6 m (25 ft) high feeder bluff that overlooks Sequim Bay (Figure 1.7). The beach is maintained by longshore currents that erode the bluff. Beach vegetation is sparse, located mostly above tidal influence at the base and on the face of the bluff, and includes some of the tree and shrub species common in the uplands noted below (DOE-PNSO 2020).

The uplands begin adjacent to and just above the spit and beach habitats, extending west of the facilities, and rising to approximately 45.7 m (150 ft) above sea level on the ridge above Washington Harbor Road (Figure 1.7) (DOE-PNSO 2020). The uplands support mostly mixed coniferous forest habitat (Figure 1.7), most of which is mature, naturally regenerated second growth, estimated to be 100–160 years old (DOE-PNSO 2020). The dominant and subdominant canopy species are Douglas fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*), respectively. Subcanopy tree species include red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), madrone (*Arbutus menziesii*), grand fir (*Abies grandis*), Indian plum (*Oemleria cerasiformis*), and Rocky Mountain maple (*Acer glabrum*). Characteristic understory flora includes common snowberry (*Symphoricarpus albus*), Saskatoon serviceberry (*Amelanchier alnifolia*), ocean spray (*Holodiscus discolor*), vine maple (*Acer circinatum*), salal (*Gaultheria shallon*), Oregon-grape (*Berberis* spp.), western swordfern (*Polystichum munitum*), rose (*Rosa* spp.), blackcap (*Rubus leucodermis*), and redflower currant (*Ribes sanguineum*) (DOE-PNSO 2020). Approximately 148 plant species, 102 bird species, and 7 other wildlife species have been observed on the PNNL Sequim Campus (Appendix B).

The relatively undisturbed nearshore areas of Puget Sound, including the Strait of Juan de Fuca, are listed by the WDFW as priority habitat for the state (WDFW 2020a) and, therefore, are considered to be a priority for management and conservation (Clallam County 2017). Priority habitat zones include shore, intertidal, and subtidal, which include the tidelands, spits, beaches, and feeder bluffs, described previously (Clallam County 2017; WDFW 2020a).

The tideland and land habitats provide potential habitat for several federally listed threatened, endangered, and/or candidate species (Table 1.2) (DOE-PNSO 2020). Two avian species of conservation concern are known to occur or potentially occur near PNNL Sequim Campus facilities, as well as eight aquatic and three invertebrate species of conservation concern (Table 1.2). No plant species of state or federal concern are currently known to occur near the PNNL Sequim Campus (Table 1.2). Sequim Bay is designated critical habitat for Puget Sound bocaccio (*Sebastes paucispinis*) and Puget Sound yelloweye (*Sebastes ruberrimus*) (79 FR 68041), bull trout (*Salvelinus confluentus*) (75 FR 63898), and Hood Canal summer-run chum salmon (*Oncorhynchus keta*) (70 FR 52630) (Table 1.2).

Several marine mammals, including harbor seal (*Phoca vitulina*), California sea lion (*Zalophus californianus*), Dall's porpoise (*Phocoenoides dalli*), and harbor porpoise (*Phocoena phocoena*) inhabit Sequim Bay (DOE-PNSO 2020). Harbor seals are considered a priority species by the state due to the species' propensity to aggregate. Aggregation areas, known as haulouts, are considered priority areas by the state (WDFW 2020a). Kiapot Point on the southwest tip of Travis Spit, located across the mouth of Sequim Bay from the PNNL Sequim Campus (Figure 1.7), is a haulout area for harbor seals (DOE-PNSO 2020). Although rare, killer whales (*Orcinus orca*) have been observed in Sequim Bay (DOE-PNSO 2020).

Table 1.2. Animal Species of Conservation Concern Known to Occur or that Potentially Occur at and in the Vicinity of the PNNL Sequim Campus

Common Name	Genus and Species	Federal Status(a)	State Status(b)
Wildlife			
Brandt's cormorant	*Phalacrocorax penicillatus*		Candidate
marbled murrelet	*Brachyramphus marmoratus*	Endangered	Threatened
Fish			
bull trout	*Salvelinus confluentus*	Threatened	Candidate
Hood Canal summer-run chum salmon	*Oncorhynchus keta*	Threatened	Candidate
North American green sturgeon	*Acipenser medirostris*	Threatened	
Pacific eulachon	*Thaleichthys pacificus*	Threatened	Candidate
Puget Sound bocaccio	*Sebastes paucispinis*	Endangered	Candidate
Puget Sound Chinook salmon	*Oncorhynchus tshawytscha*	Threatened	Candidate
Puget Sound steelhead	*Oncorhynchus mykiss*	Threatened	
Puget Sound yelloweye rockfish	*Sebastes ruberrimus*	Threatened	Candidate
Invertebrates			
island marble butterfly	*Euchloe ausonides insulanus*	Candidate	Candidate
sand-verbena moth	*Copablepharon fuscum*		Candidate
Taylor's checkerspot butterfly	*Euphydryas editha taylori*	Endangered	Endangered

Source: WDFW (2020b)

(a) Federally threatened species are likely to become an endangered species within the foreseeable future throughout all or a significant portion of their range. Federally endangered species are in danger of extinction within the foreseeable future throughout all or a significant portion of their range (USFWS 2019). Federal candidate species are those for which the U.S. Fish and Wildlife Service has sufficient information about biological vulnerability and threat(s) to support issuance of a proposed rule to list the species, but issuance of the proposed rule is precluded (61 FR 7596).

(b) State candidate animal species are those fish and wildlife species that the Washington Department of Fish and Wildlife will review for possible listing as endangered, threatened, or sensitive (WDFW 2020b). State threatened species are native to the state of Washington and are likely to become endangered within the foreseeable future throughout a significant portion of their range within the state without cooperative management or removal of threats (WDFW 2020b). State endangered species are native to the state of Washington and are seriously threatened with extinction throughout all or a significant portion of their range within the state (WDFW 2020b).

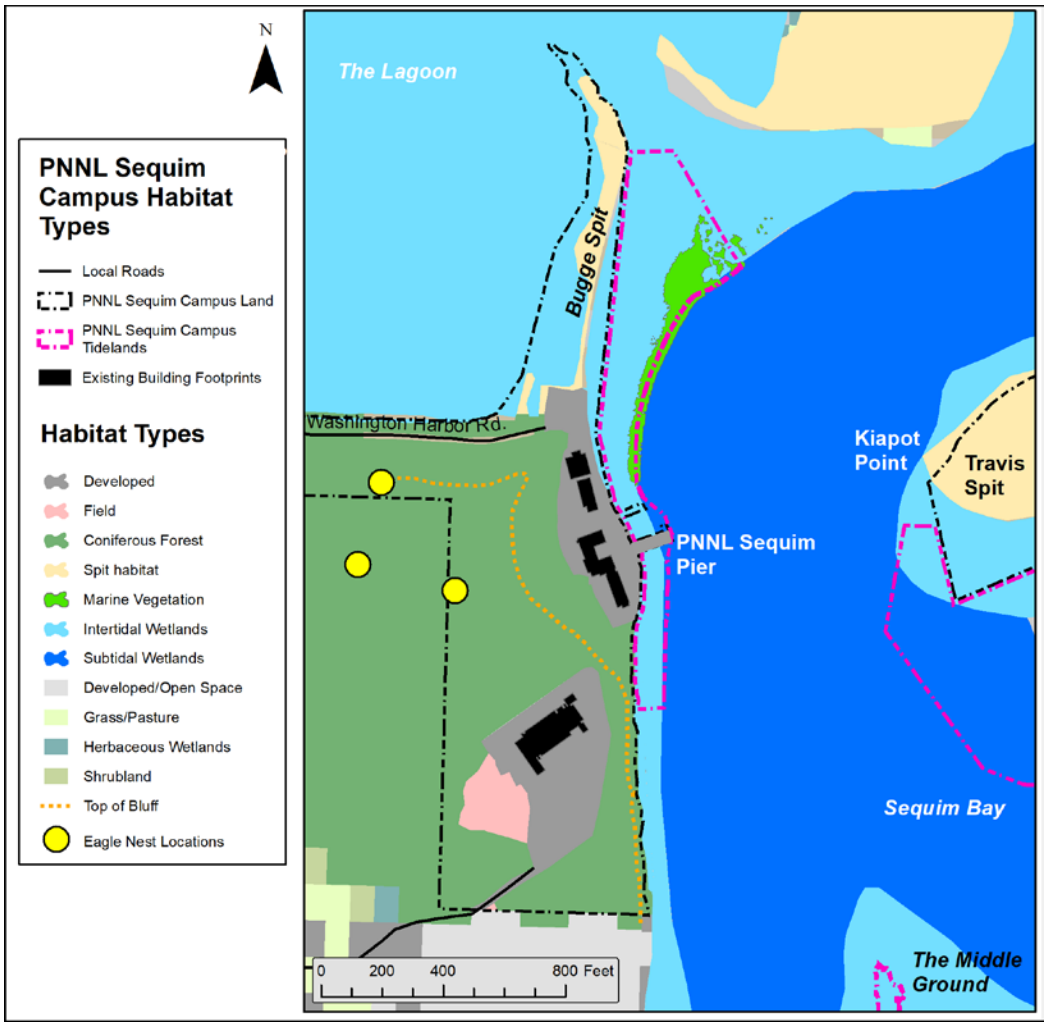

Figure 1.7. Habitat Types at the PNNL Sequim Campus

1.6 Cultural Setting – PNNL Richland Campus

The archaeological record of the Mid-Columbia Basin bears evidence of more than 10,000 years of human occupation. The history of the Mid-Columbia Basin includes four distinct periods of human occupation: the Precontact period, the Ethnographic period, the Euro-American period, and the Manhattan Project period.

1.6.1 Precontact Period

Archaeological investigations conducted throughout the Columbia Plateau provide a definitive cultural chronology dating back to the end of the Pleistocene (about 11,000 years before present [BP]). The protected area of the Hanford Site has contributed to the extensive archaeological deposits, documenting thousands of years of Precontact human activity throughout the Columbia Plateau. The archaeological record shows a progression from the earliest inhabitants who were mobile, lived in caves or rock shelters, and subsisted primarily by hunting large mammals, to the development of dwellings approximately 4,500 years ago when the inhabitants subsisted on a more diverse diet, to the eventual creation of pit houses and long-house villages and a subsistence centered around riverine resources, especially salmon.

1.6.2 Ethnographic Period

The ethnohistoric/ethnographic period began in the late 1700s to the early 1800s at the time of initial American Indian contact with non-Native American settlers in the area and extends to the present day. Ethnohistorically, the Walla Walla, Palouse, Nez Perce, Umatilla, Wanapum, and Yakama used land now encompassed by the Hanford Site. The Wanapum band reportedly occupied village sites along the Columbia River from as far north as the Wenatchee River to its confluence with the Snake River. Fishing sites at Priest Rapids and in the vicinity were used by other surrounding groups, including the Yakama, Wallula, Nez Perce, Palus, Columbia, and Spokane (Galm et al. 1981). Residents relied on a pattern of seasonal rounds that included semi-permanent residences in villages along major waterways during the winter months. Subsistence focused on seasonally available plant and animal resources. Documented archaeological sites in the vicinity of the PNNL Richland Campus include fishing and village sites along the shoreline, stone quarrying sites, temporary camps, and plant processing locations (Schroeder and Landreau 2012; Hodges et al. 2003; Smith 1910).

1.6.3 Euro-American Period

The Lewis and Clark expedition of 1805 began the Euro-American exploration and settlement of the region. Explorers sought trade items from Native Americans and trade routes were established. Gold miners, livestock producers, and homesteaders soon followed. By the 1860s, the discovery of gold north and east of the Mid-Columbia region resulted in an influx of miners traveling through the area. Ringold, White Bluffs, and Wahluke were stops along the transportation routes used by miners and the supporting industry. The mining industry created a demand for beef, and the Mid-Columbia Basin was ideal for livestock production. An increase in Euro-American settlement began in eastern Washington in the late 1800s, first by livestock producers then by homesteaders who settled the area and plowed the rangeland to plant crops beginning in the 1880s.

As farming increased, water resources other than rainfall were needed to produce higher crop yields. Many irrigation projects began; most were privately and insufficiently funded. Land speculators began constructing large-scale irrigation canals to supply water to thousands of acres in the White Bluffs, Hanford, Fruitvale, Vernita, and Richland areas (Sharpe 1999). However, poor economic conditions associated with the Great Depression of the 1930s created economic hardship for local residents. The hardship continued until the government took over the area under the *First War Powers Act of 1941* (50 U.S.C. App. 601 *et seq.*) (Marceau et al. 2003).

1.6.4 Manhattan Project and Cold War Era

In 1942, the area around Hanford, Washington, was selected by the federal government as one of the three principal Manhattan Project sites. Occupying portions of Grant, Franklin, and Benton Counties, the Hanford Site was created to support the United States' plutonium-production effort during World War II. Plutonium production, chemical separation, and R&D focused on process improvements and were the primary activities during the Manhattan Project, as well as the subsequent Cold War Era.

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Reactions

Tri-City Growth Seen

Tri-City Herald

The Hanford Site underwent a major expansion at the beginning of the cold war in the late 1940s. The town of North Richland was developed as a construction camp that eventually housed more than 13,000 people in barracks and more than 2,000 trailers. The town had a school, hospital, police and fire service, and entertainment facilities such as a tavern, movie theater, and stores. The town waned in the early 1950s as Hanford construction slowed, but the area continued to be used as Camp Hanford, headquarters for an Army battalion that first operated anti-aircraft batteries and eventually Nike missile bases around the Hanford Site. Camp Hanford closed in 1961 after the Nike missiles were decommissioned. In 1965, the Atomic Energy Commission tried to help diversify the Tri-Cities economy by restructuring the Hanford contracts and requiring new contractors to invest in private ventures and facilities. Battelle Memorial Institute was awarded the research contract to run the Pacific Northwest Laboratory (eventually PNNL) in 1966. Battelle purchased 93 ha (230 ac) of former North Richland/Camp Hanford land, and hired the firm of Naramore, Bain, Brady, and Johanson to design the first four buildings of the PNNL Richland Campus. These buildings, along with others that were completed by the early 1970s, are now each individually eligible for listing on the National Register of Historic Places and constitute a Historic District.

1.7 Cultural Setting – PNNL Sequim Campus

The archaeological record suggests the presence of northwest coastal populations as early as 10,000 BP (Ackerman et al. 1985). Sites dating to the earliest occupation of the region often contain assemblages of sea mammal bones, as well as evidence of heavy reliance on salmon, herring, and shellfish. The richness of these resources may have supported semi-sedentary winter occupation of coastal sites as early as 7,000 BP (Cannon 1991).

As the Holocene era progressed and the climate of the region warmed, salmon and the human populations that subsisted on them could move into upland areas and places away from the coasts that were previously inaccessible. As the Canadian Cordilleran glacier retreated, Puget Sound was created, and new interior coastal territories opened up (Schalk 1988). By about 5,000 BP, consumption of shellfish began to play a dominant role in regional subsistence patterns. The abundance of shellfish, salmon, and other wild resources in the region formed the basis of an economic and subsistence pattern that was exceptionally stable. This stability allowed for the development of complex hunter/fisher/gatherer societies that persisted into the late 18th century (Fagan 2001), as well as a homogeneous regional social system facilitated by widespread regional trade networks (Croes 1989).

1.7.1 Ethnographic Period

The PNNL Sequim Campus is located within the Central Coast Salish Culture Area, which includes the southern end of the Strait of Georgia, most of the Strait of Juan de Fuca, the lower Frasier Valley, and other nearby areas. Five traditional languages were spoken throughout the area: Squamish, Halkomelem, Nooksack, Northern Straits, and Klallam (Suttles and Lane 1990a). Klallam speakers lived in the vicinity of the PNNL Sequim Campus. There were 13 Klallam winter villages in this region (Schalk 1988).

Fishing for salmon and other anadromous fish was a major component of the subsistence pattern within the Central Coast Salish Culture Area. In addition to salmon, saltwater fish such as halibut, herring, lingcod, and flounder were caught. Invertebrates such clams, cockles, mussels, sea urchins, crabs, and barnacles were abundant (Schalk 1988; Suttles and Lane 1990a).

The Klallam-speaking people hunted whales opportunistically (Schalk 1988). Terrestrial game played a relatively small role in the overall subsistence pattern (Schalk 1988), but deer and other mammals were hunted by a small number of specialized hunters. Women gathered at least 40 different edible plants including sprouts, stems, bulbs, roots, berries, fruits, and nuts.

Most travel in the region was by canoe, and winter village sites were located where canoes could be beached. Villages often consisted of one or more rows of plank houses paralleling the shore. Houses were constructed on a post and beam framework, with plank walls and shed roofs (Suttles and Lane 1990a).

One important aspect of Salish society was the practice of ritual feasts and gift-giving events known as potlatches, which marked important events or a change in an individual's status (Suttles and Lane 1990a; Fagan 2001). A typical potlatch included members from several or all the houses of a village preparing a feast and giving large quantities of accumulated wealth and gifts to guests from neighboring villages. The redistribution of accumulated goods was important for establishing and reinforcing status or fame and as an investment in securing relationships and support networks between villages and neighbors (Suttles and Lane 1990b).

1.7.2 Historic Period

The earliest Euro-American settlement in Clallam County and the Sequim area was known as Whiskey Flat, which was located on the cliffs above the Strait of Juan de Fuca in the 1850s (Morgan 1996). By the end of the nineteenth century, the settlement of New Dungeness had grown, and the county courthouse was moved to Port Angeles. At this time, the Sequim area was a developing agricultural area. The Sequim Prairie irrigation ditch was completed in 1896, which allowed for expanded farming in the area (Morgan 1996).

Before being chosen as the site of the PNNL Sequim Campus, the location was home to the Bugge Clam Cannery, which had started business on the site in 1905. The cannery eventually expanded to processing salmon and produce, and a creamery was added. The original cannery burned in 1929, but the Bugge family rebuilt and continued to operate the cannery until the land was purchased by Battelle in 1967 (Russell 1971).

In 1967, Battelle began to develop the PNNL Sequim Campus with the intention to "provide facilities for research projects which require ocean waters or oceanic environments" (Battelle-Northwest 1967). Most of the cannery and outbuildings were removed by the early 1970s for the construction of the PNNL Sequim Campus (Brownell 2018).

2.0 Compliance Summary

Operations at PNNL in CY 2019 were conducted to comply with all applicable federal, state, and local environmental laws, regulations, and guidance; presidential Executive Orders; and DOE Orders, directives, policies, and guidance. PNNL endeavors to conduct operations in a sustainable manner that is protective of the environment. Table 2.1 and Table 2.2 summarize PNNL's compliance with federal and state laws and regulations, respectively, and subsequent sections provide brief descriptions of each statute or regulation.

2.1 Sustainability and Environmental Management System

The DOE-Battelle Prime Contract for the management and operation of PNNL (DOE-PNSO 2019) incorporates applicable requirements from DOE Order 436.1, *Departmental Sustainability*, including associated performance goals, objectives, and systems. This Order and related Executive Orders are briefly discussed in the following sections.

2.1.1 DOE Order 436.1, Departmental Sustainability

DOE Order 436.1 was approved on May 2, 2011. The purpose of this Order is to

> "…1) ensure the Department carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges, and advances sustainable, efficient and reliable energy for the future,
>
> 2) institute wholesale cultural change to factor sustainability and greenhouse gas (GHG) reductions into all DOE corporate management decisions, and
>
> 3) ensure DOE achieves the sustainability goals established in its Strategic Sustainability Performance Plan pursuant to applicable laws, regulations and Executive Orders (EO[s]), related performance scorecards, and sustainability initiatives…."

PNNL has incorporated these requirements by modifying the DOE-Battelle Prime Contract to include the development of a site sustainability plan (e.g., PNNL 2020), incorporation of sustainable acquisition requirements into applicable processes, and the development of an environmental management system (EMS) that is certified to meet the requirements of the International Organization for Standardization (ISO) 14001:2015 standards.

The PNNL FY 2020 Site Sustainability Plan (PNNL 2020) identifies the status and accomplishments of sustainability projects related to DOE's sustainability goals. Prepared and submitted to DOE annually, the sustainability plan includes Pollution Prevention Program activities, accomplishments, and continuous improvement opportunities. Section 3.0 of this report provides further information concerning PNNL's EMS and the status of PNNL's sustainability goals.

Table 2.1. Status of Federal Environmental Laws and Regulations Applicable to PNNL, 2019

Statute/Regulation	2019 Status	Report Section(s)
Air Quality and Protection		
The *Clean Air Act* and its Amendments regulate the release of air pollutants from facilities and unmonitored sources through permitting and air-quality restrictions.	PNNL conducted operations under permits issued by the Washington State Department of Health, Washington State Department of Ecology, Benton Clean Air Agency, and Olympic Region Clean Air Agency. No events were reported for emissions of regulated substances to the air or substances of concern. Radioactive air emissions were more than 10,000 times lower than the regulatory standard of 10 mrem/yr (0.1 mSv/yr) at both the PNNL Richland Campus and the PNNL Sequim Campus.	2.4.1, 2.4.2
Cultural and Historic Resources		
The *Antiquities Act of 1906*; *Archeological and Historic Preservation Act of 1974*; *Archaeological Resources Protection Act of 1979*; and *National Historic Preservation Act of 1966* require the establishment of programs to preserve and protect historical and cultural resources including sites, documents, buildings, artifacts, and records using permits, access restrictions, and other means.	The PNNL cultural resources program supported 38 projects. Twelve archaeological sites were re-evaluated, and five new sites were identified and documented. Section 110 monitoring was also conducted; no new impacts were identified.	2.7.2
DOE Policy 141.1, "Department of Energy Management of Cultural Resources"	PNNL implements this policy to protect and manage cultural resources, by identifying impacts of unauthorized public use on prehistoric sites, protecting sensitive sites, and conducting annual monitoring activities.	2.7
Energy Independence		
The *Energy Independence and Security Act of 2007* (EISA) encourages United States energy independence and security, while promoting energy efficiency, conservation, and savings.	PNNL evaluates buildings under EISA energy and water evaluation requirements. PNNL also implements stormwater management practices to promote water drainage and reduce runoff.	2.2, 2.5.2, 3.0
DOE Order 436.1, *Departmental Sustainability*, establishes implementation requirements that include the preparation of a site sustainability plan and an environmental management system (EMS).	PNNL has developed and implements a site sustainability plan that incorporates the annual status and strategy for achieving the goals and objectives of DOE Order 436.1. PNNL has a fully integrated EMS that is certified to meet International Organization for Standardization (ISO) 14001:2015 standards.	2.1.1, 3.0

Statute/Regulation	2019 Status	Report Section(s)
Executive Order 13834, "Efficient Federal Operations," establishes goals and requirements related to energy and environmental performance with respect to facilities, vehicles, and overall operations.	PNNL produced the *Pacific Northwest National Laboratory FY 2020 Site Sustainability Plan*, which focuses on the goals and requirements of Executive Order 13834.	2.1.2, 3.0
Environmental Safety and Health Reporting		
DOE Order 231.1B, *Environment, Safety, and Health Reporting*, requires the gathering, analysis, and reporting of information about environmental safety and health issues.	PNNL monitors and conveys information via reports, emails, LabWeb News articles, and staff meetings. The PNNL Annual Site Environmental Report is a requirement of this Order.	1.0
DOE Order 414.1D, *Quality Assurance*, states the roles and requirements for providing quality assurance (QA) for work performed by DOE and its contractors.	The PNNL *Quality Assurance Program Description/Quality Management M&O Program Description* describes the Laboratory-level QA program that applies to all work performed by PNNL staff, conforming to DOE Order 414.1D requirements.	7.0
Hazardous Materials and Waste Management		
The *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) provides regulations for the identification, assessment, and remediation of sites contaminated by hazardous materials.	Neither the Richland Campus nor the Sequim Campus contains a PNNL CERCLA operable unit. The PNNL Richland Campus is not part of any Hanford CERCLA operable unit and had no continuous releases.	2.6.2
The *Emergency Planning and Community Right-to-Know Act of 1986* stipulates the public's right to information about hazardous materials in the community and the establishment of emergency planning procedures.	PNNL submitted two Tier Two reports, providing information concerning potential hazards. PNNL was not required to submit a Toxic Release Inventory Report.	2.6.8
The *Federal Facility Compliance Act of 1992* amends the *Resource Conservation and Recovery Act of 1976* (RCRA) and CERCLA and establishes new mixed waste reporting requirements.	PNNL provided information as part of the Hanford Site Mixed Waste Land Disposal Restrictions Summary Reports pursuant to Tri-Party Agreement Milestone M-26.	2.6.5
The *Federal Insecticide, Fungicide, and Rodenticide Act* regulates the storage and use of pesticides.	Licensed PNNL staff or certified commercial applicators were used to purchase, store, and apply pesticides on the PNNL Richland Campus and PNNL Sequim Campus.	2.6.7

Statute/Regulation	2019 Status	Report Section(s)
The *Resource Conservation and Recovery Act of 1976* (RCRA) tracks hazardous waste from generation to treatment, storage, or disposal (referred to as cradle-to-grave management).	PNNL is responsible for one RCRA-permitted storage and treatment unit. PNNL generates hazardous waste in eight RCRA facilities (EPA Site ID#s). Washington State Department of Ecology personnel inspected seven of PNNL's eight facilities. Three minor noncompliances were identified and corrected.	2.6.4
The *Superfund Amendments and Reauthorization Act of 1986* amends and reauthorizes CERCLA.	PNNL Richland Campus areas near the Hanford Site have been evaluated and require no further action. Groundwater near the PNNL Richland Campus is monitored for Hanford Site contaminant migration. No contamination was identified at the PNNL Sequim Campus that would require response under CERCLA or the *Superfund Amendments and Reauthorization Act*.	2.6.2
The *Toxic Substances Control Act* regulates and tracks regulated hazardous chemicals, primarily polychlorinated biphenyls (PCBs).	PNNL contributed to the 2018 PCB annual document log report for the Hanford Site and 2018 PCB annual report; both were published in 2019 and submitted to the U.S. Environmental Protection Agency as required.	2.6.6
Radiation Protection		
DOE Order 435.1, *Radioactive Waste Management*, establishes requirements for managing high-level waste, transuranic waste, low-level waste, and mixed wastes.	PNNL's Radioactive Waste Management Basis Program identifies and implements radioactive waste-management controls through internal workflows and procedures.	2.8.2, 2.8.3
DOE Order 458.1, *Radiation Protection of the Public and the Environment*, establishes requirements related to radiation protection of the public and the environment, including estimating radiological dose.	PNNL implements programs to assure that facilities, emissions, effluents, and wastes are protective of the public, workers, and the environment.	2.8.1, 2.8.2, 2.8.3, 4.1, 4.3, 4.4
The *Atomic Energy Act of 1954* encompasses the management of low-level and mixed low-level wastes and radioactive materials.	PNNL's Radiation Protection Management and Operation Program includes safeguarding and monitoring radioactive materials through work controls, dosimetry, bioassay, and safety information.	2.8.3
Water Quality and Protection		
The *Clean Water Act* seeks to maintain and improve surface water quality through criteria and permitting, including point-source discharges to United States surface waters and indirect discharges to sewer systems, as well as the discharge of dredged or fill material into U.S. waters and/or wetlands.	PNNL conducted operations under permits issued by the Washington State Department of Ecology and the City of Richland. The PNNL Sequim Campus operated under a National Pollutant Discharge Elimination System (NPDES) permit issued by the Washington State Department of Ecology. One Nationwide Permit was acquired for an offsite scientific research study.	2.5.1, 2.7.1, 7.3, 7.4

Statute/Regulation	2019 Status	Report Section(s)
The *Safe Drinking Water Act of 1974* establishes standards and requirements for public drinking water systems.	The PNNL Richland Campus receives all drinking water for use in laboratory and nonlaboratory spaces from the City of Richland. The City is responsible for meeting water-quality standards under the *Safe Drinking Water Act of 1974*. At the PNNL Sequim Campus, water is provided exclusively from onsite wells and PNNL is considered the water purveyor.	2.5.2, 2.5.3, 7.4
Wildlife and Ecosystems		
The *Bald and Golden Eagle Protection Act* provides for the protection of bald and golden eagles.	Biological resource reviews provided assurance that proposed actions did not adversely affect bald or golden eagles.	2.7.1
The *Coastal Zone Management Act of 1972* encourages the development of coastal zone management plans to preserve, protect, and enhance natural coastal resources and the wildlife using coastal habitats.	PNNL considers coastal resources and the fish and wildlife that use those habitats when evaluating proposed actions. No federal consistency determinations were acquired by PNNL.	2.7.1
The *Endangered Species Act of 1973* (ESA) provides for the protection of threatened and endangered plant and animal species.	No endangered or threatened species were observed during biological field surveys of the PNNL Richland Campus. Four ESA authorizations were acquired and six no effect determinations were made or acquired for offsite scientific research studies.	2.7.1
The *Forest Service Organic Administration Act of 1897* (FSOAA) provides for the protection and administration of U.S. Forest Service lands.	No authorizations under the FSOAA were acquired in 2019.	2.7.1
The *Magnuson–Stevens Fishery Conservation and Management Act* governs marine fisheries management.	Three essential fish habitat authorizations were for offsite scientific research studies.	2.7.1
The *Marine Mammal Protection Act of 1972* provides for the protection of all marine mammals.	Two *Marine Mammal Protection Act* consultations were conducted for offsite scientific research studies.	2.7.1
The *Migratory Bird Treaty Act* makes it illegal to take, capture, or kill migratory birds or their feathers, nests, or eggs.	A number of migratory birds were observed during the biological field survey of the PNNL Richland Campus and the lands encompassing the PNNL Sequim Campus. PNNL biologists resolved 19 inquiries concerning migratory birds on the PNNL Richland Campus and PNNL Sequim Campus.	2.7.1

Statute/Regulation	2019 Status	Report Section(s)
The *National Environmental Policy Act of 1969* (NEPA) requires the formulation of an environmental impact statement, environmental assessment, or categorical exclusion for federal projects that have the potential to affect the quality of the human environment.	PNNL environmental compliance representatives and NEPA staff conducted 1,192 NEPA reviews during CY 2019 for research and support activities. The U.S. Department of Energy (DOE)-Richland Operations Office approved nine generic categorical exclusions; one activity-specific categorical exclusion was revised and approved by the DOE Pacific Northwest Site Office.	2.3
The *National Park Service Organic Act* provides for the management of national parks and monuments.	No scientific research and collecting permits were acquired for offsite studies.	2.7.1
The *National Wildlife Refuge System Administration Act of 1966* provides administrative and management directives for refuges under the jurisdiction of the U.S. Fish and Wildlife Service.	One special use permit was acquired for an offsite scientific research study.	2.7.1
The *Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990* prevents the spread of nonindigenous aquatic nuisance species to non-infested waters.	An aquatic invasive plant and animal species interception program has been developed and implemented by PNNL.	2.7.1
The *Rivers and Harbors Appropriation Act of 1899* prohibits obstruction or alteration of navigable waters.	Two Section 10 permits were acquired for offsite scientific research.	2.7.1
Executive Order 11988, "Floodplain Management," requires federal agencies to evaluate the potential effects of any actions within a floodplain.	No activities were performed that required a floodplain evaluation.	2.7.1
Executive Order 11990, "Protection of Wetlands," requires federal agencies to minimize the loss or degradation of wetlands and to preserve and enhance their natural and beneficial values.	No offsite activities were performed that required wetland evaluations.	2.7.1

Table 2.2. Status of Washington State Environmental Laws and Regulations Applicable to PNNL, 2019

Statute/Regulation	2019 Status	Report Section(s)
The *Hazardous Waste Management Act of 1976* provides for safe planning, regulation, control, and management of hazardous waste.	PNNL manages hazardous wastes in a safe and responsible manner. Inventories and storage methods are regulated, and reports are submitted as required.	2.6.1
The *Shoreline Management Act of 1971* establishes guidelines for shoreline use, environmental protection, and public access.	One Shoreline Substantial Development Permit and one Exemption were obtained for offsite scientific research studies.	2.7.1
The *Washington Clean Air Act* implements and supplements the federal *Clean Air Act*, overseeing state air quality.	PNNL operated under permits issued by the Washington State Department of Health, Washington State Department of Ecology, Benton Clean Air Agency, and Olympic Region Clean Air Agency. No events were reported for air emissions of regulated substances or substances of concern.	2.4.1
The *Washington Pesticide Application Act* provides for the control of pesticide application and use to protect public health and welfare.	Licensed PNNL staff or certified commercial applicators are used to apply pesticides.	2.6.7
The *Washington Pesticide Control Act* establishes guidelines for proper use and control of pesticides.	Licensed PNNL staff or certified commercial applicators are used to apply pesticides.	2.6.7
The Washington *State Environmental Policy Act* (SEPA) identifies environmental impacts of state and local decisions and gives agencies the authority to deny a proposal when adverse environmental impacts are identified.	PNNL environmental compliance representatives and staff review research and support activities, completing SEPA checklists as required.	2.3

2.1.2 Executive Order 13834, "Efficient Federal Operations"

Executive Order 13834 of May 17, 2018, (83 FR 23771) requires that federal agencies meet statutory requirements to increase energy efficiency, improve performance, eliminate resource use when unnecessary, and protect the environment. The Order revokes Executive Order 13693 of March 19, 2015 (80 FR 15871), "Planning for Federal Sustainability in the Next Decade," which established goals and requirements in the areas of greenhouse gas reduction and promoted sustainable buildings, clean and renewable energy, water-use efficiency and management, fleet management, sustainable acquisition, pollution prevention and waste reduction, energy performance contracts, and electronic stewardship.

Executive Order 13834 (83 FR 23771) establishes goals and requirements for reducing building energy use, implementing energy efficiency measures, reducing potable and non-potable water consumption, managing stormwater and wastewater, increasing energy and water use efficiency, modernizing buildings to comply with building energy efficiency requirements and sustainable design principles, preventing pollution, diverting waste, and stewarding electronics. PNNL has developed detailed plans and milestones for achieving energy efficiency objectives and goals as directed by Executive Order 13834; details are available in Section 3.0 of this report.

2.2 Energy Independence and Security Act of 2007

The *Energy Independence and Security Act of 2007* (EISA) (42 U.S.C. § 17001) was enacted "to move the United States toward greater energy independence and security." It promotes the production of clean, renewable fuels, R&D of biofuels, improved vehicle technology, energy savings through improved standards including those for appliances and lighting, improved energy savings in buildings and industry, the reduction of stormwater runoff, water conservation and protection, the development and extension of new technologies (including solar, geothermal, marine and hydrokinetic, and energy storage), carbon capture and sequestration research, and energy transportation and infrastructure provisions. In fiscal year (FY) 2019, PNNL completed an evaluation of two buildings subject to EISA Section 432 continuous (4-year cycle) comprehensive energy and water requirements. To date, approximately 48% of buildings (43% by total square footage) have met the criteria for DOE Federal Energy Management Program Guiding Principles for high-performance sustainable buildings (HPSBs), far exceeding the 2025 goal of 17% (PNNL 2020).

Whole-building metering for electricity, natural gas, and water have been completed for all viable buildings, enabling facility system analyses, as needed. Stormwater management practices are implemented to promote water drainage and reduce runoff (see Section 2.5.2 of this report). Also, a 125 kW photovoltaic array continued operation in 2019, contributing to onsite energy generation and, together with a solar water heater, additional small photovoltaic arrays on monitoring stations, and renewable energy certificate purchases, it offset 23% of PNNL's electrical use and 17% of its total electric and thermal energy (PNNL 2020).

2.3 National Environmental Policy Act of 1969

The *National Environmental Policy Act of 1969* (NEPA) (42 U.S.C. § 4321 *et seq.*) was enacted to assure that potential environmental impacts, as well as technical factors and costs, are considered during federal agency decision-making. The PNNL NEPA Compliance Program supports Laboratory compliance with NEPA and the Washington *State Environmental Policy Act* (SEPA) (Revised Code of Washington [RCW] 43.21C, as amended). Program activities include preparing sitewide and activity-specific categorical exclusions, environmental assessments, and Washington SEPA checklists. NEPA reviews of PNNL activities are conducted by PNSO. NEPA compliance is verified through assessments conducted by PNNL and PNSO.

PNNL environmental compliance representatives and NEPA staff conducted 1,192 NEPA reviews during CY 2019 for research and support activities (845 Electronic Prep and Risk System reviews, 322 William R. Wiley Environmental Molecular Sciences Laboratory [EMSL] user proposals, and 25 facility-modification permits). NEPA staff reviewed Electronic Prep and Risk reviews to verify that potential project environmental impacts were adequately considered, and NEPA (and as appropriate, SEPA) coverage was correctly applied. In nearly every case, activities were adequately addressed in previously approved NEPA documentation, such as generic categorical exclusions, environmental assessments, environmental impact statements, and supplement analyses. When there was no adequate previously approved documentation, PNNL staff prepared additional NEPA documentation, such as project-specific categorical exclusions, for approval by DOE.

No environmental assessments or environmental impact statements were published by PNSO during 2019, although work was started on an environmental assessment for future development of the PNNL Sequim Campus.

Categorical exclusions represent an effective and necessary means of addressing activities that (1) clearly fit within a class of actions that DOE has determined do not individually or cumulatively have a significant effect on the environment, (2) do not have extraordinary circumstances that may affect the environment, and (3) are not connected to other actions that may have potentially significant impacts. A single determination for a generic categorical exclusion is allowed for recurring activities undertaken during a specified time period.

There were no new PNSO-approved generic categorical exclusions in 2019. A total of 17 generic categorical exclusions have been previously approved by PNSO to cover PNNL research and operations activities. When projects clearly are within the definition of a categorical exclusion, but a generic categorical exclusion is not applicable, a project- or activity-specific categorical exclusion is prepared. There was one activity-specific PNSO-approved categorical exclusion in 2019, covering the purchase and operation of a new aircraft to support the Atmospheric Radiation Monitoring program. A list of all PNSO-approved categorical exclusions is available at https://science.osti.gov/pnso/NEPA-Documents/Categorical-Exclusion-Determinations.

2.4 Air Quality

Federal regulations that apply to air quality at the PNNL Richland Campus and PNNL Sequim Campus and the permits necessary to maintain compliance are discussed in this section.

2.4.1 Clean Air Act

The *Clean Air Act* (42 U.S.C. § 7401 *et seq.*) is administered by EPA. It regulates air emissions from stationary and mobile sources, both criteria and hazardous air pollutants. The Act authorized EPA to establish National Ambient Air Quality Standards for the protection of public health and welfare. The establishment of these pollutant standards was combined with state implementation plans to facilitate attainment of the standards. The *Washington Clean Air Act* (RCW 70.94), which implements and supplements the federal law, has been revised periodically to keep pace with changes at the federal level. The Washington State Department of Ecology is responsible for developing most statewide air-quality rules, and enforces Title 40 of the *Code of Federal Regulations* Part 52 (40 CFR Part 52), 40 CFR Part 60, 40 CFR Part 61, 40 CFR Part 63, 40 CFR Part 68, 40 CFR Part 82, and 40 CFR Part 98, as well as the state requirements in WAC 173-400, WAC 173-441, WAC 173-460, and WAC 173-480.

The Benton Clean Air Agency (BCAA) implements and enforces most federal and state requirements on the PNNL Richland Campus through BCAA Regulation 1 (BCAA 2018). Requirements applicable to the PNNL Richland Campus include Article 4, "General Standards for Particulate Matter;" Article 5, "Outdoor Burning;" Article 8, "Asbestos;" Article 9, "Source Registration;" and Article 10, "Fees and Charges." The Olympic Region Clean Air Agency (ORCAA) implements and enforces most federal and state requirements at the PNNL Sequim Campus through ORCAA Regulations (ORCAA 2020). Requirements applicable to the PNNL Sequim Campus include Regulation 4, "Registration;" Regulation 6, "Required Permits;" Regulation 7, "Prohibitions;" and Regulation 8, "Performance Standards."

2.4.2 Clean Air Act Amendments of 1990 and the National Emissions Standards for Hazardous Air Pollutants

Section 112 of the *Clean Air Act* addresses emissions of hazardous air pollutants. The *Clean Air Act Amendments of 1990* revised Section 112 to require standards for major and certain specific stationary source types. The amendments also revised the National Emissions Standards for Hazardous Air Pollutants (NESHAP) regulations that govern emissions of radionuclides from DOE facilities (40 CFR Part 61, Subpart H). These regulations address the measurement of point-source emissions; but incorporate fugitive emissions with regard to complying with established regulations for radioactive air emissions, including standards, monitoring provisions, and annual reporting requirements. The NESHAP regulations cover all pollutants not regulated by the National Ambient Air Quality Standards that are classified as hazardous. PNNL is in compliance with all NESHAP requirements at both the PNNL Richland Campus and the PNNL Sequim Campus.

2.4.3 Radioactive Emissions

Federal regulations in 40 CFR Part 61, Subpart H, require the measurement and reporting of radionuclides emitted from DOE facilities and the resulting maximum public dose from those emissions. These regulations impose a standard of 10 mrem/yr (0.1 mSv/yr) effective dose equivalent (EDE), which is not to be exceeded. Washington State adopted the 40 CFR Part 61, Subpart H standard in its regulations (WAC 246-247) that require the calculation and reporting of the EDE to the MEI (maximum exposed individual) from point-source emissions and from radon and fugitive source emissions. While the WAC 246-247 receptor location considers whether an individual resides or abides at the evaluated location, an additional assessment is performed for the location that has the maximum offsite nuclide air concentrations whether or not the reside/abide criterion is met (WAC 173-480).

On the PNNL Richland Campus, the Physical Sciences Facility (PSF) and Life Sciences Laboratory 2 (LSL2) have the potential to emit radionuclides.[1] Radioactive emission point sources at the PNNL Richland Campus are actively ventilated stacks that use electrically powered exhausters and from which emissions are discharged under controlled conditions. The sources are major, minor, and fugitive emissions units. In addition, several PNNL Richland Campus sitewide radioactive air permits, commonly called Potential Impact Category 5 (PIC-5) permits (Barnett 2018), were used to assign dose from very low potential emissions sources associated with campus-wide operations. The low-level radioactive sources permitted under PIC-5 include emissions for instrument and operational checks, nondispersible radioactive materials, volumetrically released radioactive materials, and certain facility restoration activities.

Details regarding ambient air, stack emissions monitoring, and PIC-5 permit programs for the PNNL Richland Campus and PNNL Sequim Campus are reported annually. Richland Campus data for 2019 are available in the *PNNL Richland Campus Radionuclide Air Emissions Report for Calendar Year 2019* (Snyder et al. 2020a). The PNNL Sequim Campus has one minor fugitive emission unit that has the potential to emit radionuclides. Radioactive air emissions results for the PNNL Sequim Campus are available in the *PNNL Sequim Campus Radionuclide Air Emissions Report for Calendar Year 2019* (Snyder and Barnett 2020). During CY 2019, the PNNL Richland Campus and PNNL Sequim Campus maintained compliance with state and federal regulations and with issued air emissions permits, as described below. In particular, radioactive air emissions were more than 10,000 times lower than the regulatory standard of 10 mrem/yr (0.1 mSv/yr) EDE for the period at each facility.

2.4.4 Air Permits

PNNL has several permits that control airborne emissions from facilities within the PNNL Richland Campus boundary. Permits for radioactive air emissions are issued by the Washington State Department of Health (WDOH) as a Radioactive Air Emissions License (RAEL). For the PNNL Richland Campus, WDOH has issued RAEL–005, which was last renewed on June 17, 2015; the renewal cycle for a WDOH RAEL is every 5 years. Permits for nonradiological air emissions at the PNNL Richland Campus are issued by the BCAA as an Order of Approval; they can cover particulate, volatile organic compound, and toxic air pollutant emissions. The current Orders of Approval issued by the BCAA to the PNNL Richland Campus are listed below:

[1] As a group of research buildings, the PSF expects to host changing types of research over time. The LSL2 ceased operations with dispersible radioactive material in 2019 and has no new or planned radiological operations.

- PNNL Site – EMSL, PSF Complex, LSL2 Halogenated Solvent Degreaser Operations (Order of Approval No. 2019-0005)
- LSL2 Building Operations (Order of Approval No. 2007-0006, Revision 1)
- Richland North Building Operations (Order of Approval No. 2012-0017)
- Richland North Research (Order of Approval No. 2012-0016).

The PNNL Sequim Campus has two air permits for airborne emissions: RAEL–014 issued by the WDOH and a nonradiological regulatory order issued by the ORCAA (Order of Approval 13NOI968).

2.5 Water Quality and Protection

Federal regulations that apply to water quality at the PNNL Richland Campus and PNNL Sequim Campus are discussed in this section, which addresses wastewater, drinking water, and stormwater regulations and permitting processes.

2.5.1 Clean Water Act

The *Clean Water Act* (33 U.S.C. § 1251 *et seq.*) establishes the basic structure for regulating discharges of pollutants into the waters of the United States, as well as quality standards for surface waters. The basis of the *Clean Water Act* was enacted in 1948 and was called the *Federal Water Pollution Control Act*. Significantly reorganized and expanded with amendments in 1972, it became commonly known as the *Clean Water Act*. Under the *Clean Water Act*, the EPA has implemented pollution control programs such as setting wastewater standards for industry and implementing water-quality standards for all contaminants in surface waters. The *Clean Water Act* made it unlawful to discharge any pollutant from a point source into navigable waters unless a permit is obtained. The EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls these point-source discharges. Point sources are discrete conveyances such as pipes or manmade ditches. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. The EPA delegated responsibility for the Washington State NPDES permit program to the Washington State Department of Ecology in August 1989.

The Washington State Department of Ecology has issued Permit No. WA0020419 to the City of Richland for discharges from its Publicly Owned Treatment Works to the Columbia River. To assure that it meets its NPDES permit conditions, the City of Richland issues industrial wastewater discharge permits to industrial users that discharge process wastewater to the City of Richland sanitary sewer system, as codified in Richland Municipal Code Chapter 17.30.

On the PNNL Richland Campus, the discharge of process wastewater to the City of Richland sanitary sewer system is governed by three City of Richland industrial wastewater discharge permits. Industrial wastewater discharge permit CR-IU001 regulates discharges from facilities on the PNNL Richland Campus and leased facilities, and requires monitoring at one discharge point, Outfall CS-001. Permit CR-IU005 regulates discharges from EMSL to Outfall 001. Permit CR-IU011 regulates process wastewater discharged from PSF. All process wastewater from PSF is monitored at a single compliance

point (Outfall PS-001). All waste streams regulated by these permits are reviewed by PNNL staff and evaluated for compliance with the applicable permit prior to being discharged.

Process wastewater from PNNL Sequim Campus facilities is discharged directly to Sequim Bay under the authorization of Washington State Department of Ecology NPDES Permit No. WA0040649, after treatment by an onsite wastewater treatment system. The wastewater treatment system consists of particulate filters, ultra-violet lamps, and granulated activated carbon. All waste streams regulated by this permit are reviewed by PNNL staff and evaluated for compliance prior to being discharged.

2.5.2 Stormwater Management

Stormwater on the PNNL Richland Campus is primarily managed via underground injection control wells and grassy swales. The underground injection control wells are registered with the Washington State Department of Ecology as required by WAC 173-218. Best management practices are used to minimize pollution in stormwater. These practices include storing chemicals inside or under cover when possible to prevent contact with stormwater, routinely sweeping and cleaning parking lots, promptly notifying manager of spills, cleaning up spills, and conducting good housekeeping.

Stormwater at the PNNL Sequim Campus is managed via a stormwater drain system that includes grated drain boxes for paved areas and a trench that drains to an infiltration pond. Drain boxes provide simple oil separation through the use of a submerged discharge outlet. In addition, separate drain boxes in the boat storage yard and in the wastewater treatment system area contain multimedia filtration systems (sedimentation chamber, oil adsorbent, and granular activated carbon adsorbent). The infiltration pond is an engineered stormwater collection basin with an overflow trench.

Stormwater discharges from the PNNL Richland Campus and PNNL Sequim Campus are not subject to federal or state NPDES stormwater regulations. However, stormwater management practices that promote water drainage and reduce runoff as outlined under EISA Section 438 are considered and implemented as part of PNNL sustainability practices (PNNL 2020). The registrations of underground injection control wells for stormwater have been completed as required by *Safe Drinking Water Act of 1974*.

2.5.3 Safe Drinking Water Act of 1974

The *Safe Drinking Water Act of 1974* (42 U.S.C. § 300f *et seq.*) is the main federal law that assures the quality of drinking water in the United States. Under the Act, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards. The *Safe Drinking Water Act of 1974* was originally passed by Congress to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources—rivers, lakes, reservoirs, springs, and groundwater wells.

The Act focuses on all waters actually or potentially designated for use as drinking water, whether from aboveground or underground sources. The Act authorizes the EPA to establish minimum standards to protect tap water and requires all owners or operators of public water systems to comply with these primary (health-related) standards. State governments, which can be approved to implement these rules for EPA, also encourage attainment of

secondary standards.[1] Under the *Safe Drinking Water Act of 1974*, EPA also established minimum standards for state programs to protect underground sources of drinking water from endangerment by underground injection of fluids.

The PNNL Richland Campus receives all drinking water for uses in laboratory and nonlaboratory spaces from the City of Richland drinking water supply and is not subject to the *Safe Drinking Water Act of 1974*.

Water for PNNL Sequim Campus facilities is provided exclusively from an onsite well. PNNL is considered the water purveyor and is responsible for all monitoring and sampling of the drinking water distribution system. All drinking water parameters sampled met compliance requirements.

As described in Section 6.0 of this report, the BSF/CSF buildings use groundwater for heating and cooling. Water is withdrawn from production wells and discharged to the ground via underground injection control wells. The registrations of underground injection control wells for injection of ground-source heat pump return flow water have been completed as required by *Safe Drinking Water Act of 1974*.

2.5.4 Emerging Contaminants

Per- and polyfluoroalkyl substances (PFAS) are a family of chemicals that are emerging contaminants of concern due to their potential adverse health effects and widespread contamination at sites across the United States. PFAS chemicals are used to manufacture stain-resistant, water-resistant, and non-stick products and are used in certain types of firefighting foam. There are currently no enforceable federal standards for PFAS chemicals, but Washington State has passed legislation to restrict the use of PFAS in food packaging and to ban the new sale and distribution of PFAS-based firefighting foams. Washington State is also developing legislation to monitor certain PFAS chemicals in drinking water, create cleanup standards for groundwater contamination, and establish approved analytical methods for testing for PFAS. A review of PNNL properties and activities was conducted to determine if the potential for PFAS contamination exists. One decommissioned fire suppression system that contained PFAS chemicals was identified and there is no recorded activation of the system. No other PNNL activities or properties were identified to have potential PFAS contamination. Currently, no monitoring or testing for PFAS chemicals has occurred or been required for PNNL facilities.

2.6 Environmental Restoration and Waste Management

This section describes PNNL activities conducted to protect the environment through the proper management of waste.

[1] Secondary standards are established to give operators of public water systems guidance about removing contaminants that may cause the water to appear cloudy or colored, or to taste or smell bad, even though the water is actually safe to drink.

2.6.1 Tri-Party Agreement

The "Hanford Federal Facility Agreement and Consent Order" (also known as the Tri-Party Agreement [Ecology et al. 1989]) is an agreement between the Washington State Department of Ecology, EPA, and DOE (the Tri-Party Agreement agencies) to achieve compliance on the Hanford Site with the treatment, storage, and disposal unit regulations and corrective action provisions of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) (42 U.S.C. § 9601 *et seq.*) and the *Resource Conservation and Recovery Act of 1976* (RCRA) (42 U.S.C. § 6901 *et seq.*, and 42 U.S.C. § 6927(c) *et seq.*). The Tri-Party Agreement is an interagency agreement (also known as a federal facility agreement) under Section 120 of CERCLA, a corrective action order under RCRA, and a consent order under the Washington State *Hazardous Waste Management Act of 1976* (RCW 70.105). The Agreement (1) defines RCRA and CERCLA cleanup commitments, (2) establishes responsibilities, (3) provides a basis for budgeting, and (4) reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones.

The Tri-Party Agreement is available on the DOE Hanford Site website at http://www.hanford.gov/?page=81. Printed copies of the Tri-Party Agreement, which is current as of September 30, 2019, are publicly available at DOE's Public Reading Room, located in the Washington State University–Tri-Cities Consolidated Information Center, 2770 University Drive, Richland, Washington, and at public reading rooms in Seattle and Spokane, Washington, and Portland, Oregon.

Under the Tri-Party Agreement, Hanford waste sites were grouped into "operable units" based on geographic proximity or similarity of waste-disposal history. The Tri-Party Agreement only applies to PNNL facilities operating on the Hanford Site. It does not apply to the PNNL Richland Campus, PNNL Sequim Campus, or other PNNL offices. The PNNL Richland Campus is not part of any Hanford Site CERCLA operable unit or subject to any cleanup action under the Tri-Party Agreement. PNNL maintains administrative controls similar to those at adjacent uncontaminated portions of the Hanford Site 300 Area (e.g., access control and groundwater use restrictions). PNNL provides information to DOE-RL and its contractors with regard to the facilities it occupies on the Hanford Site to support the preparation of the annual land disposal restrictions report required by the Tri-Party Agreement M-26 milestone series. Some wells located on the PNNL Richland Campus are monitored by Hanford Site contractors as part of the regional groundwater monitoring network. Sampling data are available in the *Hanford Site RCRA Groundwater Monitoring Report for 2019* (DOE-RL 2020b).

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

CERCLA was promulgated to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. CERCLA was amended by the *Superfund Amendments and Reauthorization Act of 1986* (42 U.S.C. § 9601 *et seq.*), which made several important changes and additions, including clarification that federal facilities are subject to the same provisions of CERCLA as any nongovernmental entity. Executive Order 12580 of January 23, 1987, "Superfund Implementation" (52 FR 2923), directs that DOE, as the lead agency, must conduct CERCLA response actions (i.e., removal and remedial actions). Such actions would be subject to oversight by EPA and/or the Washington State Department of Ecology.

Two Hanford 300 Area operable units, listed on the National Priorities List on November 3, 1989, are located near the PNNL Richland Campus.

A portion of the PNNL Richland Campus located north of Horn Rapids Road was investigated as part of the Hanford 300-FF-2 Operable Unit in the late 1990s. Site characterization efforts found vestiges of petroleum hydrocarbons, irrigation canals, and debris (windblown garbage, porcelain china, battery cores, cans, and glass). After a site evaluation, EPA issued a CERCLA Final Record of Decision (EPA and DOE-RL 2013) that concluded that PNNL Richland Campus areas north of Horn Rapids Road require no further remedial action under CERCLA.

Groundwater under the northern portion of the PNNL Richland Campus is routinely monitored for contaminants migrating from Hanford Site contamination plumes, as well as nitrates migrating from offsite locations. See Section 6.0 of this report for further information concerning groundwater monitoring on the PNNL Richland Campus.

No PNNL Sequim Campus facilities require action under CERCLA guidelines.

2.6.3 Washington State Dangerous Waste/Hazardous Substance Reportable Releases to the Environment

The Washington State Dangerous Waste Regulations (WAC 173-303-145) require that spills or non-permitted discharges of dangerous waste or hazardous substances to the environment be reported to the Washington State Department of Ecology. This requirement applies to discharges to soil, surface water, groundwater, or air when such discharges threaten human health or the environment, regardless of the quantity of the dangerous waste or hazardous substance released.

During CY 2019, no spills or non-permitted discharges that posed a threat to human health or the environment occurred at the PNNL Richland Campus or PNNL Sequim Campus. Minor spills were cleaned up immediately and disposed of in accordance with applicable requirements.

2.6.4 Resource Conservation and Recovery Act of 1976

RCRA was enacted to protect human health and the environment through cradle-to-grave management of hazardous waste from its generation through treatment, storage, and disposal. The Washington State Department of Ecology has the authority to enforce RCRA requirements in the state under WAC 173-303, "Dangerous Waste Regulations."

PNNL, in cooperation with DOE-RL, operates one RCRA-permitted storage and treatment unit group—the 325 Hazardous Waste Treatment Units. This unit group is located in the Radiochemical Processing Laboratory in the Hanford 300 Area and is permitted as part of the Hanford Facility RCRA Permit. The Hanford Facility RCRA Permit expired on September 27, 2004. However, DOE and PNNL continue to operate in compliance with the expired permit until the permit is reissued, as authorized by WAC 173-303-806(7) and the Washington State Department of Ecology. The Hanford RCRA Permit may be viewed at https://fortress.wa.gov/ecy/nwp/permitting/hdwp/rev/8c/index.html.

With the exception of the 325 Hazardous Waste Treatment Units, the PNNL Richland Campus and PNNL Sequim Campus facilities operate under the generator requirements of WAC 173-303. During CY 2019, PNNL facilities followed the generator requirements for waste management and shipped nonradioactive waste to offsite facilities for proper disposal.

RCRA and WAC 173-360A also include requirements for the proper management of underground storage tanks. In CY 2019, Battelle administered two underground storage tanks for the storage of diesel fuel for backup generators on the PNNL Richland Campus in Richland—a 20,000-gallon tank and 600-gallon tank. The tanks are routinely monitored, and no problems were observed. No underground tanks are used at the PNNL Sequim Campus.

Washington State Department of Ecology performed just one RCRA compliance inspection in 2019, an inspection of the 325 Hazardous Waste Treatment Units. No areas of noncompliance were identified by the inspection report.

2.6.5 Federal Facility Compliance Act of 1992

The *Federal Facility Compliance Act of 1992* (42 U.S.C. 6939c and 6961), enacted by Congress on October 6, 1992, amended Section 6001 of RCRA to specify that the United States 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 also given authority to conduct inspections of federal facilities to enforce compliance with state hazardous waste programs. A portion of the Act also requires DOE to provide mixed waste information to EPA and the states. PNNL provides this information as part of the *Calendar Year 2019 Hanford Site Mixed Waste Land Disposal Restrictions Full Report* (DOE-RL 2020a), pursuant to Tri-Party Agreement Milestone M-26.

2.6.6 Toxic Substances Control Act

Requirements of the *Toxic Substances Control Act* (15 U.S.C. § 2601 *et seq.*) that apply to PNNL primarily involve the regulation of polychlorinated biphenyls (PCBs). Federal regulations for PCB use, storage, and disposal are provided in 40 CFR Part 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." PCB wastes at PNNL are stored and/or disposed of in accordance with this regulation.

The 2018 Hanford Site Polychlorinated Biphenyl Annual Document Log (DOE-RL 2019a) and the 2018 Hanford Site Polychlorinated Biphenyl Annual Report (DOE-RL 2019b) were produced in 2019 and describe the PCB waste-management and disposal activities that occur on the Hanford Site, including PNNL Richland Campus activities related to PCBs. The Annual Report is provided to EPA as required by 40 CFR 761.180. The facilities at the PNNL Sequim Campus did not generate enough PCB waste to require reporting under 40 CFR 761.180 in 2019.

2.6.7 Federal Insecticide, Fungicide, and Rodenticide Act

The *Federal Insecticide, Fungicide, and Rodenticide Act* (7 U.S.C. § 136 *et seq.*) is administered by EPA. Washington State Department of Agriculture rules implementing the Act requirements include the *Washington Pesticide Control Act* (RCW 15.58), the *Washington Pesticide Application Act* (RCW 17.21), and rules related to general pesticide use codified in WAC 16-228, "General Pesticide Rules." In 2019, commercial pesticides used at the PNNL Richland Campus and PNNL Sequim Campus were managed in accordance with these rules and applied either by licensed PNNL staff or by a licensed commercial applicator.

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

The *Emergency Planning and Community Right-to-Know Act of 1986* (EPCRA) (42 U.S.C. § 11001 *et seq.*) requires each state to establish an emergency response commission and local emergency planning committees and develop a process for gathering and distributing information about hazardous chemicals present in local facilities. These local emergency planning committees develop emergency plans for local planning districts. Facilities that produce, use, release, or store toxic or hazardous substances in quantities above threshold levels must submit information about the chemicals to local emergency planning committees.

EPCRA has four major provisions: emergency planning, emergency release notification, hazardous chemical inventory reporting, and toxic chemical release inventory reporting. Each provision requires reporting when thresholds are exceeded (Table 2.3).

PNNL EPCRA reporting for the PNNL Richland Campus combines the quantities of chemicals in the Hanford 300 Area facilities that PNNL occupies and those present in on-campus facilities. EPCRA reports for the PNNL Sequim campus are submitted separately from those for the PNNL Richland Campus because the former is located in a different county (Clallam).

Table 2.3. Provisions of the *Emergency Planning and Community Right-to-Know Act of 1986*

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
302	40 CFR Part 355: "Emergency Planning"	The presence of an extremely hazardous substance in a quantity equal to or greater than the threshold planning quantity at any one time.	Within 60 days of threshold planning quantity exceedance.	SERC; LEPC
302	40 CFR Part 355: "Emergency Planning"	Change occurring at a facility that is relevant to emergency planning.	Within 30 days after the change has occurred.	LEPC
304	40 CFR Part 355: "Emergency Release Notification"	Release of an extremely hazardous substance or a CERCLA hazardous substance in a quantity equal to or greater than the reportable quantity.	Initial notification: immediate (within 15 minutes of knowledge of reportable release). Written follow-up within 14 days of the release.	SERC; LEPC
311	40 CFR Part 370: "Reporting Requirements – Material Safety Data Sheet Reporting"	The presence at any one time at a facility of an OSHA hazardous chemical in a quantity equal to or greater than 4,500 kg (10,000 lb) or an extremely hazardous substance in a quantity equal to or greater than the threshold planning quantity or 230 kg (500 lb), whichever is less.	Revised list of chemicals due within 3 months of a chemical exceeding a threshold.	SERC; LEPC; local fire departments
312	40 CFR Part 370: "Reporting Requirements – Tier Two Report"	The presence at any one time at a facility of an OSHA hazardous chemical in a quantity equal to or greater than 4,500 kg (10,000 lb), or an extremely hazardous substance in a quantity equal to or greater than the threshold planning quantity or 230 kg (500 lb), whichever is less.	Annually by March 1.	SERC; LEPC; local fire departments
313	40 CFR Part 372: "Reporting Requirements – Toxic Release Inventory Report"	Manufacture, processing, or use at a facility of any listed Toxic Release Inventory chemical in excess of its threshold amount during the course of a calendar year. Thresholds are 11,300 kg (25,000 lb) for manufactured or processed chemicals or 4,500 kg (10,000 lb) for chemicals otherwise used, except for persistent, bio-accumulative, toxic chemicals, which have thresholds of 45 kg (100 lb) or less.	Annually by July 1.	EPA; SERC

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*; CFR = *Code of Federal Regulations*; EPA = U.S. Environmental Protection Agency; LEPC = Local Emergency Planning Committee; OSHA = Occupational Safety and Health Administration; SERC = State Emergency Response Commission.

The Annual Tier Two inventory report for the Pacific Northwest National Laboratory (PNNL) Richland Campus was submitted on February 7, 2019, to the Washington State Emergency Response Commission, Benton County Emergency Management, and the Richland Fire Department via the SecureAccessWA website. Under the governing regulations, R&D chemicals are exempt from reporting. The report includes inventories located at PNNL-occupied 300 Area Hanford facilities and facilities on the PNNL Richland Campus (comprising both PNSO and Battelle-owned facilities). This report identified lead-acid batteries, diesel fuel, and the urea content of fertilizer products stored at PNNL in excess of the reporting threshold.

Using the same process, the Annual Tier Two inventory report for the PNNL Sequim Campus was submitted to the Washington State Emergency Response Commission, Clallam County Emergency Management, and the Clallam County Fire District 3 on February 5, 2019. Similar to previous years, this report identifies diesel fuel as the only material in excess of the reporting threshold at the PNNL Sequim Campus.

Neither the PNNL Richland Campus nor PNNL Sequim Campus was required to submit a Toxic Release Inventory Report for 2019, because no releases of Toxic Release Inventory chemicals occurred in excess of reporting thresholds.

Table 2.4 provides an overview of PNNL reporting under EPCRA for CY 2019.

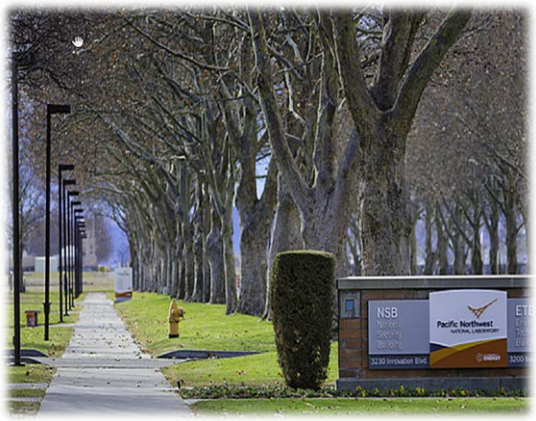
Table 2.4. *Emergency Planning and Community Right-to-Know Act of 1986* Compliance Reporting, 2019

Section	Description of Reporting	Reporting Status	Notes
302	Emergency planning notifications	Not required	No changes in previously reported inventories of sulfuric acid and no new extremely hazardous substances managed in excess of thresholds.
304	Extremely hazardous substance release notification	Not required	No releases occurred.
311	Material Safety Data Sheet	Yes	No changes in previously reported inventories.
312	Chemical inventory	Yes	The CY 2018 Tier Two reports for the PNNL Richland Campus and PNNL Sequim Campus were submitted to the Washington State Department of Ecology, the LEPC, and local fire departments in February 2019.
313	Toxic release inventory	Not required	No releases were greater than the reporting threshold requirement.

CY = calendar year; LEPC = Local Emergency Planning Committee; PNNL = Pacific Northwest National Laboratory.

2.7 Natural and Cultural Resources

The Pacific Northwest Site Office Cultural and Biological Resources Management Plan (CBRMP; DOE-PNSO 2015) provides direction and guidance related to protecting and managing biological and cultural resources on the PNNL Richland Campus in accordance with applicable laws and regulations. The CBRMP was developed as a requirement of DOE Policy 141.1, "Department of Energy Management of Cultural Resources," to provide for the protection and management of cultural and biological resources, identify impacts of unauthorized public use on prehistoric sites, identify actions that will protect sensitive sites, and provide details of annual monitoring activities to identify potential impacts. The CBRMP is implemented by application of PNNL's internal cultural and biological resource protection procedures, which are updated regularly to reflect relevant changes in applicable laws and regulations and compliance methods.



PNNL conducts field research for which environmental permits are required, often at locations throughout the Pacific Northwest other than the PNNL Richland Campus or PNNL Sequim Campus. The Environmental Research Permitting (ERP) program was established in 2016 to centralize the acquisition of permits and authorizations in compliance with laws and regulations applicable to PNNL research projects. The ERP program also maintains an online, internal PNNL database for environmental permits (the Environmental Permitting Information Center) and tracks reporting requirements on behalf of research projects.

The following sections describe the laws and regulations applicable to (1) the management of biological and cultural resources on the PNNL Richland Campus, and (2) the environmental permits required to protect biological and cultural resources that may be affected by research projects conducted on the PNNL Richland Campus, PNNL Sequim Campus, and other research locations.

2.7.1 Biological Resources

A number of federal and state laws, Executive Orders, regulations, and related memoranda contain requirements for (1) managing biological and cultural resources on the PNNL Richland Campus and PNNL Sequim Campus, and (2) acquiring the environmental permits required to protect biological and cultural resources that may be affected by research projects conducted on the PNNL Richland Campus, PNNL Sequim Campus, and other research locations. This section and Table 2.5 summarize the requirements and catalog PNNL's compliance activities related to biological resources in 2019.

Federal Statutes and Regulations

The *Endangered Species Act* (16 U.S.C. § 1531 *et seq.*) contains requirements for the designation and protection of wildlife, fish, plant, and invertebrate species that are in danger of becoming extinct because of natural or manmade factors, and the conservation of habitats upon which they depend. Under Section 7(a)(2) of the Act, federal agencies are required to evaluate actions that they perform, fund, or permit to determine whether they would affect any species listed as endangered or threatened or impact designated critical habitat. Consultation with the U.S. Fish and Wildlife Service (USFWS) and/or the National Marine Fisheries Service (NMFS) is required if the action may affect listed species or critical habitat. The biological resource review process and consultation with USFWS and/or NMFS are the primary means by which PNNL determines whether any listed species or critical habitat may be affected by a proposed action.

The *Migratory Bird Treaty Act* (16 U.S.C. § 703 *et seq.*) makes it illegal to take, capture, or kill any migratory bird, or to take any part, nest, or egg of any such birds. A Department of the Interior Office of the Solicitor Memorandum (M-37050, issued in December 2017 [DOI 2017]) and a subsequent explanatory Memorandum (issued in June 2018 [DOI 2018]) clarified that an active nest of a migratory bird may be destroyed while conducting any activity where the intent of the action is not to kill migratory birds or destroy their nests or contents (incidental take). Although incidental take by PNNL projects would not constitute a violation of the MBTA, PNNL projects that have a potential to affect avian species listed under the Act use the PNNL biological resource review process as described in the CBRMP (DOE-PNSO 2015) and implemented by PNNL's internal biological resource protection procedures to protect migratory birds. In 2019, PNNL biologists resolved 19 inquiries concerning migratory birds on the PNNL Richland Campus and PNNL Sequim Campus, and installed deterrents in areas of habitual nesting to avoid potential impacts on active bird nests.

The *Bald and Golden Eagle Protection Act* (16 U.S.C. § 688 *et seq.*) prohibits anyone without a permit from disturbing, wounding, killing, harassing, or taking bald eagles (*Haliaeetus leucocephalus*) or golden eagles (*Aquila chrysaetos*), alive or dead, including their parts, nests, or eggs. The Act also applies to impacts made around previously used nest sites, if, upon an eagle's return, normal breeding, feeding, or sheltering habits are influenced negatively. The PNNL biological resource review process provides assurance that a proposed action will not adversely affect bald or golden eagles. Mitigation includes performing work according to the spatial and timing restrictions established for seasonal use locations, such as nest sites and communal night roosts in applicable jurisdictional management plans for the species.

Table 2.5. Environmental Research Permits Obtained in 2019 for PNNL Research Activities

Issuer and Permit Type	Regulatory Driver	Number of Permits
Bonneville Power Administration		
No Effect Determination (ESA)	ESA	1
Clallam County		
Shoreline Substantial Development Permit	SMA	1
Hanford Fire Department		
Fire Permit	NA	1
Mission Support Alliance		
Hanford Site Access Permit	NA	1
Hanford Site Excavation Permit	WAC	1
National Marine Fisheries Service		
ESA Section 7/MSFCMA Essential Fish Habitat Formal Consultation	ESA, MSFCMA	1
ESA Section 7/MSFCMA Essential Fish Habitat Informal Consultation	ESA, MSFCMA	2
MMPA Consultation	MMPA	2
Willamette Biological Opinion – Determination of Take	ESA	1
Oregon Department of Fish and Wildlife		
Access Permit	NA	1
Scientific Taking Permit – Fish	OAR	2
PNNL for DOE-PNSO		
No Effect Determination (ESA)	ESA	4
Private Landowner		
Property Access	NA	2
Skamania County		
Shoreline Substantial Development Permit Exemption	SMA	1
U.S. Army Corps of Engineers		
Civil Works Permit	RHA	1
RHA Section 10 – Individual Permit	RHA	2
Nationwide Permit 5 – Scientific Measurement Devices	RHA, CWA	1
U.S. Fish and Wildlife Service		
No Effects Determination (ESA)	ESA	1
Special Use Permit	NWRSAA, CFR	1
Washington Department of Ecology		
CZMA Consistency Certification	CZMA	1
Washington Department of Fish and Wildlife		
Fish Transport Permit	WAC	3
Hydraulic Project Approval	WAC	1
Right of Entry	WAC	1
Washington Department of Natural Resources		
Aquatic Lands Right of Entry License	WAC	2
Total		35

CFR = *Code of Federal Regulations*; CWA = *Clean Water Act*; CZMA = *Coastal Zone Management Act*; ESA = *Endangered Species Act of 1973*; MMPA = *Marine Mammal Protection Act of 1972*; MSFCMA = *Magnuson–Stevens Fishery Conservation and Management Act*; NWRSAA = *National Wildlife Refuge System Administration Act of 1966*; OAR = Oregon Administrative Rules; RHA = *Rivers and Harbors Appropriation Act of 1899*; SMA = *Shoreline Management Act of 1971*; WAC = Washington Administrative Code.
NA = not applicable

The *Magnuson–Stevens Fishery Conservation and Management Act* (16 U.S.C. § 1801 *et seq.*) is the primary law governing marine fisheries management in the United States. It provides a national program for the conservation and management of U.S. fishery resources in order to prevent overfishing, rebuild overfished stocks, assure conservation, and facilitate long-term protection of essential fish habitats (waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity). Under Section 305(b)(2) of the Act, federal agencies must consult with the NMFS about any action that might adversely affect essential fish habitat. The PNNL biological resource review process and consultation with NMFS are the primary means by which PNNL determines whether any essential fish habitat may be affected by a proposed action.

The *Marine Mammal Protection Act of 1972* (16 U.S.C. § 1361 *et seq.*) provides a program for the protection of all marine mammals based on some species or stocks being in danger of extinction or depletion due to human activities. The purpose of the Act is to assure that actions that may affect marine mammal species or stocks do not cause them to fall below their optimum sustainable population levels. Consultation with the NMFS is required if an action may affect any marine mammal species. The biological resource review process and consultation with NMFS are the primary means by which PNNL determines whether marine mammal species may be affected by a proposed action.

The *Rivers and Harbors Appropriation Act of 1899* (RHA; 33 U.S.C. § 403 *et seq.*) is the oldest federal environmental law in the United States. Section 10 of the Act prohibits the creation of any obstruction, excavation, or fill within a navigable waterway without a permit, including but not limited to the building of any wharfs, piers, jetties, or other structures. Authorization for issuing permits under both RHA Section 10 and *Clean Water Act* Section 404 (Section 2.5.1) is delegated to the U.S. Army Corps of Engineers (USACE), within the Department of the Army. One of several permit types may be issued depending on the type of use and the project's impacts on navigable waters. The USACE has established a system of Nationwide Permits to streamline permitting certain activities known to have minimal impacts. Nationwide Permits are often acquired for PNNL research projects. PNNL obtains Department of the Army permits from USACE for each project, as applicable, as part of its biological resource review process.

The *Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990* (16 U.S.C. § 4701 *et seq.*) provides for the development and execution of environmentally sound control methods that prevent the unintentional introduction and dispersal of nonindigenous aquatic nuisance species into waters of the United States. PNNL has developed and implements an aquatic invasive plant and animal species interception program to comply with this Act. This program is detailed in Section 2.7.1.1 of this report.

Executive Order 11990 of May 24, 1977, "Protection of Wetlands" (42 FR 26961), requires federal agencies to minimize the destruction, loss, or degradation of wetlands on federal lands, and to preserve and enhance the natural and beneficial values of wetlands on federal lands. The Order does not apply to non-federal property. The Order states that federal agencies should avoid undertaking or providing assistance for new construction located in wetlands unless the agency finds (1) that there is no practicable alternative to such construction, and (2) that the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use. Compliance with this Order, as well as the wetland provisions of the *Clean Water Act* (see Section 2.5.1 of this report), is achieved through the biological resource review process at PNNL.

Executive Order 11988 of May 24, 1977, "Floodplain Management" (42 FR 26951), requires federal agencies to evaluate the potential effects of any actions within a floodplain to minimize any direct or indirect impacts on the floodplain's natural and beneficial values. Potential floodplain impacts are considered through the biological resource review process at PNNL.

Executive Order 13112 of February 3, 1999,"Invasive Species" (64 FR 6183) and its amendment Executive Order 13751 of December 5, 2016, "Safeguarding the Nation from the Impacts of Invasive Species" (81 FR 88609), established a National Invasive Species Council to oversee implementation of the Order and require federal agencies to identify actions that may affect the status of invasive species; prevent introduction of invasive species; detect, respond to, monitor, and control populations of invasive species; provide for restoration of native species and habitats in ecosystems that have been invaded; and conduct research and public outreach to control and prevent the introduction of invasive species. See Section 2.7.1.2 of this report for a description of the PNNL noxious weed control program.

Executive Order 13186 of January 10, 2001, "Responsibilities of Federal Agencies to Protect Migratory Birds" (66 FR 3853), requires agencies to avoid or minimize the adverse impact of their actions on migratory birds and to assure that environmental analyses under NEPA evaluate the effects of proposed federal actions on such species. A Memorandum of Understanding (MoU) between DOE and the USFWS regarding implementation of Executive Order 11386, identifies specific areas in which enhanced collaboration between DOE and the USFWS will substantially contribute to the conservation and management of migratory birds and their habitats (DOE and USFWS 2013). Compliance with the Order and MoU are assured by PNNL's biological resource review process as described in the CBRMP (DOE-PNSO 2015) and implemented by PNNL's internal biological resource protection procedures.

The *Coastal Zone Management Act of 1972* (16 U.S.C. § 1451 *et seq.*) includes the establishment of a National Coastal Zone Management Program administered by the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean and Coastal Resource Management. Most coastal and Great Lakes states have a federally approved coastal zone management program (CMP) to preserve, protect, develop, and, where possible, restore or enhance valuable natural coastal resources such as wetlands, floodplains, estuaries, beaches, dunes, barrier islands, and coral reefs, as well as the fish and wildlife using those habitats. Federally funded research performed by PNNL that may affect natural resources of the coastal zone must be consistent with the policies of the applicable coastal state's federally approved CMP. The *Coastal Zone Act Reauthorization Amendments of 1990* include Section 6217, which calls upon states that have a federally approved CMP to develop coastal nonpoint pollution control programs to improve, safeguard, and restore the quality of coastal waters. Section 6217 is administered jointly by EPA and NOAA. PNNL maintains compliance with the federal consistency provisions and Section 6217 of this Act through its biological resource review process and its ERP program.

The U.S. Coast Guard (USCG) administers 33 CFR Part 66, *Navigation and Navigable Waters*, "Private Aids to Navigation." For the safe navigation of watercraft, the installation of a fixed structure or floating object in any navigable water of the United States requires review by the USCG to determine whether a permit and/or private aid to navigation (a buoy, light, or day beacon owned and maintained by a private organization or individual [PATON]) is necessary. The USCG also publishes the *Local Notice to Mariners* (LNM) weekly, which provides information about the location of structures to facilitate navigational safety

in marine environments. Permits, PATONs, and LNMs allow research projects to be located in navigable waters without posing undue hazard to watercraft. PNNL maintains compliance with these regulations through its ERP program.

The *Forest Service Organic Administration Act of 1897* (formally titled the *Sundry Civil Appropriations Act of 1897*, but commonly called the *Forest Service Organic Act*) specified the purpose for establishing forest reserves and their administration and protection. The U.S. Forest Service, within the U.S. Department of Agriculture, administers the use of national forests, including for scientific research, under 36 CFR Part 251. Uses such as scientific research and specimen collecting are deemed "special uses" and require a permit. PNNL maintains compliance with these regulations through its ERP program.

The *National Park Service Organic Act* established the National Park Service in 1916 to oversee management of national parks and monuments. The National Park Service, within the U.S. Department of the Interior, administers the use of such lands under Chapter 1 of 36 CFR, which governs parks, forests, and public property. A Scientific Research and Collecting Permit is required for activities pertaining to natural resources that involve fieldwork, specimen collection, or that may potentially disturb resources or visitors. PNNL maintains compliance with these regulations through its ERP program.

The *National Wildlife Refuge System Administration Act of 1966* formally established the National Wildlife Refuge System and provided administration and management directives under the jurisdiction of the USFWS. The USFWS, in accordance with 50 CFR, issues permits for uses, including scientific research, deemed compatible with the purposes of specific refuge areas. PNNL maintains compliance with these regulations through its ERP program.

The *Columbia River Gorge National Scenic Area Act* (16 U.S.C. § 544 *et seq.*) was enacted to protect and enhance the scenic, recreational, and natural resources and to support the economy of the Columbia River Gorge. The Act is implemented through a Gorge Management Plan (CRGC and USFS 2016), overseen by the U.S. Forest Service and an Oregon-Washington bi-state Columbia River Gorge Commission. The U.S. Forest Service conducts consistency reviews for proposed projects that are to be located within designated management areas. PNNL maintains compliance with this Act through its ERP program.

State Statutes and Regulations

PNNL conducts research studies at locations throughout the Northwest and must also comply with applicable state and local statutes, regulations, and directives at those sites. Principal relevant rulings are summarized in the following paragraphs.

The Washington State *Shoreline Management Act of 1971* (RCW 90.58, as amended) establishes policy for shoreline use and environmental protection along shorelines that include rivers and streams with a mean annual flow greater than 0.6 m^3/s (21 ft^3/s), which includes the Columbia River in Benton and Franklin Counties. The shoreline jurisdiction extends 61 m (200 ft) landward of these waters, and includes associated wetlands, floodways, and up to 61 m (200 ft) of floodway-contiguous floodplains. The Act requires that shoreline uses be consistent with the control of pollution and protection of natural resources, including the land, vegetation, wildlife, water, and aquatic life from adverse effects. County

Shoreline Master Programs (Ecology 2020) implement the policies of the Washington State *Shoreline Management Act of 1971* and establish a shoreline-specific combined comprehensive plan, zoning ordinance, and development permit system. PNNL maintains compliance with the Act by meeting the provisions of County Shoreline Master Programs through PNNL's ERP program.

Several chapters and sections of the Washington Administrative Code (WAC) govern activities that affect fish and wildlife or their habitat, aquatic lands, and excavation activities in the state of Washington. WAC 220-200-150 requires a Scientific Collection Permit from the WDFW for the collection of fish, shellfish, wildlife, or nests of birds for research purposes, as well as a Fish Transport Permit for transporting fish or the viable eggs/gametes of fish into or through Washington. WAC 220-660 requires a Hydraulic Project Approval from the WDFW for construction or projects that will use, divert, obstruct, or change the natural flow or bed of any waters of the state (see RCW 77.55). WAC 332-30 governs the use of state-owned aquatic lands and outlines necessary use authorizations from the Washington State Department of Natural Resources. WAC 296-155-655 requires that utility companies or landowners be contacted prior to excavation activities, resulting in the issuance of an Excavation Permit. PNNL maintains compliance with these regulations through its ERP program.

PNNL regularly conducts research activities in the state of Oregon and must comply with state regulations involving fish and wildlife or their habitat, and aquatic lands as governed by the Oregon Administrative Rules (OARs). OAR 635-007 and OAR 635-043 direct the administration of Scientific Taking Permits for fish and for wildlife, respectively, under the jurisdiction of the Oregon Department of Fish and Wildlife. OAR 141-082 governs the use of state-owned submerged land and OAR 141-089 governs removal/fill activities within waters of the state under the jurisdiction of the Oregon Department of State Lands. PNNL maintains compliance with these regulations for research activities through its ERP program.

PNNL Programs

Programs and activities performed to assure compliance with the preceding biological resource statutes and drivers are discussed in the following paragraphs.

PNSO prepared the CBRMP (DOE-PNSO 2015) in response to the direction and guidance provided in DOE Policy 141.1, "Department of Energy Management of Cultural Resources," related to protecting and managing cultural and biological resources. The plan provides direction regarding the requirements for annual surveys and monitoring for species of concern, review of project activities for environmental impacts, and identification and control of invasive species. The CBRMP is implemented by application of PNNL's internal cultural and biological resource protection procedures.

As stipulated in the CBRMP (DOE-PNSO 2015), projects involving soil or vegetation disturbance or work outdoors are routinely evaluated to determine their potential to affect biological resources prior to implementation. Fifty-four biological resource reviews were conducted for PNNL projects in CY 2019—40 on the Richland Campus, 8 at the PNNL Sequim Campus or for PNNL Sequim Campus-related projects, and 6 at other locations.

Potential project impacts were evaluated for plant or animal species protected under the ESA, species proposed or candidates for such protection, and species of concern; species listed by the state of Washington as threatened, endangered, sensitive, candidate, or monitor; Washington State priority habitats; and bird species protected under the *Migratory Bird Treaty Act* and *Bald and Golden Eagle Protection Act*. Federally and state-listed species on the PNNL Richland Campus and PNNL Sequim Campus are listed in Table 1.1 and Table 1.2, respectively. No projects violated related federal or state laws, regulations, or conservation priority guidance.

Staff ecologists performed pedestrian and visual reconnaissance surveys of biological resources found on the undeveloped portions of the PNNL Richland Campus from April through August 2019, except for the riparian zone adjacent to the Columbia River. The primary objective of the field surveys was to determine the occurrence of the plant and animal species and habitats of concern for project-specific biological resource reviews. Lists of plant and animal species identified on the undeveloped portions of the PNNL Richland Campus from 2009 to 2019, and at the PNNL Sequim Campus from 2006 to 2019 and their status are provided in Appendix A and Appendix B, respectively.

2.7.1.1 Aquatic Invasive Species Interception

Several non-native invasive aquatic species identified by the WDFW (2001) are of concern for boaters in Washington State, including PNNL staff operating research watercraft, and are addressed by PNNL's Aquatic Invasive Species Interception Program. These include some Prohibited Level 1 and Prohibited Level 3 species listed by the state of Washington (WAC 220-640-030 and WAC 220-640-050, respectively). Prohibited Level 1 and Level 3 species are considered to pose either a high (Level 1) or moderate to high (Level 3) invasive risk and are either a priority (Level 1) or may be appropriate (Level 3) for prevention (RCW 77.135.030). Prohibited Level 1 species include zebra mussels (*Dreissena polymorpha*) and quagga mussels (*D. rostriformis bugensis*). Prohibited Level 3 species include New Zealand mud snail (*Potamopyrgus antipodarum*) and all other Dreissenid mussel species. PNNL's Aquatic Invasive Species Interception Program also includes several invasive or potentially invasive tunicate species (e.g., club tunicate [*Styela clava*]), identified by WDFW (Pleus et al. 2008), and aquatic plant species such as Eurasian water milfoil (*Myriophyllum spicatum*), a Class B noxious weed (WAC 16-750-011). Class B noxious weeds are species designated for control where they are not yet widespread, to prevent new infestations (WNWCB 2020).

PNNL's Aquatic Invasive Species Interception Program prevents the conveyance and dispersal of the species listed above. Water bodies are researched beforehand to determine if there are known invasive species present, and if there are any specific state requirements and control programs. In addition, the boat manifest details invasive species known to exist in the body of water where the launch is planned. Watercraft, equipment, and trailers recovered from infested water bodies are self-inspected, decontaminated, and quarantined according to protocols specific to the type or types of infestation: aquatic weed, tunicate, and/or New Zealand mud snail and Dreissenid mussel (Zook and Phillips 2012). The boat operator is responsible for meeting PNNL invasive species-specific requirements, completing a PNNL Watercraft and Trailer Self-Inspection Form, where applicable, and submitting the inspection form to the boat custodian. Boat custodians notify boat operators of watercraft condition and status relative to completion of decontamination and quarantine requirements prior to launch.

2.7.1.2 Noxious Weed Control

Several non-native plant species listed as Class B or Class C noxious weeds (as classified by the state of Washington, WAC 16-750-011 and WAC 16-750-015, respectively) have been identified on the PNNL Richland Campus (Larson and Downs 2009; Duncan et al. 2019; see Appendix A). Class B noxious weeds are species designated for control where they are not yet widespread to prevent new infestations (WNWCB 2020). On the PNNL Richland Campus, Class B species include:

- broadleaf pepperweed (*Lepidium latifolium*),
- burning-bush (*Bassia* [*Kochia*] *scoparia*),
- cotton [Scotch] thistle (*Onopordum acanthium*),
- diffuse knapweed (*Centaurea diffusa*),
- puncturevine (*Tribulus terrestris*),
- rush skeletonweed (*Chondrilla juncea*),
- Russian knapweed (*Rhaponticum* [*Acroptilon*] *repens*), and
- yellow starthistle (*Centaurea solstitialis*).

Rush skeletonweed occurs throughout areas of natural vegetation on the PNNL Richland Campus and is most prevalent in previously disturbed areas or along road edges. It spreads by seed and by root, forming dense stands if left unchecked. Diffuse knapweed occurs sporadically throughout areas of natural vegetation and reproduces primarily by seed. Russian knapweed reproduces by seed and roots; it can form dense stands where water is adequate. Yellow starthistle is an annual or biennial plant that reproduces by seed; scattered, relatively small patches occur throughout undeveloped areas of the site. Cotton thistle was first identified on the PNNL Richland Campus in 2016. It reproduces by seed. Broadleaf pepperweed occurs in seasonally moist areas (e.g., low areas or near the river). It is a perennial that spreads by seed and root. Burning-bush and puncturevine are annual plants typically found along road edges.

Class C noxious weeds are already widespread, and control is determined on a case-by-case basis at the county level (WNWCB 2020). These species are not typically targeted for control on the PNNL Richland Campus. Known Class C species on the PNNL Richland Campus are:

- baby's-breath (*Gypsophila paniculata*),
- bindweed (*Convolvulus arvensis*),
- bur-grass (*Cenchrus longispinus*),
- common groundsel (*Senecio vulgaris*),
- common St. John's-wort (*Hypericum perforatum*),
- creeping [Canada] thistle (*Cirsium arvense*),
- heart-podded hoarycress (*Lepidium draba*),
- Himalayan blackberry (*Rubus bifrons*),
- reed canarygrass (*Phalaris arundinacea*),
- Russian olive (*Elaeagnus angustifolia*), and
- tree-of-heaven (*Ailanthus altissima*).

Since 2010, PNNL has carried out a noxious weed control program on the PNNL Richland Campus. Certified Facilities and Operations staff, in coordination with staff ecologists, use hand-spraying methods (spot application of herbicide to individual weeds within a surveyed/traversed area) to control populations of Class B noxious weeds in upland areas of natural vegetation. The hand-spraying method facilitates avoidance of non-target (i.e., native) species. The herbicide applied is Milestone™ (along with

water conditioner, drift control agent, surfactant, and blue visibility dye). Hand-pulling or chopping is used opportunistically for those species for which mechanical control is effective (e.g., annual or biennial plants with limited occurrence such as yellow starthistle and cotton thistle).

Control efforts in 2019 (Figure 2.1) and recent years have reduced the density and helped prevent the spread of certain Class B noxious weeds on the PNNL Richland Campus. The primary target species of the treatment program in 2019 were rush skeletonweed, diffuse knapweed, and Russian knapweed, and were focused on areas north of Horn Rapids Road. Yellow starthistle and cotton thistle were sprayed when encountered during herbicide application days. They were also hand-pulled (yellow starthistle) or hand-chopped to the ground and flower heads were bagged (cotton thistle) when observed outside of the spray period (Figure 2.2). Herbicide application was conducted on four days between May 23 and June 26, 2019.

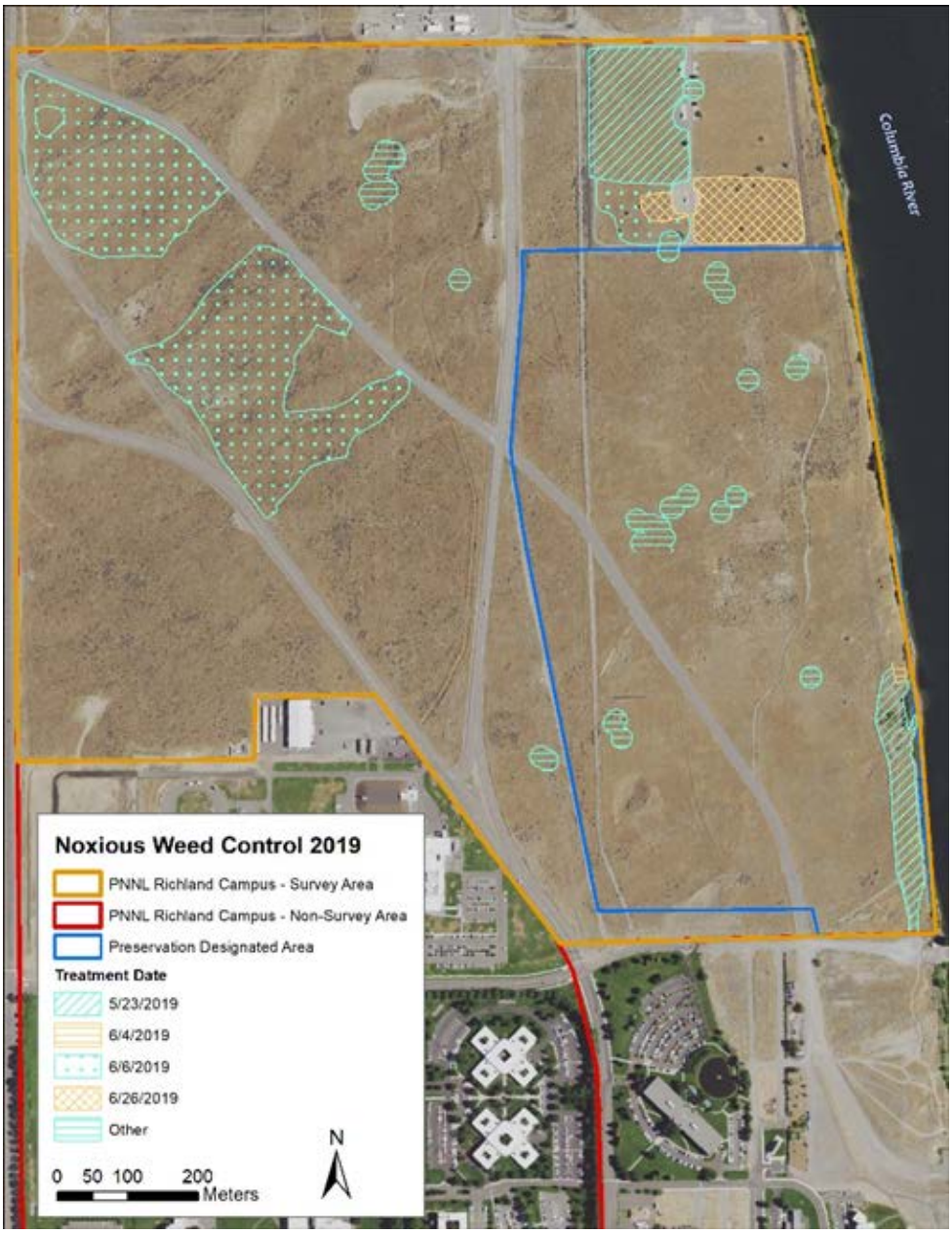


Figure 2.1. Areas Treated for Noxious Weeds on the PNNL Richland Campus in 2019

Figure 2.2. Cotton Thistle Before (left) and After (right) Hand-Chopping for Removal and Disposal of Flower Heads

2.7.1.3 Habitat Mitigation

In 2013, PNNL began site preparation in support of Phase 2 construction of the PSF. The initial land clearing for this development phase resulted in the loss of approximately 6.6 ha (16.3 ac) of mature sagebrush steppe habitat. As stipulated in the mitigation action plan prepared for this activity (DOE-PNSO 2013), this habitat loss needed to be mitigated. PNNL performed compensatory mitigation for this habitat loss by working with the National Fish and Wildlife Foundation and the USFWS to establish replacement habitat on the Fitzner-Eberhardt Arid Lands Ecology Reserve, which is part of the Hanford Reach National Monument. The USFWS coordinated the planting of 112,158 shrub seedlings in three plots over approximately 321 ha (794 ac) in early December 2016. Approximately three-quarters of the shrub seedlings were big sagebrush, and the balance consisted of antelope bitterbrush, winterfat (*Krascheninnikovia lanata*), snow buckwheat, green rabbitbrush, gray rabbitbrush, spiny hopsage (*Grayia spinosa*), and purple sage (*Salvia dorrii*). Twenty-four monitoring transects were established in the spring of 2017 and the numbers of plants by species (composing more than 1% of the total number of seedlings planted in 2016) were counted; survival was assessed in 2018. Sagebrush survival was approximately 30%, snow buckwheat was approximately 60%, bitterbrush 50%, and rabbitbrush 18%. Survival will be assessed again in spring 2020 and 2022.

2.7.2 Cultural Resources

The cultural resources at PNNL represent thousands of years of human land use. A number of federal laws, regulations, and Executive Orders provide the framework for protection of cultural resources on the PNNL Richland and Sequim Campuses. This section summarizes the requirements and catalogs PNNL's compliance activities in 2019.

The *National Historic Preservation Act of 1966* (NHPA; 54 U.S.C. § 300101 et seq.) and its amendments established historic preservation as a national policy and define it as the protection, rehabilitation, restoration, and reconstruction of districts, sites, buildings, structures, and objects that are significant in American history, architecture, archaeology, or engineering. The Act also expanded the National Register of Historic Places (NRHP) listing to include resources of state and local significance, and it established the Advisory Council on Historic Preservation as an independent federal agency. As a result of Public Law 113-287 (enacted on December 19, 2014), the *National Historic Preservation Act of 1966* was repealed from 16 U.S.C. § 470 et seq., and reenacted in 54 U.S.C. Subtitle III, *National Preservation*

Programs, Division A, "Historic Preservation." Section 106 of the NHPA specifically requires federal agencies to consider the impact of federally funded, permitted projects or projects occurring on federally managed lands on cultural resources that are eligible for listing or listed in the NRHP. At PNNL the cultural resources review process supports compliance with NHPA Section 106.

The *Antiquities Act of 1906* (54 U.S.C. § 320301–320303 and 18 U.S.C. § 1866(b)) provided for the protection of historic and prehistoric remains and structures on federal lands. It established a permit system for conducting scientific archaeological investigations and established criminal penalties and fines to manage looting and vandalism of archaeological sites on public lands. By the 1970s, the penalties were no longer commensurate with the severity of the offenses, and in 1974 the Ninth Circuit Court of Appeals proclaimed the Act to be unconstitutionally vague. In response, Congress enacted the *Archaeological Resources Protection Act of 1979* (16 U.S.C. § 470aa). As a result of Public Law 113-287 (enacted on December 19, 2014), the *Antiquities Act of 1906* was repealed from 16 U.S.C. § 431–433 and reenacted in 54 U.S.C. § 320301–320303, *Monuments, Ruins, and Objects of Antiquity*, and 18 U.S.C. § 1866(b), *Historic, Archeologic, or Prehistoric, Items and Antiquities*.

The *Archaeological Resources Protection Act of 1979* (16 U.S.C. § 470aa-mm) provides for the protection of archaeological resources and sites on federal and tribal lands. It also describes the conditions required preceding the issuance of a permit to excavate or remove any archaeological resource, the curation and record requirements for resource removal or excavation, and the penalties for convicted violators. At PNNL, the annual site monitoring activities support compliance with the *Archaeological Resources Protection Act of 1979*.

The *Native American Graves Protection and Repatriation Act of 1990* (25 U.S.C. § 3001 *et seq.*) established a means for Native Americans to request the return of human remains and other sensitive cultural articles held by federal agencies. It also contains provisions regarding the requirement to inventory any remains and associated funerary objects, the intentional excavation of remains or cultural items, and the illegal trafficking of those items.

The *American Indian Religious Freedom Act* (42 U.S.C. § 1996 *et seq.*) was established in 1978 for the protection and preservation of the traditional religious ceremonial rights and cultural practices of American Indians. These rights include access to sacred sites, repatriation of sacred items held in museums, and freedom to worship through traditional ceremonies. The Act also required governmental agencies not to interfere with Native American religious practices and to accommodate access to and use of religious sites to the extent that the use is practicable and consistent with an agency's essential functions. Because the *American Indian Religious Freedom Act* could not enforce its provisions, the *American Indian Religious Freedom Act Amendments of 1994* were established to provide for the management of federal lands "in a manner that does not undermine or frustrate traditional Native American religions or religious practices" (103 HR 4155).

The *Archeological and Historic Preservation Act of 1974* (54 U.S.C. § 312501–312508) provides for the preservation of historical American sites, buildings, objects, and antiquities of national significance. It also imparts the preservation of historical and archaeological data (including relics and specimens), which might otherwise be irreparably lost or destroyed, and requires preservation of significant historical and archaeological data affected by any federal or federally related land modification activity. As a result of Public Law 113-287 (enacted on December 19, 2014), the *Archeological and Historic Preservation Act of*

1974 was repealed from 16 U.S.C. § 469–469c-2 and reenacted in 54 U.S.C. § 312501–312508, Preservation of Historical and Archaeological Data.

Executive Order 11593 of May 15, 1971, "Protection and Enhancement of the Cultural Environment" (36 FR 8921), requires federal agencies to inventory their cultural resources and establish policies and procedures to assure the protection, restoration, and maintenance of any sites, structures, or objects of historical, architectural, or archaeological significance.

Executive Order 13007 of May 29, 1996, "Indian Sacred Sites" (61 FR 26771), directs federal agencies to accommodate access to and ceremonial use of Indian sacred sites and to avoid adversely affecting the physical integrity of these sites. Where appropriate, agencies shall maintain the confidentiality of sacred site locations.

Executive Order 13175 of November 6, 2000, "Consultation and Coordination with Indian Tribal Governments" (65 FR 67249), directs federal agencies to develop a process for assuring meaningful tribal input when developing regulatory policies that have tribal implications and to consult with tribal authorities.

Executive Order 13287 of March 3, 2003, "Preserve America" (68 FR 10635), directs federal agencies to increase their knowledge of historic resources in their care, enhance the management of these assets, and seek partnerships with state, tribal, and local governments to make better-informed and efficient use of those resources.

DOE Policy 141.1, "Department of Energy Management of Cultural Resources," assures that DOE maintains a program that reflects the spirit and intent of cultural resource legal mandates. Two specific goals are to:

- assure that DOE programs and field elements integrate cultural resources management into their missions and activities, and
- raise the level of awareness within DOE concerning the importance of the Department's cultural resource-related legal and trust responsibilities.

The purpose of DOE Order 144.1, Admin Chg 1, *Department of Energy American Indian Tribal Government Interactions and Policy*, is to communicate the departmental, programmatic, and field responsibilities for interacting with American Indian Governments and to communicate DOE's American Indian and Alaska Native Tribal Government Policy, including its Guiding Principles and implementation framework.

Most of the work completed by the cultural resources program at PNNL is focused on Section 106 compliance, as required by the NHPA. The NHPA requires federal agencies to consider the effect of their project on any district, site, building, structure, or object that may be eligible for inclusion in the NRHP in order to avoid, minimize, or mitigate these impacts.

In FY 2019, the PNNL cultural resources program supported 38 projects by performing surveys or verifying results from previous surveys. Ten of the 38 projects were activities exempt under existing agreement documents. Twelve archaeological sites were re-evaluated, and five new sites were identified and documented. These findings were reported to the Washington State Department of Archaeology and Historic Preservation.

The PNNL cultural resources program continues to consult with the Plateau Tribes (Confederated Tribes of the Colville Reservation, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of the Yakama Nation, the Nez Perce, and the Wanapum) for undertakings on the PNNL Richland Campus. For undertakings on the PNNL Sequim Campus, consultation is directed at the Peninsula tribes, including the Hoh Indian Tribe, Jamestown S'Klallam Tribe, Lower Elwha Klallam Tribe, the Lummi Nation, Makah Indian Tribe of the Makah Indian Reservation, Port Gamble S'Klallam Tribe, and the Quileute Nation. The Confederated Tribes of Warm Springs of Oregon are also regularly consulted.

2.7.2.1 Section 110 Activities

PNNL's cultural resources program performs annual site condition monitoring to comply with NHPA Section 110. Annual site condition monitoring also enables PNNL cultural resources staff to determine if the integrity of known resources has been compromised in any way.

Annual Section 110 monitoring was conducted on October 9, 2019. Monitoring was conducted by the PNNL cultural resources staff with the participation of PNSO and tribal cultural resources staff. Photographs and field notes were taken at set points for each archaeological site to assess the site condition and identify potential changes to the site caused by human or natural causes. In addition, information was collected and added to file records to update the current knowledge of the sites.

No previously unrecorded impacts at any of the sites monitored were identified during the 2019 monitoring trip. Previously noted manmade disturbances are no longer visible, because vegetation has completely covered them. Animals have increasingly used the area, as noted by the significant increase in game trails, animal droppings, burrowing, tracks, and other activities. Overall, there was larger vegetation growth throughout. Sites will continue to be monitored annually.

2.8 Radiation Protection

PNNL is subject to the radiation protection statutes and regulations designed to protect the health and safety of the public, the workforce, and the environment.

2.8.1 DOE Order 458.1, Radiation Protection of the Public and the Environment

During the reporting period of this annual site environmental report, PNNL was working under the requirements of DOE Order 458.1, January 2013 (Admin Chg 3). Section 2.d (As Low As Reasonably Achievable [ALARA]), Section 2.g (Control and Management of Radionuclides from DOE Activities in Liquid Discharges), and Section 2.k (Release and Clearance of Property) of DOE Order 458.1 were added to PNNL's contract with PNSO in July 2011 and were fully implemented on September 1, 2012.

Section 2.d of DOE Order 458.1 requires each contractor to establish an environmental ALARA process to control and manage radiological activities so that doses to the public and releases to the environment are kept ALARA (Figure 2.3). The ALARA process must be applied to the design or modification of facilities and to the conduct of radiological work activities.

Section 2.g of DOE Order 458.1 requires each contractor to establish and implement procedures and practices related to control and management of radionuclides from DOE activities in liquid discharges.

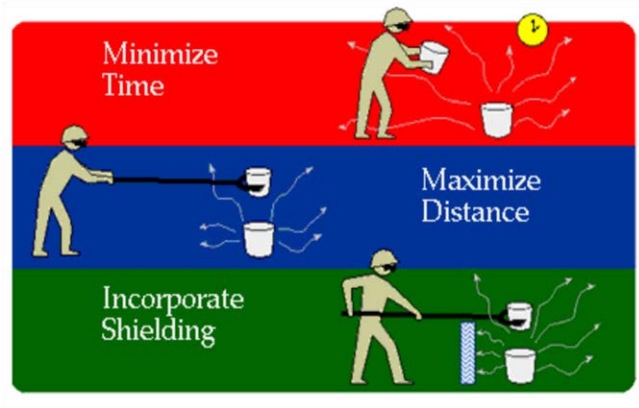


Figure 2.3. Elements of the As Low As Reasonably Achievable (ALARA) Principle

Section 2.k of DOE Order 458.1 provides the requirements with which each contractor must comply when releasing property that potentially contains residual radioactivity. Dose constraints for the public are established based on the type of property (i.e., personal property and real property). Requirements for releasing property based on process knowledge, radiological surveys, or a combination of both are provided. The process of obtaining pre-approved release limits and activity-specific release limits for releasing property is also described in the Order. The public is required to be notified annually of property released from contractor facilities.

PNNL radiation protection procedures implement Sections 2.d and 2.k of DOE Order 458.1. Procedures include guidance on the environmental ALARA program, the use of process knowledge and historical knowledge when releasing property, the preparation and approval of requests for authorized limits, and the preparation of an annual site environmental report. A description of PNNL programs that implement these sections of the Order is found in Section 4.3 of this report.

No property with detectable residual radioactivity above guideline limits was released in 2019.

A description of how PNNL complies with the liquid discharge requirements in Section 2.g of DOE Order 458.1 is found in Section 4.1 of this report.

2.8.2 DOE Order 435.1, Radioactive Waste Management

The purpose of DOE Order 435.1 is to establish requirements for assuring that DOE radioactive waste is managed in a manner that is protective of workers public health and safety, and the environment. The Order takes a cradle-to-grave approach to managing waste and includes requirements for waste generation, storage, treatment, disposal, and post-closure monitoring of facilities.

Radioactive waste shall be managed such that the requirements of other DOE Orders, standards, and regulations are met, including the following:

- 10 CFR Part 835, "Occupational Radiation Protection"
- DOE Order 440.1B, Chg 2, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees*
- DOE Order 458.1, Admin Chg 3, *Radiation Protection of the Public and the Environment.*

DOE Order 435.1 establishes requirements for the management of high-level waste, transuranic waste, and low-level waste. It also covers mixed waste (i.e., high-level waste, transuranic waste, or low-level waste that also contain chemically hazardous constituents). DOE Order 435.1 (approved in 1999) superseded a previous set of requirements (DOE Order 5820.2A, dated September 26, 1988) for managing radioactive waste. DOE Order 435.1, Chg 1, approved in 2001, includes minor revisions to the original Order and was formally certified again in 2007.

PNNL's Radioactive Waste Management Basis Program identifies the hazards associated with radioactive waste management at PNNL along with their potential impacts. Controls for the protection of the public, workers, and environment are also presented. Controls are implemented through internal PNNL workflows and waste-management procedures.

2.8.3 Atomic Energy Act of 1954

The *Atomic Energy Act of 1954* (42 U.S.C. § 2011 *et seq.*) was promulgated to assure the proper management of radioactive materials. Through the Act, DOE regulates the control of radioactive materials under its authority, including the treatment, storage, and disposal of low-level radioactive waste from its operations, and establishes radiation protection standards for itself and its contractors. Accordingly, DOE promulgated a series of regulations (e.g., 10 CFR Part 820, 10 CFR Part 830, and 10 CFR Part 835) and directives (e.g., DOE Order 435.1, Chg 1 [Section 2.8.2] and DOE Order 458.1, Admin Chg 3 [Section 2.8.1]) to protect public health and the environment from potential risks associated with radioactive materials. PNNL complies with the *Atomic Energy Act of 1954* through its Radiation Protection Management and Operation Program and Radioactive Waste Management Basis Program.

2.9 Major Environmental Issues and Actions

Releases of radioactive and regulated materials to the environment are reported to DOE and other federal, state, and/or local agencies as required by law. The specific agencies notified depend on the type and amount of material released, and the location of each release event. This section describes any releases to the environment that occurred at PNNL during CY 2019.

2.9.1 Continuous Release Reporting

A continuous release is a hazardous release exceeding reporting thresholds under CERCLA regulations (40 CFR 302.8) that is "continuous" and "stable in quantity and rate" for which reduced reporting requirements apply. There were no continuous releases on the PNNL Richland Campus or PNNL Sequim Campus in 2019.

2.9.2 DOE Order 232.2A, Occurrence Reporting and Processing of Operations Information

DOE Order 232.2A requires the reporting of incidents that could adversely affect the public or workers, the environment, or the mission that occur at DOE sites and/or during DOE operations. Releases requiring regulatory agency notification (Section 2.9.3) and receipt of formal or informal regulator correspondence alleging violations (Section 2.6) are required to be reported to DOE through the reporting system. PNNL reports all incidents to DOE as required.

2.9.3 Unplanned Releases

No environmentally significant releases occurred at PNNL in 2019.

2.10 Summary of Permits

Table 2.6 summarizes air, liquid, and hazardous waste permits for the PNNL Richland Campus and PNNL Sequim Campus during 2019. Project-specific permits are also acquired but are not reflected in the table because they are usually of limited term and scope.

Table 2.6. PNNL Air, Liquid, and Hazardous Waste Permits, 2019

Issuer	Permit #	Location(s) Regulated	Activity(ies) Regulated	Expiration Date[a]
Air Emissions				
Washington State Department of Health	FF-01[b]	PNNL-occupied locations on the Hanford Site	Radioactive air emissions	10/20/2022
Washington State Department of Health	RAEL-005	PNNL Richland Campus	Radioactive air emissions	6/17/2020
Washington State Department of Health	RAEL-014	PNNL Sequim Campus	Radioactive air emissions	1/1/2023
Washington State Department of Ecology	00-05-006, Renewal 3	PNNL-occupied locations on the Hanford Site	Radioactive and nonradioactive air emissions	8/1/2024
Benton Clean Air Agency	Order 2019-0005	PNNL Site – EMSL, PSF Complex, LSL2 Halogenated Solvent Degreaser	Nonradioactive air emissions	None
Benton Clean Air Agency	Order 2012-0017	PNNL Richland Campus – Building Operations	Nonradioactive air emissions	None
Benton Clean Air Agency	Order 2012-0016	PNNL Richland Campus – R&D Pilot-Scale Processes and Field Experiments	Nonradioactive air emissions	None
Benton Clean Air Agency	Order 2007-0006, Rev. 1	Life Sciences Laboratory II – Building Operations	Nonradioactive air emissions	None
Washington State Department of Ecology	Order 02NWP-001	300 Area Standby Generators (Radiochemical Processing Laboratory & 331 Buildings)	Nonradioactive air emissions	None
Olympic Region Clean Air Agency	Order of Approval 13NOI968	PNNL Sequim Campus Standby Generators	Nonradioactive air emissions	None

Issuer	Permit #	Location(s) Regulated	Activity(ies) Regulated	Expiration Date[a]
Liquid Effluents[c]				
City of Richland	CR-IU001	PNNL Richland Campus	Liquid effluent discharges to city sewer	4/1/2020
City of Richland	CR-IU005	W.R. Wiley Environmental and Molecular Sciences Laboratory	Liquid effluent discharges to city sewer	8/21/2022
City of Richland	CR-IU011	Physical Sciences Facility (new buildings north of Horn Rapids Road)	Liquid effluent discharges to city sewer	3/9/2023
City of Richland	CR-IU010[b]	PNNL-occupied locations on the Hanford Site	Liquid effluent discharges to city sewer	11/30/2021
Washington State Department of Ecology	ST 4511[b]	PNNL-occupied locations in the Hanford Site 300 Area	Discharge of wastewater from maintenance, construction, and hydro testing activities; allows for cooling water, condensate, and industrial stormwater discharges to ground	12/31/2019
Washington State Department of Ecology	ST-9274	Biological Sciences Facility and Computational Sciences Facility	Reinjection of well water used in ground-source heat pump	6/6/2020
Washington State Department of Ecology	WA0040649	PNNL Sequim Campus	Treated liquid effluent discharges to Sequim Bay	11/30/2022
Washington State Department of Ecology	WA0026859	PNNL Scientific Focus Area Tracer Injection Project	Tracer injection into water sampling tubes to study the interaction of groundwater and surface water along the Columbia River shoreline	5/31/2023
Hazardous Waste				
Washington State Department of Ecology	WA7890008967	325 Hazardous Waste Treatment Units (located in the 300 Area)	Treatment and storage of dangerous waste (primarily mixed waste)	9/27/2004

(a) Expired permits generally remain in force while renewal applications are processed by the issuing agency.
(b) Permit is issued to DOE-Richland Operations Office and/or its contractor(s); PNNL is obligated to comply with these permits through an operating agreement between the DOE-Richland Operations Office and the Pacific Northwest Site Office.
(c) PNNL also conducts activities in leased facilities that have wastewater permits issued to the owner. These permits are not listed here, but compliance-related impacts from PNNL activities are included in this report.

3.0 Environmental Management System

PNNL has a mature, robust EMS that has been certified to meet the requirements of ISO 14001 standards since 2002. The EMS is integrated into PNNL's Integrated Safety Management Program, which assures that staff are aware of project scope, risks/hazards, and controls available to address functions, processes, and procedures used to plan and perform work safely. The outcome of the integration is the accomplishment of PNNL missions while protecting the worker, the public, and the environment.

Management at PNNL periodically assesses environmental performance from a programmatic perspective to determine whether issues require attention and to facilitate the identification and communication of best management practices. PNNL management also routinely evaluates progress on key environmental improvement projects.

The EMS is audited annually to verify that it is operating as intended and in conformance with ISO 14001 standards. In early 2020, PNNL successfully renewed its ISO 14001:2015 Certificate of Registration through 2023 (Figure 3.1). In addition, the 2019 EMS performance data submitted to the Federal Facilities Environmental Stewardship & Compliance Assistance Center received a "Green" score for the EMS performance metrics listed below.

- Environmental aspects were identified or re-evaluated using an established procedure and updated as appropriate.
- Measurable environmental goals, objectives, and targets were identified, reviewed, and updated as appropriate.
- Operational controls were documented to address significant environmental aspects consistent with objectives, and targets were fully implemented.
- Environmental training procedures were established to assure that training requirements for individual competence and responsibility were identified, carried out, monitored, tracked, recorded, and refreshed as appropriate to maintain competence.
- EMS requirements were included in all appropriate contracts, and contractors fulfilled defined roles and specified responsibilities.
- EMS audit/evaluation procedures were established, audits were conducted, and nonconformities were addressed or corrected.
- Senior leadership review of the EMS was conducted, and management responded to recommendations for continual improvement.

NSF ISR

Certificate of Registration

This certifies that the Environmental Management System of

Battelle - Pacific Northwest Division

Pacific Northwest National Laboratory
902 Battelle Boulevard
Mail Stop J2-25
Richland, Washington, 99354, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 14001:2015

Scope of Registration:
Pacific Northwest National Laboratory, operated by Battelle for the U.S. Department of Energy: Research and development activities and associated facilities operations.

Certificate Number: 6Z781-EM10
Certificate Issue Date: 17-JAN-2020
Registration Date: 26-JAN-2020
Expiration Date *: 25-JAN-2023

Tom Chestnut,
Sr Vice President - ISR,
NSF-ISR, Ltd.

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Figure 3.1. Certificate of Registration for PNNL Conformance with ISO-14001:2015 Standards

PNNL examines its operations to determine which categories of environmental impacts (referred to as "aspects" in the ISO 14001 standards) have the greatest potential to occur, and therefore, require consideration and control through the EMS process. PNNL performs annual environmental aspect and impact analyses, including risk analyses and work evaluations, to assure regulatory requirements and any concerns of the public or other interested parties are addressed. The 11 most significant aspects and the EMS controls used to minimize the potential impacts of each aspect are as follows:

- Chemical Use and Storage. As a research laboratory, PNNL has many buildings in which chemicals/biological materials are used and/or stored for research operations and maintenance activities. Controls used to avoid potential hazards include training, inventory control procedures, approvals prior to requisitioning, and work procedures for chemical/biological material use, as well as adequate safety requirements. PNNL implements a "ChemAgain" program, which redistributes surplus chemicals internally in an effort to reduce PNNL's chemical waste.
- Biological Material Use and Storage. As a research laboratory, PNNL has many buildings in which biological materials are used and/or stored for research activities. Controls used to avoid potential hazards include training and work procedures for biological material use and adequate safety requirements.
- Regulated Waste Generation. The use of chemical and radioactive materials creates waste streams that may be regulated as dangerous waste, radioactive waste, or both dangerous and radioactive (mixed) waste. Wastes within these categories are subject to the regulations of the Washington State Department of Ecology (for dangerous and mixed waste) and DOE (for radioactive and mixed waste). In addition to the controls imposed by these requirements, PNNL seeks to reduce generated wastes. Projects are regularly reviewed, and procedures are scrutinized to minimize the production of regulated wastes. Any generated waste may be treated to be made less hazardous or nonhazardous for proper disposal.
- Radioactive Material Use and Storage. Research at PNNL may involve the use of radioactive materials. All radioactive materials are labeled and controlled. Controls include restricted access to radiation areas and special training requirements for staff requiring access.
- Emissions to Air. Potential air emissions are evaluated, and permits are obtained when required. Active controls for the management of chemicals, radioactive materials, and regulated wastes seek to minimize PNNL air emissions. Sources of air emissions include boilers, diesel generators, vehicle exhaust, R&D activities, and facility and grounds maintenance and operations.
- Effluents to Water. PNNL seeks to minimize liquid discharges to the environment. Discharges include laboratory drain water to sewer systems and stormwater to dry wells in parking lots, which are regulated by state and local permits and/or regulations. Discharges are evaluated to assure they conform to regulations and permits.
- Energy Use. Using energy judiciously is a prime objective at PNNL. Energy reduction goals are established and activities to reduce energy consumption are implemented.
- Solid Waste Generation. The use of office products, electronics, and equipment, along with construction, demolition, and normal maintenance activities, create nonregulated solid waste streams. Reduction or elimination of environmental hazards, conservation of environmental resources, and maximization of operational sustainability are achieved through the incorporation of electronic stewardship practices, reuse of materials, and operation of recycling programs.

- Fuel Usage. PNNL seeks to minimize the use of petroleum-based fuels by purchasing vehicles that use alternative fuels, such as ethanol-85, and by acquiring high-fuel–efficiency vehicles, including hybrid and all-electric vehicles. PNNL has also acquired electric vehicles for on-campus transportation and has installed solar-powered electric vehicle charging stations across the Richland Campus. In addition, PNNL was instrumental in obtaining the first biofuel service station in Richland, Washington, and when appropriate, uses bio-diesel to fuel generators.
- Physical Interaction with the Environment. Some PNNL projects are performed outdoors in direct contact with the environment. These projects include facility construction, maintenance, and modifications, as well as occasional R&D activities. Work proposed to be performed outdoors is reviewed to minimize potential impacts and assure the protection of workers, the public, and environmental resources.
- Water Use. PNNL recognizes the value of water in the eastern Washington environment. PNNL maintains water-use reduction goals and implements actions to reduce water consumption.

The benefits of implementing a well-performing EMS include enabling upfront planning to incorporate sustainability and pollution prevention opportunities, early identification of environmental requirements to avoid project delays, high-level integration with existing programs to improve efficiency, reduced operational costs, and enhanced public recognition as a "good neighbor."

PNNL has been using a multi-disciplinary Sustainability Core Team as a best practice to drive continuous improvement in its environmental performance with regard to sustainability and to enable an integrated approach to managing environmental aspects and impacts. The Sustainability Core Team is a diverse, authorized working group composed of key EMS program leads and managers. Core Team members are held accountable for the successful execution of PNNL's sustainability goals and targets.

3.1 Environmental Operating Experience and Performance Measurement

Executive Order 13834 of May 17, 2018, "Efficient Federal Operations" (83 FR 23771), affirms that it is the policy of the United States that agencies meet energy and environmental performance statutory requirements in a manner that increases efficiency, optimizes performance, eliminates unnecessary use of resources, and protects and environment. PNNL's comprehensive and diverse approach meets the principles of Executive Order 13834 requirements. Details about PNNL's plan to advance DOE's sustainability mission are captured in the PNNL *FY 2020 Site Sustainability Plan* (PNNL 2020). The plan contains the annual status and strategy for achieving long-term goals in the areas of energy reduction, sustainable buildings, clean and renewable energy, water-use efficiency and management, fleet management, sustainable acquisition, pollution prevention and waste reduction, energy performance contracts, electronic stewardship, and climate change resilience.

Select sustainability goals, PNNL's 2019 performance status, and planned actions are detailed in Table 3.1.

Table 3.1. Status of Select PNNL Sustainability Goals through FY 2019 and Two-Year Strategy (PNNL 2020)

DOE Goal	FY 2019 Performance Status	2-Year Strategy
Energy Management		
30% energy intensity (kBtu per gross square foot) reduction in goal-subject buildings by FY 2015 from a FY 2003 baseline and 1.0% year over year (YOY), thereafter.	Current Performance: 3.1% increase compared to FY 2015 energy use intensity—a 2.1% YOY increase.	PNNL plans to build three new federal buildings and modernize existing buildings and infrastructure. Projected business growth may increase energy use; however, successful implementation of energy conservation measures is expected to offset energy intensity.
Water Management		
20% potable water intensity (gal per gross square foot) reduction by FY 2015 from a FY 2007 baseline and 0.5% YOY, thereafter.	Current Performance: 67.5% reduction compared to FY 2007 baseline—a 2.9% YOY decrease. New energy-efficient chillers were installed in FY 2019 at a PNNL Richland Campus facility to help reduce potable water used in cooling towers.	Continue implementing site water management plan opportunities for further reductions.
Non-potable freshwater consumption (gal) reduction of industrial, landscaping, and agricultural. YOY reduction has no set target.	Actual: 187,900 kgal—a 2.6% YOY reduction.	Continue implementing site water management plan opportunities for further reductions.
Waste Management		
Reduce at least 50% of nonhazardous solid waste, excluding construction and demolition debris, by sending it to treatment and disposal facilities.	Current Performance: 62%	Continue expanding the nitrile glove recycling program and assessing waste reduction opportunities.
Reduce construction and demolition materials and debris sent to treatment and disposal facilities. YOY reduction; no set target.	Diverted 79% through recycling	Continue monitoring construction and demolition recycling performance and improve waste diversion requirements awareness.

DOE Goal	FY 2019 Performance Status	2-Year Strategy
Clean and Renewable Energy		
"Renewable Electric Energy" requires that renewable electric energy account for not less than 30.5% of a total agency electric consumption.	Current Performance: 23.3%	PNNL will meet the DOE renewable electric energy goal of 30.5% of annual electric consumption, and the 7.5% goal per 42 United States Code (U.S.C) 15852 through onsite generation and renewable energy certificates (RECs), when cost effective.
Continue to increase renewable energy as percentage of total energy usage (electric and non-electric thermal usage). YOY increase; no set target, but an indicator in the Office of Management and Budget scorecard.	Current Performance: 17%	PNNL will meet the renewable electric energy goal of 7.5% of annual electric consumption per 42 U.S.C 15852, through onsite generation and RECs, when cost effective.
Green Buildings		
At least 15% (by count) of owned existing buildings to be compliant with the revised Guiding Principles for High-Performance Sustainable Buildings by FY 2020, with annual progress, thereafter.	Current Performance: 43%	All new facilities will meet the Guiding Principles.
Electronic Stewardship		
Purchases: 95% of eligible acquisitions each year are Electronic Product Environmental Assessment Tool (EPEAT)-registered products.	Current Performance: 98%	Continue to purchase EPEAT-registered products when available.
Power management: 100% of eligible personal computers, laptops, and monitors have power management enabled.	Current Performance: 100%	Continue to implement power management features upon initial setup.
Automatic duplexing: 100% of eligible computers and imaging equipment have automatic duplexing enabled.	Current Performance: 99%	Continue to use duplex printing as default configuration on capable units.
End of Life: 100% of used electronics are reused or recycled using environmentally sound disposition options each year.	Current Performance: 100%	Continue to reuse and recycle electronics.

3.2 Accomplishments, Awards, and Recognition

PNNL achieved several sustainability milestones in FY 2019, with the exception of energy use. Our improvement strategy includes using PNNL's Building Operating Control Center automated controls to improve operations, and to add or upgrade building sensors to support energy conservation efforts. Other accomplishments include those highlighted below.

Innovative Approach to Sustainability

PNNL won the 2019 U.S. Department of Energy (DOE) Sustainability Award for the Innovative Approach to Sustainability for our Voting-based Control for Occupancy Comfort and Energy Savings project.

This innovative project represented a joint effort between PNNL researchers and sustainability engineers using occupant feedback to make real-time thermal comfort adjustments and to modify building operation set points for continuous work environment improvements. This approach was easy to sustain and was reproducible for other laboratories. The three-month pilot turned into a 12-month pilot with additional QuickStarter funding. After 12 months, PNNL saved more than 8,000 kWh (~5%) of electricity, more than 400 MMBtu (~34%) of natural gas, and approximately 70 tons in chilled water compared to the prior year, all while increasing occupants' comfort and optimizing building operations by enabling real-time feedback through interactive operations.

Better Building Smart Labs Accelerator Partner

PNNL is a participant in DOE's Better Building Smart Labs Accelerator Partner Program. In FY 2019, PNNL developed a Smart Labs evaluation tool to help with consistent reviews and for validating buildings and laboratory spaces as "Smart Labs." To date, PNNL has qualified one building and 20 laboratory spaces using the Smart Labs evaluation tool. PNNL plans to repeat this process for new facilities and existing buildings, where appropriate. PNNL is in the process of preparing another new facility for the start of construction in early spring of 2020—the Energy Science Capability (ESC) building. This facility will be the next sustainable laboratory building compliant with the 2016 Guiding Principles and will be equipped with controls and sensors enabling Smart Labs operation.

4.0 Radiological Environmental Monitoring and Dose Assessment

This section describes the environmental monitoring programs for radiological constituents and the associated estimated dose assessments for the PNNL Richland Campus. Reported doses are calculated rather than measured, so they represent potential or estimated, rather than actual, doses.

4.1 Radiological Liquid Discharges and Doses

PNNL prohibits the discharge of liquid waste streams that contain radiological material to sanitary sewer systems, the ground, or surface water. Wastewater in PNNL facilities is expected to be free of radioactive materials but may have the potential for contamination in the event of a failure of an engineered barrier or administrative control. In facilities in which wastewater generated in radiologically controlled areas has the potential to become contaminated, it is discharged to retention tanks. After each retention tank is filled, it is isolated, and its contents are analyzed for radiological components. The results of the analyses are compared to screening limits in WAC 246-221-190, "Disposal by Release into Sanitary Sewerage Systems." If the analytical results indicate that the concentrations of radiological components in the wastewater are below the WAC screening limit, the wastewater is released to the City of Richland's sanitary sewer system. If the analytical results indicate that the concentrations of radiological components in the wastewater are above the WAC screening limit, the wastewater is transported to a waste treatment facility. These wastes may be transferred and discharged to a treatment facility authorized or permitted to receive radiological material. Further evaluation is then performed to determine the source of the radiological component in the discharge.

The City of Richland may authorize the discharge of individual waste streams that contain radiological material to the sewer system. As described in Section 4.1.1, there is currently only one authorized discharge of a liquid waste stream containing radiological material to the City of Richland sanitary sewer.

4.1.1 Annual Report for DOE Order 458.1

This report has been prepared in accordance with DOE Order 458.1 (4)(g)(8)(a)(7), which requires that the contractor prepare and provide a report that describes and summarizes discharges of liquids containing radionuclides from DOE activities into non-federally owned sanitary sewers. PNNL has one waste stream that has the potential for containing radionuclides that is approved for discharge to the City of Richland's sanitary sewer system. This waste stream is associated with fume hood washdown operations in PSF.

On November 2, 2010, the City of Richland authorized the release of "…very low levels of volumetrically released radioactive material." These volumetrically released radioactive materials can be handled without concern for measurable contamination and without radiological postings or labeling pursuant to 10 CFR Part 835.

The total amount of radioactive material used in each fume hood is very small. Each washdown is estimated to be 190 L (50 gal). The worst-case concentration of radioactivity in each washdown is estimated to be 7.1×10^{-7} pCi/L.

In 2019, the fume hoods were washed down an estimated total of 28 times. The screening criteria, as referenced in the City of Richland's Industrial Wastewater Discharge Permit CR-IU011 for PSF, are based on WAC 246-221-190, Appendix A, Table III. The screening limits for each washdown are 20 pCi/L for gross alpha activity and 100 pCi/L for beta/gamma activity. If all activity in each washdown is conservatively presumed to be alpha activity, the concentration of radioactive material is more than a million times less than these WAC screening limits. This affirms that the washdowns are negligible in terms of the screening limits for discharge to the City of Richland's sewer systems.

4.2 Radiological Air Discharges and Doses

The federal regulatory standard for a maximum dose to any member of the public is 10 mrem/yr (0.1 mSv/yr) EDE. The standard is set forth in 40 CFR Part 61, Subpart H, and applies to radionuclide air emissions other than radon from DOE facilities.

Washington State has adopted the federal dose standard of 10 mrem/yr (0.1 mSv/yr) EDE in WAC 246-247-040(1). In addition to the maximum dose attributable to radionuclides emitted from point sources, WAC 246-247-060(6) requires that the dose to the MEI include doses attributable to fugitive emissions, radon, and nonroutine events.

Radionuclide air emissions are routinely sampled and tracked at the PNNL Richland Campus and PNNL Sequim Campus. Regulatory compliance reporting and monitoring results are reported in an annual air emission report for each location (Snyder et al. 2020a; Snyder and Barnett 2020). CY 2019 data are summarized in the following sections.

4.2.1 Radiological Air Discharges and Doses – PNNL Richland Campus

Operations are registered with the state of Washington under RAEL–005. For CY 2019, the PNNL Richland Campus MEI location was 0.67 km (0.4 mi) south-southeast of the PSF 3410 Building. Table 4.1 lists the relative contributions of each nuclide to the MEI dose.

There were no nonroutine emissions from the PNNL Richland Campus in CY 2019. Emissions were determined from both sampling and, for non-sampled emissions, by the 40 CFR Part 61, Appendix D method. The CAP88-PC Version 4.0 code was used for estimating dose. The dose of 1.5×10^{-5} mrem (1.5×10^{-7} mSv) effective dose[1] is more than 10,000 times smaller than the 10 mrem/yr WAC 246-247 compliance standard. This dose is many orders of magnitude below the average annual individual background dose of 310 mrem (3.1 mSv) from natural terrestrial and cosmic radiation and inhalation of naturally occurring radon (NCRP 2009). In 2019, modeling was done to determine the location of the maximum offsite radioactive material air concentration. An effective dose of 1.5×10^{-5} mrem (1.5×10^{-7} mSv) was estimated, located at the same place as the MEI.

[1] The EDE and effective dose units can be considered equivalent for the purposes of this report and reflect the units calculated by the software used.

Table 4.1. PNNL Richland Campus Emissions and Dose Contributions by Radionuclide, 2019 (Snyder et al. 2020a)

Radionuclide	Releases (Ci)	Campus MEI Dose (mrem EDE)	Percent of Total EDE
Hydrogen-3 (tritium)	1.2×10^{-4}	1.9×10^{-8}	<1
Sodium-24	4.0×10^{-8}	5.1×10^{-10}	<1
Cobalt-60	5.9×10^{-8}	1.9×10^{-7}	1
Bromine-82	1.3×10^{-8}	2.0×10^{-10}	<1
Rubidium-83	1.4×10^{-10}	4.0×10^{-7}	3
Krypton-83m	4.4×10^{-1}	2.6×10^{-9}	<1
Strontium-82	9.2×10^{-10}	2.0×10^{-10}	<1
Strontium-85	1.8×10^{-8}	2.0×10^{-9}	<1
Yttrium-88	7.4×10^{-10}	5.6×10^{-10}	<1
Xenon-133	2.0×10^{-5}	6.6×10^{-10}	<1
Cesium-137	1.2×10^{-6}	5.7×10^{-6}	37
Lead-210	3.8×10^{-9}	8.6×10^{-8}	1
Lead-214	7.5×10^{-9}	3.0×10^{-10}	<1
Bismuth-210	3.3×10^{-9}	9.3×10^{-10}	<1
Bismuth-214	7.5×10^{-9}	2.7×10^{-10}	<1
Polonium-210	3.2×10^{-9}	5.6×10^{-8}	<1
Radon-222	3.5×10^{-7}	1.5×10^{-10}	<1
Radium-226	8.7×10^{-9}	6.9×10^{-7}	5
Uranium-233/234	3.9×10^{-8}	4.7×10^{-7}	3
Plutonium-238	1.0×10^{-8}	4.4×10^{-7}	3
Plutonium-239/240	1.2×10^{-7}	5.6×10^{-6}	36
Americium-241	5.0×10^{-9}	2.6×10^{-7}	2
Americium-243	1.1×10^{-8}	4.3×10^{-7}	3
Curium-243/244	9.1×10^{-10}	2.7×10^{-8}	<1
All other nuclides	4.1×10^{-7}	9.0×10^{-10}	<1
PIC-5 emissions – VRRM	NA	9.4×10^{-7}[(a)]	6
PIC-5 emissions – NDRM	NA	6.6×10^{-8}[(a)]	<1
PIC-5 emissions – Facilities Restoration	-	0	0
PIC-5 emissions – LLS	-	0	0
Total	4.4×10^{-1}	1.5×10^{-5}	100

(a) The PIC-5 emission doses are assigned based on permit value except for the LLS, which is assigned based on calculations from actual emissions.

To convert Ci to GBq, multiply Ci by 37. To convert mrem to mSv, multiply mrem by 0.01.

LLS = low-level sources; NA = not applicable; NDRM = nondispersible radioactive material; PIC-5 = Potential Impact Category 5; VRRM = volumetrically released radioactive material.

The estimated regional collective dose from PNNL's Richland Campus air emissions in CY 2019 was also estimated using CAP88-PC Version 4.0. Estimates of population exposure to radionuclide air emissions consider site-specific meteorology and population distributions. The population consists of approximately 432,000 people residing within an 80 km (50 mi) radius of the Hanford Site 300 Area (Hamilton and Snyder 2011), with one adjustment to add 640 residents in the sector that accounts for the two phases of apartment units constructed and occupied southwest of the former Research Technology Laboratory (RTL) Complex, which was demolished in 2018.

The close proximity of the Hanford Site 300 Area and relatively rural region within 80 km (50 mi) of the PNNL Richland Campus permits the Hanford Site 300 Area 80 km (50 mi) population estimate to be applicable. Pathways evaluated for population exposure include inhalation, air submersion, ground shine, and consumption of food. The CY 2019 total collective dose from radionuclide air emissions estimated from nuclides that originated from the PNNL Richland Campus was 8.4×10^{-5} person-rem (8.4×10^{-7} person-Sv).

No operations from the storage and disposal of radium-bearing material that result in radon emissions are conducted at the PNNL Richland Campus; therefore, 40 CFR Part 61, Subpart Q, does not apply to PNNL Richland Campus operations. In addition, no uranium milling or uranium ore processing activities are conducted at the PNNL Richland Campus; therefore, 40 CFR Part 61, Subpart T, does not apply to PNNL Richland Campus operations.

4.2.2 Radiological Air Discharges and Doses – PNNL Sequim Campus

PNNL Sequim Campus operations for the sitewide minor, fugitive, nonpoint source emission unit is registered with the state of Washington under RAEL–014. For CY 2019, the PNNL Sequim Campus MEI location was 0.23 km (0.15 mi) west of a central PNNL Sequim Campus emission location (coordinates: 48.078, -123.047). This emission location is central to all operations areas at the PNNL Sequim Campus (Figure 1.3). Radiological operations at the PNNL Sequim Campus emit very low levels of radioactive materials. Table 4.2 lists the relative contributions to the MEI dose. The 40 CFR Part 61, Appendix D method was used to determine the routine emissions from the PNNL Sequim Campus in CY 2019. There were no unplanned emissions from the site during the year. The COMPLY Code (a computerized screening tool for evaluating radiation exposure from atmospheric releases of radionuclides) Version 1.7 (Level 4) was used for estimating dose (EPA 1989).

Table 4.2. PNNL Sequim Campus Emissions and Dose Contributions, 2019 (Snyder and Barnett 2020)

Radionuclide	Releases[(a)] (Ci)	Dose to MEI (mrem EDE)	Percent of Total EDE (Percent)
Iodine-125	1.2×10^{-8}	1.1×10^{-6}	<1
Thorium-232	1.0×10^{-9}	4.9×10^{-5}	18
Remaining alpha (as americium-241)	1.7×10^{-8}	2.3×10^{-4}	82
Remaining beta (as cesium-137)	1.2×10^{-9}	6.4×10^{-7}	<1
Total	3.2×10^{-8}	2.8×10^{-4}	100

(a) Emissions based on 40 CFR Part 61, Appendix D methods.
To convert Ci to GBq, multiply Ci by 37; to convert from mrem to μSv, multiply mrem by 10.

The dose to the PNNL Sequim Campus MEI was 2.8×10^{-4} mrem (2.8×10^{-6} mSv) EDE. This dose is many orders of magnitude below the average annual individual background dose from natural terrestrial and cosmic radiation and inhalation of naturally occurring radon. In 2019, modeling was done to determine the location of the maximum offsite radioactive material air concentration near the PNNL Sequim Campus. The maximum modeled air concentration was 7.8×10^{-4} mrem (7.8×10^{-6} mSv) effective dose where no members of the public routinely inhabit the shore, at the boundary location 0.13 km (0.08 mi) east-northeast of the central PNNL Sequim Campus location.

Collective dose was determined for the estimated 2.35 million people who live within 80 km (50 mi) of the PNNL Sequim Campus; about 362,000 of them reside in Canada (Zuljevic et al. 2016). Victoria, British Columbia, is the only major Canadian city within 80 km (50 mi) of the PNNL Sequim Campus and is more than 32 km (20 mi) away. The maximum collective dose was determined assuming the total CY 2018 PNNL Sequim Campus curies released were dispersed in a single direction, resulting in the maximum collective dose. This direction was determined to be toward the west, which only contains U.S. populations. The MEI dose was multiplied by a population-weighted air concentration for a collective dose of 3.1×10^{-4} person-rem (3.1×10^{-6} person-Sv). If the release were dispersed only to the maximum Canadian sector (north-northwest), the maximum estimated Canadian collective dose would be 1.3×10^{-4} person-rem (1.3×10^{-6} person-Sv).

No storage or disposal of radium-bearing materials occurs at the PNNL Sequim Campus; therefore, 40 CFR Part 61, Subpart Q, does not apply to PNNL Sequim Campus operations. No uranium mill tailings or ore disposal activities have been conducted at the PNNL Sequim Campus; therefore, 40 CFR Part 61, Subpart T, does not apply to PNNL Sequim Campus operations.

4.3 Release of Property Having Residual Radioactive Material

Principal requirements for the release of DOE property having residual radioactivity are set forth in DOE Order 458.1, Admin Chg 3, *Radiation Protection of the Public and the Environment*. These requirements are designed to assure the following:

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

Property as defined in DOE Order 458.1 consists of real property (i.e., land and structures), personal property, and materials and equipment. PNNL has two paths for releasing property to the public: (1) pre-approved surface contamination guidelines for releasing property potentially contaminated on the surface, and (2) pre-approved volumetric release limits for releasing small-volume research samples. A summary of the two release paths is provided in the following sections. No property with detectable residual radioactivity above DOE-authorized levels was released from PNNL during CY 2019.

4.3.1 Property Potentially Contaminated on the Surface

PNNL uses the previously approved surface activity guideline limits (Table 4.3) derived from guidance in DOE Order 458.1 when releasing property potentially contaminated on the surface. As part of research activities conducted in PNNL facilities, PNNL releases hundreds of items of personal property annually for excess to the general public, including office equipment, office furniture, labware, and research equipment. The PNNL Radiation Protection organization has a documented process for releasing items based on process knowledge, radiological surveys, or a combination of both. No property with detectable residual radioactivity above the pre-approved surface activity guidelines was released from PNNL during CY 2019.

In 2013, in accordance with PNNL Prime Contract Section J, Appendix J, paragraph eight (DOE-PNSO 2017), PNNL (Battelle) initiated a survey program with an objective to release five Battelle Memorial Institute-owned buildings for unrestricted use. These facilities include the Engineering Development Laboratory (EDL), Physical Sciences Laboratory (PSL), and LSL2 on the PNNL Richland Campus, and the PNNL Sequim Campus MSL-1 and MSL-5 facilities. In September 2017, PNNL received authorization from PNSO to release EDL, PSL, and LSL2 for unrestricted use. During CY 2018, the PNNL Sequim Campus MSL-1 and MSL-5 facilities had undergone minor mitigation activities and radiological characterization consistent with the radiological clearance process but were not formally cleared because of ongoing and future DOE radiological work scope.

In addition to the survey program of five Battelle Memorial Institute-owned buildings for unrestricted use, the RTL Complex was decommissioned. In CY 2018, the RTL Complex was demolished, and the materials were shipped as waste to the Environmental Restoration Disposal Facility on the Hanford Site. The remaining RTL property was fenced and managed as vacant land while final soil sample results were reviewed. In June 2019, PNNL received authorization from PNSO to release the RTL Complex for unrestricted use.

Table 4.3. Pre-Approved Surface Activity Guideline Limits

Radionuclides	Allowable Total Residual Surface Contamination Limits (dpm/100 cm²)		
	Removable	Total	
		Average	Maximum
Uranium-natural, uranium-235, uranium-238, and associated decay products	1,000	5,000	15,000
Transuranic elements,[a] radium-226, radium-228, thorium-230, thorium-228, protactinium-231, actinium-227, iodine-125, iodine-129	20	100	300
Natural thorium, thorium-232, strontium-90, radium-223, radium-224, uranium-232, iodine-126, iodine-131, iodine-133	200	1,000	3,000
Beta/gamma-emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except strontium-90 and others noted above	1,000	5,000	15,000
Select hard-to-detect radionuclides (carbon-14, iron-55, nickel-59, nickel-63, selenium-79, technetium-99, palladium-107, and europium-155)	10,000	50,000	150,000
Tritium organic compounds; surfaces contaminated with tritium gas, tritiated water vapor, and metal tritide aerosols	10,000	Not applicable	Not applicable

(a) All transuranic elements except plutonium-241, which is treated as a beta/gamma-emitter.
dpm = disintegrations per minute

4.3.2 Property Potentially Contaminated in Volume

Final RTL surface soil surveys were completed during CY 2018 using the MARSSIM process in accordance with DOE Order 458.1. PNNL received the authorized limits listed in Table 4.4 for surface soil at the RTL Complex in 2017. The Oak Ridge Institute for Science and Education (ORISE) conducted an independent verification and confirmed that all results were well below DOE-approved authorized limits. PNNL received authorization from PNSO to release the RTL Complex for unrestricted use in June 2019.

PNNL uses pre-approved volumetric release limits when releasing small-volume research samples and wastewater potentially contaminated in volume (Table 4.5). DOE approved these release limits in response to an authorized limits request submitted by PNNL in 2000 and 2007 (DOE-RL 2001; DOE-PNSO 2007). During CY 2019, PNNL released hundreds of liquid research samples with a total volume on the order of 1,266 L (334 gal), using the pre-approved release limits in Table 4.5. The liquid samples were not released to the public but were handled without radiological controls in PNNL facilities. When disposed of, the samples were treated as radioactive waste.

Table 4.4. Surface Soil Authorized Limits for Radiological Clearance of the Research Technology Laboratory Site

Radionuclide	Authorized Limit (pCi/g)
Cobalt-60	3.7
Plutonium-238	800
Plutonium-239/240	740
Plutonium-241	30,000
Uranium-234	700
Uranium-235	60
Uranium-238	280

Table 4.5. Pre-Approved Volumetric Release Limits

Radionuclide Groups	Volumetric Release Limit (pCi/mL)
Transuranic elements, iodine-125, iodine-129, radium-226, actinium-227, radium-228, thorium-228, thorium-230, protactinium-231, polonium-208, polonium-209, polonium-210	1
Natural thorium, thorium-232	3
Strontium-90, iodine-126, iodine-131, iodine-133, radium-223, radium-224, uranium-232	9
Natural uranium, uranium-233, uranium-235, uranium-238	30
Beta/gamma-emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except strontium-90 and others noted in the rows above	45
Tritium	450

4.4 Radiation Protection of Biota

DOE Order 458.1, Admin Chg 3, directs that DOE sites establish procedures and practices to protect biota. PNNL has adopted dose rate limits of 1 rad/d (10 mGy/d) for aquatic animals and terrestrial plants and 0.1 rad/d (1 mGy/d) for riparian and terrestrial animals for the demonstration of the protection of biota (DOE 2019a). These limits are applied similarly at the PNNL Richland Campus and the PNNL Sequim Campus.

4.4.1 Radiation Protection of Biota – PNNL Richland Campus

Environmental media pathways were evaluated during the development of the PNNL Richland Campus data quality objectives (DQOs) in support of radiological emissions monitoring (Snyder et al. 2017). Potential media exposure pathways, such as air, soil, water, and food, were considered in conjunction with both gaseous and particulate radioactive contamination of the air pathway. The DQO process determined that only the air pathway necessitates monitoring, because there are no radiological emissions via liquid pathways or directly to contaminated land areas. It also determined that the extremely small amount of emissions would be impossible to differentiate from background levels in nearby locations such as the Columbia River, and from food sources. While these measures are used primarily to demonstrate protection of the public, they also adequately demonstrate protection of biota. Therefore, biota monitoring for radionuclides both near and far from the PNNL Richland Campus is not conducted.

Routine operations were conducted on the PNNL Richland Campus during CY 2019—there were no unplanned radiological emissions. The resultant absorbed dose (external and internal) rates were less than the DOE criteria of 1 rad/d (10 mGy/d) for both aquatic animals and terrestrial plants, and less than 0.1 rad/d (1 mGy/d) for both riparian animals and terrestrial animals (Table 4.6). The dose rates are based on the PNNL-reported total particulate radionuclide emissions for CY 2019 (Snyder et al. 2020a). Calculations are based on conservative assumptions that all the particulate radioactive material is concentrated into either 2,500 m^3 (8.8×10^4 ft^3) of contaminated water (equivalent to the volume of an Olympic swimming pool) or 50 m^2 (538 ft^2) of contaminated soil or sediment, with a soil density of 224 kg/m^2 (14 lb/ft^2) to a depth of 15 cm (6 in.) (equivalent to a representative garden area) (Napier 2006). For comparison, an average of 289×10^6 m^3 (1.02×10^{10} ft^3) of Columbia River water flows past the PNNL Campus on a daily basis, and the PNNL Richland Campus occupies approximately 3.1×10^6 m^2 (3.34×10^7 ft^2) of area.

Doses to terrestrial plants and terrestrial animals are assumed to be from contaminated soil, while doses to aquatic animals are assumed to be from contaminated water, and doses to riparian animals from contaminated sediment. The dose coefficients were determined using RESRAD-BIOTA V1.8, Level 2 (available from Argonne National Laboratory). The resulting water and soil concentrations are very conservative and are used for basic screening and calculating the contrast to adopted biota dose rate limits.

Table 4.6. Absorbed Biota Dose Rates for the PNNL Richland Campus, 2019

	Particulate Emissions[a] (Bq/yr)	Terrestrial Animal to Contaminated Soil[b] (mGy/d)	Terrestrial Plant to Contaminated Soil[c] (mGy/d)	Aquatic Animals to Contaminated Water[d] (mGy/d)	Riparian Animal to Contaminated Sediment[e] (mGy/d)
Totals	4.5×10^{6}	1.2×10^{-2}	1.6×10^{-3}	6.3×10^{-2}	8.7×10^{-3}

(a) Total particulate emissions determined from Snyder et al. (2020a).
(b) The terrestrial animal dose limit is 1 mGy/d; and may include deer, bee, earthworm, and rat. The contaminated soil area is 50 m^2 (538 ft^2) to a depth of 15 cm (6 in.) (Napier 2006).
(c) The terrestrial plant dose limit is 10 mGy/d; and may include pine tree and wild grass. The contaminated soil area is 50 m^2 (538 ft^2) to a depth of 15 cm (6 in.) (Napier 2006).
(d) The aquatic animal dose limit is 10 mGy/d; and may include crab, trout, and flatfish. The contaminated water volume is 2500 m^3 (8.8×10^4 ft^3).
(e) The riparian animal dose limit is 1 mGy/d; and may include duck and frog. The contaminated sediment area is assumed for 50 m^2 (538 ft^2) to a depth of 15 cm (6 in.).
Conversion factors: 1 Ci = 3.7×10^{10} Bq; 1 Gy = 100 rad.

4.4.2 Radiation Protection of Biota – PNNL Sequim Campus

Environmental media pathways were evaluated during the development of PNNL Sequim Campus DQOs in support of radiological emissions monitoring. Potential media exposure pathways, such as air, soil, water, and food, were considered in conjunction with potential releases of radioactive contamination to the air pathway.

The DQO process determined that, because of the low probability of potential air emissions and the absence of radiological emissions via liquid pathways or directly to land areas, no environmental sampling would be required. Because emission levels at the PNNL Sequim Campus are very low, it would be impossible to differentiate actual emissions from background levels in nearby locations such as Sequim Bay and those from food sources (Snyder et al. 2019). Reported emissions from the PNNL Sequim Campus are conservatively estimated, because neither environmental surveillance nor stack sampling is required. These conservatively estimated emissions are also adequate to demonstrate protection of the public and of biota; therefore, biota monitoring for radionuclides both near to and far from the PNNL Sequim Campus is not conducted.

Routine operations were conducted at PNNL Sequim Campus facilities during CY 2019—there were no unplanned radiological emissions. The resultant absorbed dose (external and internal) rates were less than the DOE criteria of 1 rad/d (10 mGy/d) for both aquatic animals and terrestrial plants, and less than 0.1 rad/d (1 mGy/d) for both riparian and terrestrial animals (Table 4.7). These conservative dose rates are well below dose rate limits, which are based on the PNNL-reported total particulate radionuclide emissions for CY 2019 (Snyder and Barnett 2020). Conservative assumptions are that all the particulate radioactive material is concentrated into either 2,500 m^3 ([8.8 x 10^4 ft^3] of contaminated water (equivalent to the volume of an Olympic swimming pool) or 50 m^2 (538 ft^2) of contaminated soil or sediment, with a soil density of 224 kg/m^2 (14 lb/ft^2) to a depth of 15 cm (6 in.) (equivalent to a representative garden area) (Napier 2006). For comparison, Sequim Bay contains an approximate 1.32 x 10^8 m^3 (4.66 x 10^9 ft^3) of seawater with continuous tidal flow past Travis Spit, and the PNNL Sequim Campus developed land occupies approximately 3 x 10^4 m^2 (3.2 x 10^5 ft^2) of area.

Doses to terrestrial plants and terrestrial animals are assumed to be from contaminated soil, while doses to aquatic animals are assumed to be from contaminated water, and doses to riparian animals from contaminated sediment. The dose coefficients were determined using RESRAD-BIOTA V1.8, Level 2. The resulting water and soil concentrations are very conservative and are used for basic screening and calculating the contrast to adopted biota dose rate limits.

Table 4.7. Absorbed Biota Dose Rates for the PNNL Sequim Campus, 2019

	Particulate Emissions[(a)] (Bq/yr)	Terrestrial Animal to Contaminated Soil[(b)] (mGy/d)	Terrestrial Plant to Contaminated Soil[(c)] (mGy/d)	Aquatic Animals to Contaminated Water[(d)] (mGy/d)	Riparian Animal to Contaminated Sediment[(e)] (mGy/d)
Totals	1.2×10^3	8.7×10^{-5}	5.9×10^{-5}	6.9×10^{-3}	4.2×10^{-4}

(a) Total particulate emissions determined from Snyder and Barnett (2020).
(b) The terrestrial animal dose limit is 1 mGy/d; and may include deer, bee, earthworm, and rat. The contaminated soil area is 50 m^2 (538 ft^2) to a depth of 15 cm (6 in.) (Napier 2006).
(c) The terrestrial plant dose limit is 10 mGy/d; and may include pine tree and wild grass. The contaminated soil area is 50 m^2 (538 ft^2) to a depth of 15 cm (6 in.) (Napier 2006).
(d) The aquatic animal dose limit is 10 mGy/d; and may include crab, trout, and flatfish. The contaminated water volume is 2,500 m^3 (8.8 x 10^4 ft^3).
(e) The riparian animal dose limit is 1 mGy/d; and may include duck and frog. The contaminated sediment area is assumed for 50 m^2 (538 ft^2) to a depth of 15 cm (6 in.).

Conversion factors: 1 Ci = 3.7×10^{10} Bq; 1 Gy = 100 rad

4.5 Unplanned Radiological Releases

No radiological releases to the environment exceeded permitted limits at the PNNL Richland Campus or PNNL Sequim Campus in 2019.

4.6 Environmental Radiological Monitoring

The DOE Handbook, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, provides information about basic program implementation requirements and activities (DOE-HDBK-1216-2015; DOE 2015). In addition, the WDOH may require an operator of any emission unit to conduct ambient air monitoring or other testing as necessary to demonstrate compliance with the WAC 246-247 standard; such requirements for a program would be included in the operator's license. The environmental radiological monitoring activities conducted by PNNL for both the PNNL Richland Campus and PNNL Sequim Campus are included in this report.

4.6.1 Environmental Radiological Monitoring – PNNL Richland Campus

A particulate air-sampling (environmental surveillance) network was established in 2010 to monitor radioactive particulates in ambient air near the PNNL Richland Campus as stipulated by WDOH in RAEL-005. As a result of changes in DOE-permitted operations in 2012, the air-sampling network was re-evaluated (Barnett et al. 2012b). In 2017, the particulate air-sampling network was again evaluated, because the campus expanded to the north by 35 ha (85.6 ac) (Snyder et al. 2017). The current PNNL Richland Campus particulate air-sampling network consists of four campus samplers—PNL-1, PNL-2, PNL-3, and PNL-4—and one background sampler—PNL-5 (Figure 4.1)—and co-located ambient external dose monitors.

4.6.1.1 Environmental Air Surveillance – PNNL Richland Campus

During CY 2019, air samples were collected at all sampling stations and included sampling and analysis for airborne particulate radionuclides. Two-week particulate air samples are routinely analyzed for gross alpha and gross beta activity. These gross analyses indicate potential unexpected increases in emissions. Semi-annually, filters are composited for specific radionuclide analysis. The required composite analyses include cobalt-60, uranium-233,[1] plutonium-238 and plutonium-239/240, americium-241 and americium-243, and curium 244.[2]

No PNNL activities resulted in increased ambient air concentrations at the air-sampling locations in CY 2019 (Table 4.8). The gross alpha and gross beta results were comparable to background levels. These nuclide-specific results were less than the values in 40 CFR Part 61, Appendix E, Table 2, and there was no indication of elevated levels of monitored particulate radionuclides near the PNNL Richland Campus. The lack of overall detectable concentrations supports the results of stack effluent monitoring and demonstrates that emissions from the PNNL Richland Campus are low and have minimal potential for dose to members of the public.

[1] Only uranium-233 is required, but it is reported as uranium-233/234 because the naturally occurring uranium-234 emission peak overlaps with uranium-233.
[2] Only curium-244 is required, but it is reported as curium-243/244 because the curium-243 emission peak overlaps with curium-244.

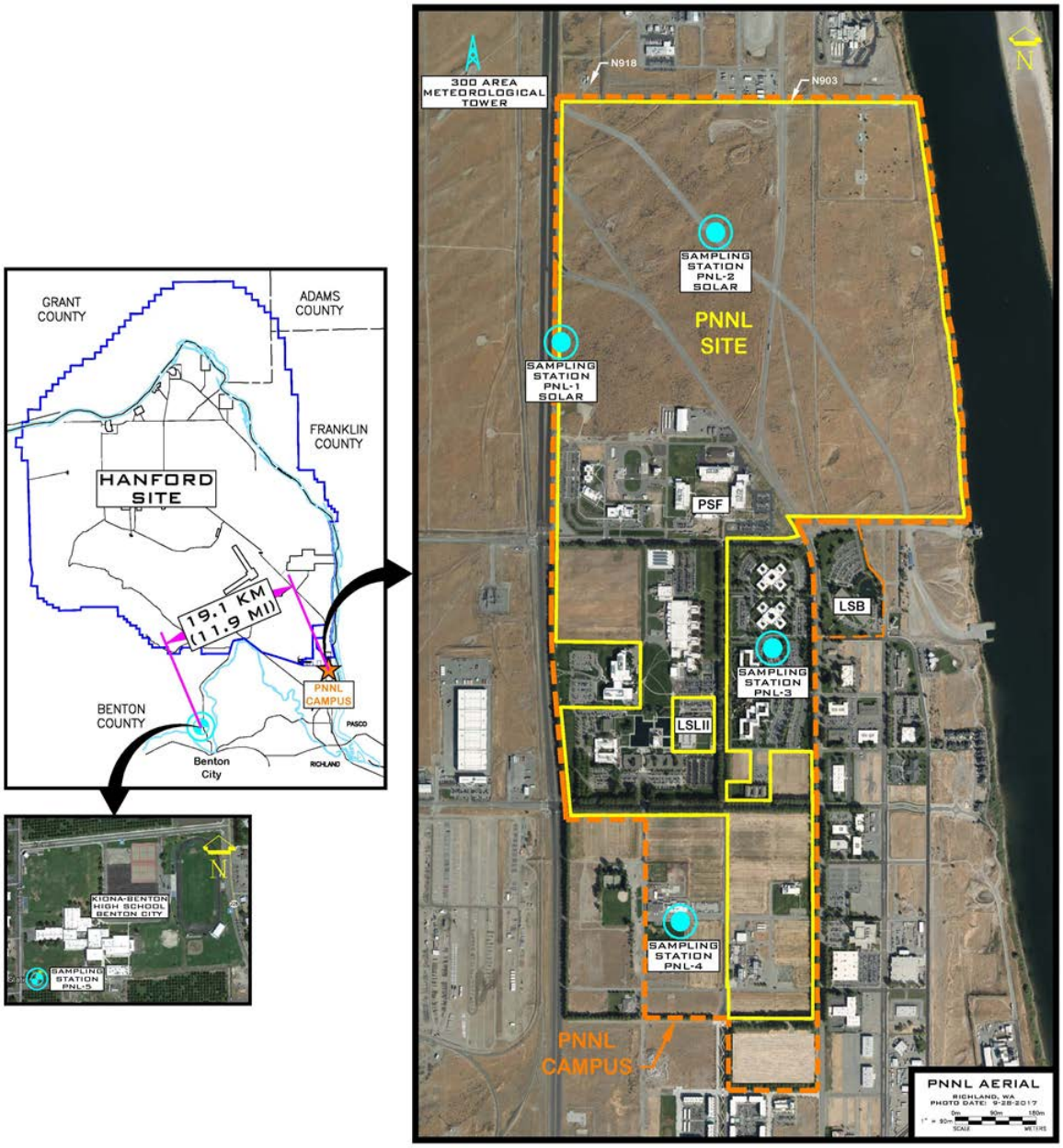

Figure 4.1. Air Surveillance Station Locations for the PNNL Richland Campus (based on Snyder et al. 2020a)

Table 4.8. Summary of 2019 Air-Sampling Results for the PNNL Richland Campus (Snyder et al. 2020a)

Nuclide	Location[a]	No. of Samples Analyzed	No. of Detections	Value ± 2σ Error (pCi/m³)[b]
Gross alpha	PNL-1	27	21	7.0×10^{-4} ± 1.9×10^{-3}
	PNL-2	27	20	7.2×10^{-4} ± 1.9×10^{-3}
	PNL-3	27	20	6.8×10^{-4} ± 1.9×10^{-3}
	PNL-4	26	23	7.9×10^{-4} ± 2.1×10^{-3}
	PNL-5	26	20	5.4×10^{-4} ± 1.5×10^{-3}
Gross beta	PNL-1	27	27	1.9×10^{-2} ± 6.5×10^{-3}
	PNL-2	27	27	1.8×10^{-2} ± 6.5×10^{-3}
	PNL-3	27	27	1.9×10^{-2} ± 6.7×10^{-3}
	PNL-4	26	26	1.9×10^{-2} ± 6.5×10^{-3}
	PNL-5	26	26	1.5×10^{-2} ± 5.2×10^{-3}
Cobalt-60	PNL-1	2	0	4.9×10^{-5} ± 1.3×10^{-4}
	PNL-2	2	0	2.1×10^{-5} ± 1.1×10^{-4}
	PNL-3	2	0	3.1×10^{-5} ± 1.1×10^{-4}
	PNL-4	2	0	8.5×10^{-6} ± 9.9×10^{-5}
	PNL-5	2	0	4.8×10^{-5} ± 1.2×10^{-4}
Cesium-137	PNL-1	2	0	3.7×10^{-5} ± 1.1×10^{-4}
	PNL-2	2	0	9.6×10^{-6} ± 9.8×10^{-5}
	PNL-3	2	1	9.8×10^{-5} ± 2.1×10^{-4}
	PNL-4	2	0	4.2×10^{-5} ± 1.5×10^{-4}
	PNL-5	2	0	-1.4×10^{-5} ± 2.0×10^{-4}
Uranium-233/234	PNL-1	2	1	3.3×10^{-5} ± 3.9×10^{-5}
	PNL-2	2	2	3.9×10^{-5} ± 2.7×10^{-5}
	PNL-3	2	2	4.5×10^{-5} ± 3.1×10^{-5}
	PNL-4	2	2	4.1×10^{-5} ± 3.1×10^{-5}
	PNL-5	2	2	4.1×10^{-5} ± 2.5×10^{-5}
Plutonium-238	PNL-1	2	0	3.2×10^{-6} ± 1.2×10^{-5}
	PNL-2	2	0	-2.1×10^{-6} ± 5.4×10^{-6}
	PNL-3	2	0	6.1×10^{-7} ± 6.5×10^{-6}
	PNL-4	2	0	5.5×10^{-6} ± 1.6×10^{-5}
	PNL-5	2	0	2.7×10^{-7} ± 4.3×10^{-6}
Plutonium-239/240	PNL-1	2	0	3.4×10^{-6} ± 1.2×10^{-5}
	PNL-2	2	0	2.3×10^{-7} ± 7.6×10^{-6}
	PNL-3	2	0	1.6×10^{-6} ± 9.2×10^{-6}
	PNL-4	2	0	6.9×10^{-6} ± 1.8×10^{-5}
	PNL-5	2	0	1.3×10^{-6} ± 8.6×10^{-6}
Americium-241	PNL-1	2	0	5.5×10^{-6} ± 1.1×10^{-5}
	PNL-2	2	0	2.0×10^{-6} ± 6.5×10^{-6}
	PNL-3	2	0	8.9×10^{-6} ± 1.3×10^{-5}
	PNL-4	2	0	4.9×10^{-6} ± 8.2×10^{-6}
	PNL-5	2	0	3.7×10^{-6} ± 9.5×10^{-6}
Americium-243	PNL-1	2	0	4.3×10^{-6} ± 1.4×10^{-5}
	PNL-2	2	0	9.7×10^{-7} ± 8.1×10^{-6}
	PNL-3	2	0	4.7×10^{-6} ± 7.7×10^{-6}
	PNL-4	2	0	-1.2×10^{-6} ± 7.7×10^{-6}
	PNL-5	2	0	1.1×10^{-6} ± 3.2×10^{-6}
Curium-243/244	PNL-1	2	0	6.2×10^{-7} ± 5.4×10^{-6}
	PNL-2	2	0	4.3×10^{-7} ± 2.4×10^{-6}
	PNL-3	2	0	2.7×10^{-6} ± 7.6×10^{-6}
	PNL-4	2	0	2.2×10^{-7} ± 4.0×10^{-6}
	PNL-5	2	0	9.4×10^{-7} ± 6.9×10^{-6}

(a) Refer to Figure 4.1 for PNL-1, PNL-2, PNL-3, PNL-4, and PNL-5 locations.
(b) The value is the average of samples collected throughout the year.
To convert pCi/m³ to Bq/m³, multiply pCi by 0.037.

4.6.1.2 Ambient External Dose Monitoring – PNNL Richland Campus

Ambient levels of external dose from gamma, beta, and X-ray sources were monitored quarterly at the five particulate air monitoring stations during 2019. The external dose monitoring program establishes baseline ambient external dose levels at the perimeter particulate sampling stations and the background (PNL-5) station. No current PNNL Richland Campus radioactive air emissions include significant quantities of external dose contributors, nor has PNNL transported high external dose sources on campus roads in 2019.

Ambient external dose monitoring is done with aluminum oxide dosimeters read by optically stimulated luminescence (OSL), using the Landauer[1] InLight® System. The system has a 5 mrem (50 μSv) minimum detection level with one sigma uncertainty of 12% for each measurement period. In addition, two control dosimeters are used, one to measure exposure during field deployment/retrieval activities and the second to measure exposure during shipment to and from the vendor. The 2019 raw data indicate that all third-quarter dosimeters were exposed to an external dose source during delivery to or from the analytical laboratory, because both the controls and sampling station raw dosimeter results are uniformly elevated (see Appendix C).

After removing control dosimeter results, daily and hourly reported results were recalculated to evaluate dose rates by the number of days monitored each quarter. Daily average dose rates and total 2019 annual background values are provided in Figure 4.2. Hourly average dose rates are provided in Table 4.9. Background values at PNL-5 are not subtracted from the PNL-1 through PNL-4 values in the figure and table data. CY 2019 annual dose rates at each Campus monitoring location are less than the PNL-5 background (40 mrem/yr with normalized 91-day quarters).

OSL dosimeter results for the 2019 monitoring periods are presented in Appendix C. Prior to CY 2019, OSL dosimeter results were presented in the PNNL Richland Campus radioactive air emissions report in units of mrem per monitored quarter (e.g., Snyder, Barnett, and Bisping 2019), but they are now presented in this annual site environmental report, because of the continued lack of significant external dose sources from PNNL Richland Campus radioactive air emissions.

In addition to the boundary and background station ambient external dose monitoring discussed above, the PNNL Radiation Protection organization performs semi-annual external dose rate surveys and direct contamination surveys of the ground within 6 m (20 ft) of PNNL buildings that contain radiological areas. For CY 2019, survey results were at background levels in areas that could be occupied by the public.

[1] Landauer, 2 Science Rd, Glenwood, IL 60425-1586. Accessed at https://www.landauer.com.

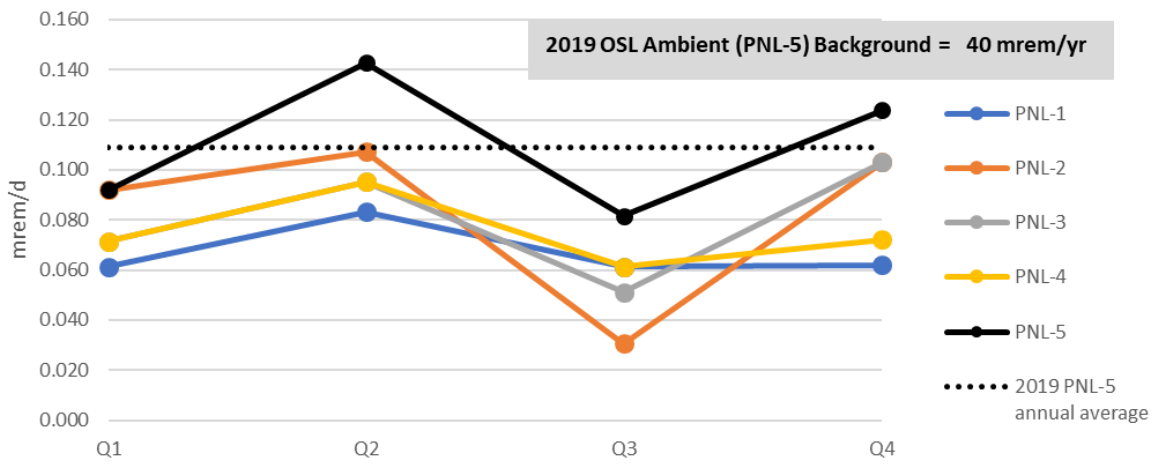

Figure 4.2. Average Daily Ambient External Dose Rates at Each Sampling Location and Calendar Quarter in 2019

Table 4.9. Average Hourly Ambient External Dose Rates at Each Sampling Location (µrem/hr)

2019 Quarter	PNL-1	PNL-2	PNL-3	PNL-4	PNL-5[(a)]
Q1	2.6	3.8	3.0	3.0	3.8
Q2	3.5	4.5	4.0	4.0	6.0
Q3	2.6	1.3	2.1	2.6	3.4
Q4	2.6	4.3	4.3	3.0	5.2
Average annual (µrem/hr)	2.8	3.5	3.3	3.1	4.6

(a) PNL-5 is the background station. No background values were subtracted from Campus perimeter stations (PNL-1 through PNL-4) results.

4.6.2 Environmental Radiological Monitoring – PNNL Sequim Campus

Emissions at the PNNL Sequim Campus are low, the radionuclide inventory is relatively small, and radiological impact estimates are well below regulatory limits, even when highly over-estimating assumptions are applied (Barnett et al. 2012a). The emissions at the PNNL Sequim Campus have historically met requirements for dose limit compliance based on estimates derived using the COMPLY Code (EPA 1989). COMPLY is applicable to sites that have low levels of releases (i.e., releases that result in an MEI dose below the minor emissions unit limit of 0.1 mrem/yr [1 µSv/yr]) (Barnett et al. 2012a). At this time, there are no data available for particulate radionuclide air sampling for baseline background or co-located ambient external dose monitoring.

The PNNL Radiation Protection organization performs semi-annual external dose rate surveys at MSL-5 exterior door locations. For CY 2019, survey results were at background levels in areas that could be occupied by the public.

4.7 Future Radiological Monitoring

The PNNL Sequim Campus RAEL-014 was renewed with an effective date of January 1, 2018. The renewal resulted in a single PNNL Sequim Campus sitewide minor, fugitive, nonpoint source emission unit, thereby eliminating specific building emission units and reducing the permit complexity. A re-evaluation of the PNNL Sequim Campus for environmental surveillance began in 2018 and concluded in CY 2019. While operations under the RAEL-014, Renewal 1, do not require emission unit sampling or monitoring nor ambient surveillance, the revised DQOs recommend baseline radioactive air background

surveillance be performed because no baseline radioactive air background data are currently available for the PNNL Sequim Campus or surrounding area. Determinations of site radiation background for ambient external environmental dose and for particulate gross alpha and gross beta in air was recommended. It further recommended that this sampling be performed at onsite locations; sampling is acceptable at onsite locations because of the historical and continued minimal radiological operations at the PNNL Sequim Campus (Snyder et al. 2019). Implementation planning at the PNNL Sequim Campus is ongoing.

5.0 Environmental Nonradiological Program Information

The Effluent, Waste, and Transportation Programs Group within the PNNL Environmental Protection and Regulatory Programs Division establishes or provides reference to already established discharge limits for toxic and radiological effluents to air and water. Specific effluent management services include establishing monitoring and sampling programs to characterize effluents from PNNL facilities including those at the PNNL Sequim Campus, verifying compliance with effluent standards and controls, assisting facility operations, and monitoring compliance with air and water permits.

The Effluent, Waste, and Transportation Programs Group provides the interface between regulatory agencies and PNNL to prepare and submit required environmental permitting documentation, and reports spills and releases to regulatory agencies. A detailed description of the responsibilities assigned to the group and interactions with other PNNL organizations is provided in the internal *Pacific Northwest National Laboratory Effluent Management Quality Assurance Plan* (EM QAP) (Ballinger and Beus 2016). The ALARA principle is applied to effluent activities to minimize the potential effects of emissions on the public and the environment.

5.1 Liquid Effluent Monitoring

Wastewater from the PNNL Richland Campus is discharged directly to the City of Richland's Publicly Owned Treatment Works. Wastewater discharges are regulated by the City of Richland under three industrial wastewater discharge permits. All waste streams regulated by these permits are reviewed by PNNL staff and evaluated relative to compliance with the applicable permit prior to their discharge. Sampling and monitoring of these waste streams are done in accordance with the permits, and the results are reported as required to the City of Richland.

Process wastewater from the PNNL Sequim Campus is discharged to an onsite wastewater treatment plant and then directly discharged to Sequim Bay under the authorization of Washington State Department of Ecology NPDES Permit No. WA0040649. This permit identifies effluent limitations and monitoring requirements for this facility. Monitoring data required by the NPDES permit for 2019 are listed in Table 5.1. One grab sample was taken each month from Outfall 008 and analyzed for the parameters identified in Table 5.1. All parameters met the NPDES permit effluent limitations. There were no regulated discharges from Outfall 007 during this time period.

Table 5.1. PNNL Sequim Campus 2019 NPDES Monitoring Results for Outfall 008[a]

Parameter	Total Samples	Quantity Found Below Method Reporting Limit	Method Reporting Limit[b]	Maximum Value
Maximum flow (gpd)	NA	NA	NA	117,500
Chlorine, total residual (µg/L)	12	12	50	<50
Antimony (µg/L)	2	1	0.5	0.56
Arsenic (µg/L)	2	2	5	<5
Beryllium (µg/L)	2	2	0.2	<0.2
Cadmium (µg/L)	2	2	0.2	<0.2
Chromium (µg/L)	2	2	2	<2
Copper (µg/L)	12	6	1.0	7.7
Lead (µg/L)	12	4	0.2	0.60
Mercury (µg/L)	2	2	0.2	<0.2
Nickel (µg/L)	2	2	2	<2
Selenium (µg/L)	2	2	10	<10
Silver (µg/L)	2	2	0.2	<0.2
Thallium (µg/L)	2	1	0.2	0.21
Zinc (µg/L)	12	12	20	<20
pH[c]	12	NA	NA	7.8

(a) There were no regulated discharges from Outfall 007 during this time period.
(b) The highest Method Reporting Limit reported for all months is listed.
(c) pH limits of 6–9 standard units are specified in the current permit.
gpd = gallons per day; NA = not applicable; µg/L = micrograms per liter.

5.2 Air Effluent

While PNNL is not a large source of nonradiological air emissions, past and present emissions include GHGs (e.g., tons of carbon dioxide-equivalent emissions), ozone-depleting substances (primarily refrigerants), hazardous air pollutants, and criteria air pollutants. The air effluent program does not monitor any stacks for nonradiological constituents, and compliance is assured by complying with regulatory standards for equipment and permit conditions. Complying typically involves activities such as using clean fuels and monitoring fuel use, adhering to required operating hours for boilers and diesel engines, and adhering to maintenance and operating requirements. Permit applications contain emission estimates based on vendor data (e.g., emission rate/hour), so monitoring of run time or fuel use is an acceptable method of determining permit compliance. In addition, reviews of research and facility construction/renovation projects are conducted to maintain compliance with all applicable requirements.

6.0 Groundwater Protection Program

Groundwater under the PNNL Richland Campus is monitored routinely through seven groundwater monitoring wells. Monitoring of the groundwater under the PNNL Richland Campus was initiated under the direction of the Washington State Department of Ecology through temporary State Waste Discharge Permit ST-9274 for the BSF/CSF ground-source heat pump. The BSF/CSF uses a novel technology for heating and cooling the buildings that relies on a ground-source heat pump. Water is pumped from four extraction wells, passed through a non-contact heat exchanger, and returned to the aquifer through four underground injection control wells. The Washington State Department of Ecology required registration of the underground injection control wells, which was completed in 2010. In February 2011, the Washington State Department of Ecology issued a water right for the nonconsumptive use of groundwater for the ground-source heat pump, allowing the withdrawal and use of groundwater by the four extraction wells at flow rates up to 7,200 L/min (1,900 gpm) and requiring injection of the water back to the aquifer.

Because the water is re-injected back into the ground, the Washington State Department of Ecology issued temporary State Waste Discharge Permit ST-9274 to have the groundwater monitored for temperature changes and potential influence on pollutants from underground contamination plumes. Permit ST-9274 required reporting outside average ambient air temperature, sampling and reporting for turbidity, total dissolved solids, nitrate+nitrite, uranium, tritium, trichloroethylene, flow, temperature, pH, dissolved oxygen, and conductivity. In August 2018[1], the Washington State Department of Ecology eliminated monitoring and sampling for turbidity, total dissolved solids, nitrate + nitrate, uranium, tritium, and trichloroethylene and reduced sampling frequency from quarterly to semi-annually for flow, temperature, pH, conductivity, and dissolved oxygen.

The groundwater is sampled and analyzed in accordance with the sampling and analysis plan for the ground-source heat pump (Fritz and Moon 2010). The discharge permit requires sampling and analysis of seven groundwater monitoring wells that are downgradient from the injection site, in addition to the extraction and injection wells. Three of the monitoring wells located on the PNNL Richland Campus are existing wells previously associated with the Hanford Site monitoring network. The other four monitoring wells were constructed and developed in accordance with the sampling and analysis plan (Fritz and Moon 2010). The sampling data are reported monthly to the Washington State Department of Ecology. Table 6.1 provides a summary of the monitoring results for the BSF/CSF ground-source heat pump for 2019. PNNL is in compliance with all sampling and monitoring requirements of the discharge permit, and results show no concern with respect to the ground-source heat pump water affecting movement of contaminant plumes. No other groundwater sampling at either the PNNL Richland Campus or PNNL Sequim Campus is required for environmental compliance.

[1] Letter from M. Durkee, Washington State Department of Ecology, to T. Moon, Pacific Northwest National Laboratory, RE: Monitoring Reduction Request, Battelle Memorial Institute Biological Sciences Facility Permit No. WA0009274, dated August 2, 2018.

Table 6.1. Biological Sciences Facility/Computational Sciences Facility Ground-Source Heat Pump Monitoring Results, 2019

Parameter	Number of Samples Analyzed	Quantity Found Below Method Reporting Limit	Method Reporting Limit	Minimum Reported Value	Maximum Reported Value
Injection Wells					
Flow (gpm)	NA	NA	NA	0	576
Temperature (°C)	NA	NA	NA	17.0	29.9
pH (pH units)	2	NA	NA	7.2	7.4
Dissolved oxygen (mg/L)	2	NA	NA	7.4	8.2
Conductivity (µS/cm)	2	NA	NA	775	832
Monitoring Wells Downgradient of the Injection Wells					
Temperature (°C)	NA	NA	NA	16.3	18.9
pH (pH units)	14	NA	NA	6.4	7.4
Dissolved oxygen (mg/L)	14	NA	NA	6.4	9.0
Conductivity (µS/cm)	14	NA	NA	795	1933

NA = Not applicable

7.0 Quality Assurance

The PNNL Quality Assurance (QA) Program is based on the requirements defined in DOE Order 414.1D, *Quality Assurance*, and 10 CFR Part 830, *Energy/ Nuclear Safety Management*, Subpart A, "Quality Assurance Requirements." PNNL has chosen to implement the following consensus standards in a graded approach:

- ASME NQA-1-2000, Quality Assurance Requirements for Nuclear Facility Applications, Part I, "Requirements for Quality Assurance Programs for Nuclear Facilities" (ASME 2001)
- ASME NQA-1-2000, Part II, Subpart 2.7, "Quality Assurance Requirements for Computer Software for Nuclear Facility Applications," including problem reporting and corrective actions (ASME 2001)
- ASME NQA-1-2000, Part IV, Subpart 4.2, "Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development" (ASME 2001).

The PNNL *Quality Assurance Program Description/ Quality Management M&O Program Description* describes the Laboratory-level QA program that applies to all work performed by PNNL. Laboratory-level procedures for implementing the QA requirements described in the standards identified above are deployed through PNNL's web-based "How Do I…?" (HDI) system, a standards-based informational system for managing and deploying requirements and procedures to PNNL staff.

7.1 Environmental Monitoring Program

Environmental sampling and monitoring activities were performed under PNNL's Environmental Management Program. These activities included sampling of water, wastewater, radiological air emissions, ambient air, and environmental dosimeters. Sampling is conducted by the Effluent Management (EM) Group or its delegates under the *Pacific Northwest National Laboratory Effluent Management Quality Assurance Plan*, EM-QA-01 (Ballinger and Beus 2016). The EM QAP has been developed to demonstrate how the EM Group is meeting QA requirements specified in environmental regulations and permits, assist EM staff in identifying applicable requirements and procedures (workflows, work controls, or process lifecycles) that are delivered through the HDI standards-based management system, and document the integration of quality into EM processes and activities. For further information about the quality requirements mentioned in this section, refer to the documents listed in Table 7.1.

The EM QAP addresses the requirements in DOE Order 414.1D and the guidance in EPA QA/R-5 (EPA 2001). The EM QAP is written in the same format as the DOE O 414.1D, so that identical requirement sections align. Sections 1–10 of the document discuss each of the 10 criteria of the DOE Order and the applicable EM procedures and processes to meet the criteria.

The related quality requirements documents were approved by the PNNL QA organization that monitors compliance. Work performed through contracts or statements of work, including sample analyses, must meet the U.S. governmental agencies, state, and local regulations, as well as other technical and guidance regulations specified by the PNNL program or the project-specific procedure. Potential suppliers of items and services that could have an impact on quality (e.g., analytical services, calibration services, providers of reference standard material) were closely evaluated before contracts were awarded.

Table 7.1. PNNL Effluent Management Quality Assurance Requirements Documents

Document Title
Effluent Management Quality Assurance Plan (EM-QA-01)
Quality Requirements for Air Chemical Emissions Management
Quality Requirements for Biological Sciences Facility/Computational Sciences Facility (BSF/CSF) Ground Source Heat Pump Monitoring to State Waste Discharge Permit ST-9274
Quality Requirements for Facility Effluent Management Planning
Quality Requirements for Industrial Wastewater Discharge Permit Sampling and Monitoring for the PNNL Campus (CR-IU001), Environmental Molecular Sciences Laboratory (CR-IU005), and Physical Sciences Facility (CR-IU011)
Quality Requirements for Marine Sciences Laboratory Monitoring to National Pollutant Discharge Elimination System Permit WA 0040649
Quality Requirements for Radionuclide Air Emissions Sampling and Monitoring
Quality Requirements for Radionuclide Air Environmental Surveillance Monitoring

PNNL's Contracts and Acquisitions Department directly supports and follows DOE's socioeconomic objectives. Acquisition Quality Support Services (AQSS), as an integral part of Contracts, provides staff to support acquisition activities. This service model appoints matrixed AQSS professionals to provide independent oversight while making sure that internal and external requirements are met.

Radiological environmental air monitoring activities were determined using the DQO process described in the EPA *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA 2006) for operations on the PNNL Richland Campus and PNNL Sequim Campus, and were documented in DQO reports supporting air monitoring by Snyder et al. (2017 and 2019, respectively). The DQO process provides a standard working tool for project managers and planners to develop DQOs for determining the type, quantity, and quality of data needed to reach defensible decisions or make credible estimates. Snyder et al. (2017) determined and documented the environmental sampling and monitoring requirements necessary to comply with applicable regulations at PNNL's Richland Campus. As determined in the DQO process for the Richland Campus, PNNL has established an environmental surveillance program that samples particulate radionuclides in ambient air at strategic locations. The Environmental Management Plan (EMP) (Snyder et al. 2020b) with its attachments—the *Sampling and Analysis Plan*, *Data Management Plan*, and *Dose Assessment Guidance*—provides a comprehensive approach to environmental radioactive air monitoring of PNNL operations.

Potential PNNL Sequim Campus radioactive air emissions are permitted under the current RAEL, and compliance is demonstrated through calculated emission rates. The renewed PNNL Sequim Campus license (RAEL-014, Renewal 1) became effective on January 1, 2018, and is renewed every 5 years. It differs from the original permit in that it consolidates the former PNNL Sequim Campus MSL-1 and MSL-5 emission units under expanded permit operations into a single sitewide emission unit. This change was a cooperative effort between WDOH, PNSO, and PNNL, and it simplifies the overall approach to working with radioactive material at the facility. As a result of this permit change, the DQO report for the PNNL Sequim Campus was revised (Snyder et al. 2019); it notes radioactive air emissions from

operations at the campus do not require emission unit sampling or monitoring, nor ambient surveillance under the RAEL-014, Renewal 1. However, it recommends that baseline radioactive air background surveillance be performed. No baseline radioactive air background data are currently available for the PNNL Sequim Campus. Determination of site radiation background for ambient external dose and for particulate gross alpha and gross beta in air is, therefore, recommended. It is recommended that this sampling be performed at onsite locations. Sampling is acceptable at onsite locations because of the historical and continued minimal radiological operations at the PNNL Sequim Campus.

In 2019, an ambient external dose surveillance program was performed at the five particulate air monitoring stations associated with the PNNL Richland Campus.

Water and wastewater sampling and monitoring at the PNNL Richland Campus are performed to meet requirements in permits issued by the City of Richland for discharges to the sewer and by the Washington State Department of Ecology for discharges to the ground. At the PNNL Sequim Campus, water and wastewater sampling and monitoring are performed to comply with NPDES and Group A Drinking Water permits. QA requirements for these activities have been integrated into the EM QAP (Ballinger and Beus 2016) and related QA documents (see Table 7.1), and include specific requirements such as sampling locations, quality objective criteria, analytical methods, and detection limits.

Chemical air emission monitoring is performed by complying with PNNL's air permits, primarily by limiting the hours of operation, using ultra-low sulfur diesel fuel when operating on diesel, and operating and maintaining PNNL combustion units (e.g., backup generators, boilers, water heaters) as described in the notice of construction application and in accordance with the manufacturer's emission-related instructions. Each research project or Facilities and Operation activity that has the potential for generating air emissions is subject to an air emissions review to identify the compliance actions and administrative controls necessary to assure compliance with existing air permits.

7.2 Sample Collection Quality Assurance

Samples are collected by PNNL personnel trained to conduct environmental sampling according to approved and documented procedures. Sampling protocols include use of appropriate sampling methods and equipment, a defined sampling frequency, specified sampling locations, and procedures for sample handling (which may include storage, packaging, and shipping) to maintain sample integrity. Chain-of-custody processes are used to track the transfer of samples from the point of collection to the analytical laboratory. QA program requirements are integrated into the statement of work for subcontracted analytical laboratories. A description of these quality control (QC) terms is provided in Table 7.2.

Water and wastewater samples are analyzed using EPA-approved methods or methods specified by the applicable regulatory agency. Some samples are required to be analyzed in the field at the time of sample collection because of short holding time limits. These analyses (e.g., pH, conductivity, and dissolved oxygen) are performed using controlled procedures to meet QC acceptance criteria, thereby demonstrating compliance with method requirements.

Table 7.2. Quality Control Terms

Quality Control Type	Description
Laboratory method blank	Control sample containing no analyte of interest; used to monitor for bias or contamination introduced during processing and analysis in the laboratory.
Duplicate	Field Duplicate: An additional sample collected as closely as possible to the same time and location to measure sources of error from field sampling activities when compared to laboratory duplicate precision results. (PNNL did not sample field duplicates.) Laboratory Duplicate: An additional aliquot or split sample from the same sample that is analyzed by the laboratory to measure analytical precision.
Matrix spike or surrogate samples	An aliquot of actual sample spiked with a known concentration of target analytes and processed in the same manner as the sample; used to determine the extent to which matrix bias or interferences affect the results when compared to a blank spike result. Instead of target analytes, surrogate analytes can be used. The surrogates are similar compounds that behave analytically like the target analyte in the specific analytical process.
Blank spike or reagent spike samples	A known concentration of target analytes added to the sample matrix prior to analysis. Blank or reagent spike samples are used to determine the accuracy associated with measuring a specific analyte by a specific method.
Laboratory control samples (LCSs)	A certified reference material or a prepared sample (created from an analyte-free sample matrix spiked with a known amount of analyte), which is carried through the preparation and analysis procedures to measure possible sources of preparation and measurement error.

7.3 Quality Assurance Analytical Results

The following laboratories conducted the analyses of environmental samples (i.e., stack air emissions, ambient air, water, wastewater, and environmental dosimeters) from the PNNL Richland Campus and PNNL Sequim Campus during 2019:

- Radiological air emission filter samples were analyzed by PNNL's Analytical Support Operations (ASO) laboratory in the Radiochemical Processing Laboratory (RPL).
- Ambient air filter samples were analyzed for radioactivity by General Engineering Laboratories (GEL), LLC, Charleston, South Carolina.
- Environmental dosimeters were read using optically stimulated luminescence technology by Landauer®, Glenwood, Illinois.
- Water and wastewater samples were analyzed by
  - ALS Environmental, Kelso, Washington;
  - Benton-Franklin Health District Laboratory, Kennewick, Washington;
  - an in-house PNNL Sequim Campus accredited laboratory; and
  - Spectra Laboratories, Port Orchard, Washington.

Analyses were performed according to a statement of work or contract, which described the activities necessary to assure that the analytical results were of high and verifiable quality. These activities included calibration and performance testing of analytical methods and equipment; implementing a QA program; maintaining analytical and support equipment and facilities; handling, protecting, and analyzing samples; checking data traceability, validity, and quality; recording all analytical data; participating in the analysis of performance evaluation programs; and communicating and reporting to the EM Group. Each analytical data package is validated prior to using and reporting data. In all cases where identified quality issues resulted in invalid data, the issue was documented, and corrective actions were taken. Information for each laboratory is summarized below:

- The ASO laboratory analyzed all airborne filter samples for radioactivity according to the criteria in their statements of work and contracts. The analytical activities included use of daily calibration and verification QC samples (e.g., blanks, spiked samples, and sample duplicate pairs) and precision and accuracy targets that require the analysis method to meet quality performance limits. A blank and an instrument control sample were measured against known standards for each batch of routine samples analyzed for alpha and beta activity. In addition, a spiked sample and a blank were included with each batch of composite analyses and were analyzed for specific isotopes in addition to alpha and beta activity. The QC samples confirmed the results that indicated that the sample batches had no measurable contamination from sample preparation activities. ASO's quality assurance plan (ASO-QAP-001, Rev. 11; PNNL 2017) is guided by Nuclear Quality Assurance standard ASME NQA-1-2000 requirements (ASME 2001), which direct the facility and management to maintain a high level of analytical testing rigor, giving special attention to radiological safety and environmental protection. ASO accomplishes assessments that address maintaining analytical instruments, checking data traceability and validity, independent DOE performance testing, and communicating results to the client. Any corrective actions are addressed by the ASO quality engineer and laboratory management.
- GEL analyzed all particulate ambient air filters for radioactivity according to the criteria in the contracted statement of work. The analytical activities included use of calibration and verification QC samples (e.g., blanks, spiked samples, and sample duplicate pairs) with precision and accuracy targets that require that the analysis method meets quality performance QC limits. A blank sample was analyzed for each analytical batch analyzed for alpha and beta activity. In addition, each analytical batch reporting composite result included a blank, a duplicate, and a laboratory control sample. The QC sample results indicated that the sample batches had no measurable contamination from sample preparation activities. The integrity and validity of analytical test results are maintained by GEL through the implementation of an internal QC program, while meeting the requirements of 40 CFR Part 61 and the U.S. Department of Defense (DoD)/DOE Consolidated Quality Systems Manual for Environmental Laboratories (DoD and DOE 2019).
- Landauer® provided dosimetry services for ambient air external dose monitoring. Services included providing an aluminum oxide dosimeter in a waterproof pouch at the frequency requested by PNNL, reading the exposed dosimeter using OSL technology, and providing dose results for the deployment period in an electronic format. Landauer provided two control dosimeters per shipment, the first to measure exposure during field deployment/retrieval activities and the second

to measure exposure during shipment to and from the vendor. No control or background value was subtracted from the PNNL Richland Campus value in Landauer-reported results. The environmental dosimeter external dose reporting information is expected to follow the ANSI/HPS Standard N13.37-2019, *Environmental Dosimetry—Criteria for System Design and Implementation* (ANSI/HPS 2019).

- ALS Environmental, the Benton-Franklin Health District Laboratory, Spectra Laboratories, and an in-house laboratory on the PNNL Sequim Campus analyzed all water and wastewater samples from the PNNL Richland and Sequim Campuses during 2019. All analytical laboratories are accredited by the Washington State Department of Ecology for the analysis of water and wastewater samples. To receive accreditation, a laboratory must implement a QAP, perform periodic proficiency testing, and be periodically inspected by the Washington State Department of Ecology to assure that it is operating within regulatory and QA requirements. Each time a laboratory is selected to perform analyses for PNNL, the PNNL AQSS group evaluates whether the lab is either accredited or currently listed on PNNL's Evaluated Supplier List. ALS Environmental and the in-house laboratory on the PNNL Sequim Campus are also accredited by the National Environmental Laboratory Accreditation Conference (NELAC) Institute (TNI), which requires adherence to a uniform and robust laboratory program that has been implemented consistently nationwide. All wastewater analyses are performed using approved *Clean Water Act* methods specified by EPA in "Guidelines Establishing Test Procedures for the Analysis of Pollutants" (40 CFR Part 136). QA/QC requirements in the contract with PNNL for wastewater analyses include the measurement or assessment of sample accuracy, precision, reliability, representativeness, completeness, and comparability. Measurements are reviewed for each analytical data package to verify that the data are valid. Analytical methods, method detection limits (MDLs), holding times, sample containers, and sample preservation laboratory activities must meet 40 CFR Part 136 requirements and are verified for each sample collected.

7.4 Inter-Laboratory Performance Programs

The bi-annual Mixed-Analyte Performance Evaluation Program (MAPEP) is a performance testing program managed by the Radiological and Environmental Sciences Laboratory (RESL) at Idaho National Laboratory. RESL is a government-owned and -operated DOE laboratory facility that provides unbiased technical DOE oversight to assure the quality and stability of analytical chemistry, radiation calibrations, and measurements. As an ISO/IEC (International Organization for Standardization/ International Electrotechnical Commission) 17043 accredited laboratory, RESL complies with the requirements of DOE Order 414.1D, *Quality Assurance*; ISO 9001:2015, *Quality Management Systems – Requirements;* and ISO/IEC 17025:2017, *General Requirements for the Competence of Testing and Calibration Laboratories*. Each year, the MAPEP program provides samples of environmental media for assessing air filter, water, soil, and vegetation, which contain specific amounts of one or more radionuclides unknown to the participating laboratory. After analysis, the results are evaluated against a stated reference value and acceptance range. For 2019, MAPEP studies 40 and 41 were issued to participating laboratories.

- GEL participated in 2019 in both performance evaluation studies (MAPEP 40 and 41). Radiological filter results for gross alpha and beta samples were 100% accurate; select gamma and alpha spectroscopy results were acceptable. Any MAPEP 40 and 41 study warnings and out of range results occurred with media other than radiological air; therefore, it is fair to say that GEL received a perfect score with the air filter results required for the PNNL environmental program. The DOE

Consolidated Audit Program (DOECAP) Accreditation Body contractual auditing organization A2LA performed the annual DOECAP analyte performance assessment per the requirements of the DOECAP for 2019. GEL maintained laboratory accreditation, which provides added confidence in the data reported by the laboratory. GEL also maintained TNI National Environmental Laboratory Accreditation Program (NELAP) 2009 accreditation certificates for 2019 with the state of Utah Department of Health (Certificate Number: SC000122020-32, expiring October 31, 2020) and the state of Washington (Certificate Number: C780-19a, expiring November 25, 2020).

- The ASO RPL at PNNL participated in MAPEP 40 and 41 testing studies. MAPEP 40 results for the gross alpha/beta air and water filter samples were received on March 6, 2019 and February 27, 2019, respectively, and submitted to the laboratory for analyses using Analytical Service Request (ASR) No. 0744. MAPEP Study 41 water and filter samples were received on September 20, 2019, and assigned ASR 0895, RPL Lab Numbers 19-2641 through 19-2644. An ASO Deficiency Report (DR-98620-12-17-19), titled *Performance Testing Sample Results for MAPEP-41 Not Provided for ASR 0895*, was issued by the ASO quality engineer. For the MAPEP-19-MaW41, technetium-99 was not reported because of poor results and hydrogen-3 (tritium) was not reported because of insufficient time to fully analyze the sample. For MAPEP-19-RdF41, strontium-90 was not reported because of poor sample results. The analytes that were missed by the ASO RPL will be re-tested on the next MAPEP 42 study that will be reported sometime in 2020.

The requirements for inter-laboratory performance do not apply to dosimetry.

Participation in inter-laboratory performance programs for the analysis of water and wastewater samples is not required pursuant to permits issued under the *Safe Drinking Water Act* or the *Clean Water Act*. PNNL considers the following standards in their review of commercial analytical laboratories for use: ISO/IEC Standard 17025:2005 and Standard 17043.

- ISO 17025:2005 provides guidance for testing and calibration laboratories. Standard 17043 provides the general requirements for proficiency testing. ALS Environmental (Kelso, Washington), Benton-Franklin Health District Laboratory, an in-house laboratory on the PNNL Sequim Campus, and Spectra Laboratories (Port Orchard, Washington) are evaluated suppliers and use an ISO/IEC 17043 accredited proficiency testing company.

- ALS Environmental is an accredited laboratory (WAC 173-50) certified by the Washington State Department of Ecology as a testing laboratory through July 08, 2020. The scope of their accreditation will be re-evaluated at that time. ALS was also accredited by Perry Johnson Laboratory Accreditation, Inc., as being certified to the ISO/IEC 17025:2005 standard and with the U.S. DoD Environmental Laboratory Accreditation Program for ISO/IEC 17025:2005 and DoD QSM Version 5.1.1.1 on February 2018; this accreditation expires on June 30, 2020. Spectra Labs and the Benton-Franklin Health District Laboratory are also accredited by the Washington State Department of Ecology to WAC 173-50 and 246-290 criteria. These accreditations are renewed annually. The in-house laboratory on the PNNL Sequim Campus is a nationally accredited laboratory by the New Jersey (NJ) Department of Environmental Protection to perform certain analytical methods with TNI requirements until June 30, 2020, and with guidance from EPA document EPA QA/R-2 quality guidelines for environmental testing. The NJ NELAP accreditation also helped the in-house laboratory at the PNNL Sequim

Campus to obtain its Washington State Department of Ecology certificate of accreditation, which is applicable until October 23, 2020. Implementation of the policies and requirements are specified in the *PNNL Marine Sciences Laboratory Quality Assurance Management Plan (QAMP)* (PNNL 2016), and detailed methodologies and practices are further defined in project standard operating procedures and project management documents.

7.5 Data Management and Calculations

Quality assurance is integrated into data management processes and calculations through the EM QAP and related QA documents, the EMP Data Management Plan, and staff procedures; parameters for dose calculations are documented as a component of the EMP. Software QA processes are used to verify the accuracy of databases used for analytical results.

Procedures identify the process for developing, testing, maintaining, and using spreadsheets to perform calculations that support or relate to a regulatory compliance, permit, or safety requirement; procedures also contain the basis for parameters and methods used in estimating environmental releases, as well as checklists used to verify and validate analytical results. For 2019, the processes for managing data and calculations were followed.

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Appendix A

Plant and Animal Species Found on Undeveloped Upland and Riparian Areas of the PNNL Richland Campus, 2009–2019

Appendix A

Plant and Animal Species Observed on Undeveloped Upland and Riparian Areas of the PNNL Richland Campus, 2009–2019

Table A.1. Plant Species Observed on the Undeveloped Upland Portions of the PNNL Richland Campus, 2009–2019

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Achillea millefolium	common yarrow			
Achnatherum hymenoides	Indian ricegrass			
Agoseris glauca	pale agoseris			
Agoseris grandiflora	large-flowered agoseris			
Agoseris heterophylla	annual agoseris			
Agropyron cristatum	crested wheatgrass			
Ailanthus altissima	tree-of-heaven			C
Allium schoenoprasum	chives			
Amaranthus albus	white pigweed			
Ambrosia acanthicarpa	bur ragweed			
Amsinckia lycopsoides	tarweed fiddleneck			
Amsinckia tessellata	tessellate fiddleneck			
Aphyllon corymbosum	flat-topped broomrape			
Artemisia campestris	Pacific sagewort			
Artemisia dracunculus	tarragon			
Artemisia ludoviciana	prairie sage			
Artemisia tridentata	big sagebrush			
Asclepias speciosa	showy milkweed			
Asparagus officinalis	garden asparagus			
Astragalus caricinus	buckwheat milkvetch			
Avena sativa	cultivated oats			
Balsamorhiza careyana	Carey's balsamroot			
Bassia scoparia	burning-bush			B
Bromus tectorum	cheatgrass			
Calochortus macrocarpus	sagebrush mariposa lily			
Capsella bursa-pastoris	shepherd's purse			
Carex douglasii	Douglas's sedge			
Cenchrus longispinus	bur-grass			C
Centaurea diffusa	diffuse knapweed			B
Centaurea solstitialis	yellow starthistle			B
Chaenactis douglasii	hoary false yarrow			
Chamaesyce serpyllifolia	thymeleaf sandmat			
Chenopodium album	white goosefoot			
Chenopodium leptophyllum	slimleaf goosefoot			
Chondrilla juncea	skeletonweed			B

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Chorispora tenella	chorispora			
Chrysothamnus viscidiflorus	green rabbitbrush			
Cichorium intybus	chicory			
Cirsium arvense	Canada thistle			C
Clematis ligusticifolia	western clematis			
Comandra umbellata	bastard toadflax			
Convolvulus arvensis	bindweed			C
Conyza canadensis	Canadian horseweed			
Coreopsis tinctoria	Columbia coreopsis			
Crepis atribarba	slender hawksbeard			
Cryptantha flaccida	weak-stemmed cryptantha			
Cryptantha fendleri	Fendler's cryptantha			
Cryptantha pterocarya	winged cryptantha			
Cymopterus terebinthinus	turpentine spring parsley			
Cynodon dactylon	cynodon			
Dalea ornata	western prairie clover			
Delphinium nuttallianum	upland larkspur			
Descurainia pinnata	western tansymustard			
Descurainia sophia	flixweed			
Dieteria canescens	hoary-aster			
Draba verna	spring Whitlow-grass			
Elaeagnus angustifolia	Russian olive			C
Eleocharis sp.	spike-rush			
Elymus elymoides	bottlebrush squirreltail			
Elymus lanceolatus	thickspike wheatgrass			
Elymus violaceus	Alaska wheatgrass			
Epilobium brachycarpum	tall annual willow-herb			
Equisetum sp.	horsetail			
Ericameria nauseosa	common rabbitbrush			
Erigeron filifolius	thread-leaf fleabane			
Eriogonum niveum	snow buckwheat			
Eriogonum vimineum	broom buckwheat			
Erodium cicutarium	redstem stork's bill			
Erysimum asperum	wallflower			
Euphorbia serpillifolia	thymeleaf spurge			
Fallopia convolvulus	climbing bindweed			
Fritillaria pudica	yellow bell			
Galium aparine	cleavers			
Gaillardia aristata	blanket-flower			
Gilia sinuata	rosy gilia			
Gratiola neglecta	common American hedge-hyssop			
Grayia spinosa	hopsage			
Greeneocharis circumscissa	matted cryptantha			
Grindelia hirsutula	hairy gumweed			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Gypsophila paniculata	baby's-breath			C
Hesperostipa comata	needle-and-thread			
Holosteum umbellatum	jagged chickweed			
Hordeum jubatum	foxtail barley			
Hymenopappus filifolius	hymenopappus			
Hypericum perforatum	common St. John's-wort			C
Iris missouriensis	Rocky Mountain iris			
Juniperus scopulorum	Rocky Mountain juniper			
Koeleria macrantha	junegrass			
Lactuca serriola	prickly lettuce			
Ladeania lanceolata	lance-leaf scurf-pea			
Lagophylla rammosissima	hareleaf			
Lamium amplexicaule	common dead-nettle			
Layia glandulosa	tidytips			
Lepidium draba	heart-podded hoarycress			C
Lepidium densiflorum	common pepperweed			
Lepidium latifolium	broadleaf pepperweed			B
Lepidium perfoliatum	clasping pepperweed			
Leymus cinereus	Great Basin wildrye			
Linanthus pungens	granite prickly-phlox			
Logfia gallica	daggerleaf cottonrose			
Lomatium macrocarpum	bigseed biscuitroot			
Malus pumila	cultivated apple			
Malva neglecta	common mallow			
Medicago sativa	alfalfa			
Melilotus officianalis	common yellow sweet-clover			
Mentha arvensis	mint			
Mentzelia albicaulis	small-flowered mentzelia			
Microsteris gracilis	microsteris			
Morus alba	white mulberry			
Narcissus pseudonarcissus	common daffodil			
Oenothera pallida	pale evening primrose			
Onopordum acanthium	cotton thistle			B
Opuntia polyacantha	starvation pricklypear			
Parthenocissus vitacea	Virginia creeper			
Phacelia hastata	silverleaf phacelia			
Phacelia linearis	thread-leaf phacelia			
Phlox longifolia	longleaf phlox			
Plantago lanceolata	English plantain			
Plantago patigonica	Indian-wheat			
Plectritis macrocera	longhorn plectritis			
Poa bulbosa	bulbous bluegrass			
Poa pratensis	Kentucky bluegrass			
Poa secunda	Sandberg's bluegrass			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Polemonium micranthum	annual Jacob's ladder			
Polygonum aviculare	doorweed			
Prunus virginiana	chokecherry			
Pseudognaphalium stramineum	cottonbatting plant			
Pseudoroegneria spicata	bluebunch wheatgrass			
Purshia tridentata	bitterbrush			
Rhaponticum repens	hardheads (Russian knapweed)			B
Ribes aureum	golden currant			
Robinia pseudoacacia	black locust			
Rosa woodsii	rose			
Rubus bifrons	Himalayan blackberry			C
Rumex salicifolius	willow dock			
Rumex venosus	veiny dock			
Salix exigua	coyote willow			
Salsola tragus	Russian thistle			
Senecio vulgaris	common groundsel			C
Setaria pumila	foxtail			
Sisymbrium altissimum	tall tumblemustard			
Sisymbrium loeselii	Loesel tumblemustard			
Solidago lepida	western Canada goldenrod			
Solanum dulcamara	climbing nightshade			
Solanum triflorum	cut-leaved nightshade			
Sonchus arvensis	sow-thistle			
Sphaeralcea munroana	Munro's globemallow			
Sporobolus cryptandrus	sand dropseed			
Stephanomeria paniculata	stiff-branched wirelettuce			
Taraxacum officinale	common dandelion			
Toxicoscordion venenosum	meadow death-camas			
Tragopogon dubius	yellow salsify			
Tribulus terrestris	puncturevine			B
Triteleia grandiflora	large-flowered triteleia			
Ulmus pumila	Siberian elm			
Ulmus americana	American elm			
Verbascum thapsus	common mullein			
Verbena bracteata	bracted verbena			
Veronica peregrina	purslane speedwell			
Vulpia microstachys	small fescue			
Vulpia octoflora	six-weeks fescue			

(a) Nomenclature according to Hitchcock, CL and A Cronquist. 2018. *Flora of the Pacific Northwest: An Illustrated Manual, 2nd Edition*. Edited by DE Giblin, BS Legler, PF Zika, and RG Olmstead. University of Washington Press, Seattle, Washington. 936pp.

(b) Noxious Weed Class: B = Prevent spread and contain or reduce existing populations; C = Weeds widespread, control methods available but not normally required.

Table A.2. Bird Species Observed on the Undeveloped Upland Portions of the PNNL Richland Campus, 2009–2019

Species Name	Common Name	State Status	Federal Status
Agelaius phoeniceus	red-winged blackbird		
Artemisiospiza nevadensis	sagebrush sparrow	Candidate	
Anas platyrhynchos	mallard		
Asio flammeus	short-eared owl		
Branta canadensis	Canada goose		
Buteo jamaicensis	red-tailed hawk		
Buteo swainsoni	Swainson's hawk		
Callipepla californica	California quail		
Carpodacus mexicanus	house finch		
Carduelis tristis	American goldfinch		
Charadrius vociferus	killdeer		
Chordeiles minor	common nighthawk		
Chondestes grammacus	lark sparrow		
Circus cyaneus	northern harrier		
Colaptes auratus	northern flicker		
Columbus livia	rock pigeon		
Corvus brachyrhynchos	American crow		
Corvus corax	common raven		
Eremophila alpestris	horned lark		
Haliaeetus leucocephalus	bald eagle		
Hirundo pyrrhonota	cliff swallow		
Hirundo rustica	barn swallow		
Icterus bullockii	Bullock's oriole		
Numenius americanus	long-billed curlew		
Pandion haliaetus	osprey		
Passer domesticus	house sparrow		
Phasianus colchicus	ring-necked pheasant		
Pica	black-billed magpie		
Riparia	bank swallow		
Sayornis saya	Say's phoebe		
Sturnella neglecta	western meadowlark		
Sturnus vulgaris	European starling		
Tachycineta thalassina	violet-green swallow		
Turdus migratorius	American robin		
Tyrannus	eastern kingbird		
Tyrannus verticalis	western kingbird		
Zenaida macroura	mourning dove		
Zonotrichia leucophrys	white-crowned sparrow		

Table A.3. Mammal Species Observed on the Undeveloped Upland Portions of the PNNL Richland Campus, 2009–2019

Species Name	Common Name	State Status	Federal Status
Canis latrans	coyote		
Castor canadensis	beaver		
Erithizon dorsatum	porcupine		
Lepus californicus	black-tailed jackrabbit	Candidate	
Odocoileus hemionus	mule deer		
Perognathus parvus	Great Basin pocket mouse		
Sylvilagus nutalli	mountain cottontail		
Taxidea taxus	badger		
Thomomys talpoides	northern pocket gopher		

Table A.4. Plant Species Observed in the Riparian Area of the PNNL Richland Campus in 2015 and 2017–2018

Species Name[(a)]	Common Name[(a)]	State Status	Federal Status	Noxious Weed Class[(b)]
Achillea millefolium	common yarrow			
Achnatherum hymenoides	Indian ricegrass			
Agropyron cristatum	crested wheatgrass			
Ailanthus altissima	tree-of-heaven			C
Allium schoenoprasum	chives			
Ambrosia acanthicarpa	bur ragweed			
Amsinckia lycopsoides	tarweed fiddleneck			
Apocynum cannabinum	clasping-leaved dogbane			
Artemisia campestris	Pacific sagewort			
Artemisia dracunculus	tarragon			
Artemisia ludoviciana	prairie sage			
Artemisia tridentata	big sagebrush			
Asclepias speciosa	showy milkweed			
Asparagus officinalis	garden asparagus			
Bromus tectorum	cheatgrass			
Centaurea diffusa	diffuse knapweed			B
Chondrilla juncea	skeletonweed			B
Chrysothamnus viscidiflorus	green rabbitbrush			
Cirsium arvense	creeping thistle			C
Clematis ligusticifolia	western clematis			
Convolvulus arvensis	bind weed			C
Conyza canadensis	Canadian horseweed			
Coreopsis tinctoria	Columbia coreopsis			
Descurainia pinnata	western tansymustard			
Descurainia sophia	flixweed			
Dieteria canescens	hoary-aster			
Eleocharis palustris	common spike-rush			
Elymus lanceolatus	thickspike wheatgrass			
Equisetum sp.	horsetail			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Ericameria nauseosa	rubber rabbitbrush			
Eriogonum niveum	snow buckwheat			
Eriogonum sp.	buckwheat			
Euphorbia glyptosperma	ribseed sandmat			
Euphorbia serpillifolia	thymeleaf sandmat			
Gaillardia aristata	blanket-flower			
Galium sp.	bedstraw			
Hesperostipa comata	needle-and-thread			
Holosteum umbellatum	jagged chickweed			
Hypericum perforatum	common St. John's-wort			C
Iris missouriensis	Rocky Mountain iris			
Lactuca serriola	prickly lettuce			
Ladeania lanceolata	lance-leaf scurf-pea			
Lepidium densiflorum	common pepperweed			
Lepidium draba	heart-podded hoarycress			C
Lepidium perfoliatum	clasping pepperweed			
Leymus cinereus	Great Basin wildrye			
Logfia gallica	daggerleaf cottonrose			
Acmispon americanus	Spanish-clover			
Lupinus sericeus	silky lupine			
Medicago sativa	alfalfa			
Melilotus officinalis	common yellow sweet-clover			
Mentha piperita	mint			
Morus alba	white mulberry			
Oenothera pallida	pale evening primrose			
Parthenocissus vitacea	Virginia creeper			
Phalaris arundinacea	reed canarygrass			C
Plantago lanceolata	English plantain			
Plantago patigonica	Indian-wheat			
Poa bulbosa	bulbous bluegrass			
Poa compressa	Canada bluegrass			
Poa secunda	Sandberg's bluegrass			
Prunus virginiana	chokecherry			
Purshia tridentata	Antelope-brush			
Rhaponticum repens	hardheads (Russian knapweed)			B
Rhus glabra	smooth sumac			
Ribes aureum	golden currant			
Robinia pseudoacacia	black locust			
Rosa woodsii	rose			
Rubus bifrons	Himalayan blackberry			C
Rumex crispus	curly dock			
Rumex patienta	patience dock			
Rumex salicifolius	willow dock			
Rumex venosus	veiny dock			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Salix exigua	coyote willow			
Salsola tragus	Russian thistle			
Sisymbrium altissimum	tall tumblemustard			
Solidago lepida	western Canada goldenrod			
Solanum dulcamara	climbing nightshade			
Sphaeralcea munroana	Munro's globemallow			
Sporobolus cryptandrus	sand dropseed			
Stephanomeria paniculata	stiff-branched wirelettuce			
Taraxacum officinale	common dandelion			
Tragopogon dubius	yellow salsify			
Ulmus americana	American elm			
Verbascum thapsus	common mullein			
Vicia cracca	bird vetch			
Xanthium strumarium	common cocklebur			

(a) Nomenclature according to Hitchcock, CL and A Cronquist. 2018. *Flora of the Pacific Northwest: An Illustrated Manual, 2nd Edition*. Edited by DE Giblin, BS Legler, PF Zika, and RG Olmstead. University of Washington Press, Seattle, Washington. 936pp.

(b) Noxious Weed Class B = Prevent spread and contain or reduce existing populations; Noxious Weed Class C = Weeds widespread, control methods available but not normally required.

Table A.5. Bird Species Observed in the Riparian Area of the PNNL Richland Campus in 2015 and 2017–2018

Species Name	Common Name	State Status	Federal Status
Actitis macularius	spotted sandpiper		
Agelaius phoeniceus	red-winged blackbird		
Anas platyrhynchos	mallard		
Ardea herodias	great blue heron		
Branta canadensis	Canada goose		
Bubo virginianus	great-horned owl		
Calidris bairdii	Baird's sandpiper		
Calidris mauri	western sandpiper		
Callipepla californica	California quail		
Ardea alba	great egret		
Columba livia	rock pigeon		
Corvus corax	common raven		
Icterus bullockii	Bullock's oriole		
Larus californicus	California gull		
Megaceryle alcyon	belted kingfisher		
Melospiza lincolnii	Lincoln's sparrow		
Melospiza melodia	song sparrow		
Mergus merganser	common merganser		
Nycticorax nycticorax	black-crowned night heron		
Pandion halaetus	osprey		
Pelecanus erythrorhynchos	American white pelican	Threatened	
Phalacrocorax auritus	double-crested cormorant		
Pica pica	black-billed magpie		
Riparia riparia	bank swallow		
Sturnus vulgaris	European starling		
Tyrannus tyrannus	eastern kingbird		
Tyrannus verticalis	western kingbird		
Turdus migratorius	American robin		
Zenaida macroura	mourning dove		

Table A.6. Mammal Species Observed in the Riparian Area of the PNNL Richland Campus in 2015 and 2017–2019

Species Name	Common Name	State Status	Federal Status
Canis latrans	coyote		
Castor canadensis	American beaver		
Erithizon dorsatum	porcupine		
Odocoileus hemionus	mule deer		
Sciurus niger	eastern fox squirrel		

Appendix B

Plant and Animal Species Observed On and In the Vicinity of the PNNL Sequim Campus

Appendix B

Plant and Animal Species Observed On and In the Vicinity of the PNNL Sequim Campus

Table B.1. Plant Species Observed on PNNL Sequim Campus Lands, 2006–2019

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Abies grandis	grand fir			
Abronia latifolia	yellow sand verbena			
Acer circinatum	vine maple			
Acer glabrum	Rocky Mountain maple			
Acer macrophyllum	bigleaf maple			
Achillea millefolium	common yarrow			
Agropyron repens	quackgrass			
Alnus rubra	red alder			
Ambrosia chamissonis	silver bursage			
Amelanchier alnifolia	Saskatoon serviceberry			
Anaphalis margaritacea	pearly-everlasting			
Arbutus menziesii	madrone			
Arctostaphylos uva-ursi	kinnikinnick			
Artemisia suksdorfii	Suksdorf's sagebrush			
Atriplex patula	spear orache			
Avena sp.	oat			
Bellis perennis	daisy			
Berberis aquifolium	shining Oregon-grape			
Berberis nervosa	dull Oregon-grape			
Brassica rapa	field mustard			
Cakile edentula	American searocket			
Calystegia soldanella	beach morning-glory			
Capsella bursa-pastoris	shepherd's-purse			
Carex sp.	sedge			
Castilleja hispida	harsh Indian-paintbrush			
Cerastium arvense	field chickweed			
Chamaenerion angustifolium	fireweed			
Chenopodium album	white goosefoot			
Cirsium arvense	creeping thistle			C
Cirsium remotifolium	Pacific fringed thistle			
Cirsium vulgare	bull thistle			
Claytonia perfoliata	miner's lettuce			
Collinsia parviflora	small-flowered blue-eyed Mary			
Conium maculatum	poison-hemlock			B
Convolvulus arvensis	small bindweed			
Cornus stolonifera	red-osier dogwood			
Corylus cornuta var. *californica*	beaked hazelnut			
Crataegus douglasii	Douglas's hawthorne			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Crataegus monogyna	1-seed hawthorn			C
Crepis capillaris	smooth hawksbeard			
Cuscuta pacifica	Pacific salt marsh dodder			
Cytisus scoparius	Scot's broom			B
Dactylis glomerata	orchard-grass			
Danthonia intermedia	timber oatgrass			
Delphinium sp.	larkspur			
Deschampsia caespitosa	tufted hairgrass			
Dipsacus sylvestris	teasel			C
Distichlis spicata	saltgrass			
Draba verna	Whitlow-grass			
Elymus glaucus	blue wildrye			
Elymus mollis	American dunegrass			
Epilobium ciliatum	common willow-herb			
Epilobium minutum	small-flowered willow-herb			
Equisetum arvense	common horsetail			
Equisetum hyemale	common scouring-rush			
Erodium cicutarium	redstem stork's bill			
Eschscholzia californica	poppy			
Fragaria virginiana	mountain strawberry			
Fritillaria affinis	checker lily			
Galium aparine	stickywilly			
Galium triflorum	sweetscented bedstraw			
Gaultheria shallon	salal			
Geranium molle	dovefoot geranium			
Glehnia leiocarpa	glehnia			
Grindelia integrifolia	Puget Sound gumweed			
Hedera helix	English ivy			
Heracleum maximum	common cow-parsnip			
Hieraceum sp.	hawkweed			
Holodiscus discolor	oceanspray			
Hordeum brachyanterum	meadow barley			
Hypericum scouleri	western St. John's-wort			
Hypochaeris radicata	hairy cat's ear			C
Ilex aquifolium	holly			M
Juncus sp.	rush			
Lathyrus japonicus	sea peavine			
Lathyrus polyphyllus	leafy peavine			
Lepidium densiflorum	common pepperweed			
Leucanthemum vulgare	oxeye-daisy			C
Linnaea borealis	twinflower			
Lomatium nudicaule	bare-stemmed biscuitroot			
Lonicera ciliosa	orange honeysuckle			
Lonicera hispidula	California honeysuckle			
Lupinus sp.	lupine			
Lysichiton americanus	skunk cabbage			
Lysimachia latifolia	western starflower			
Maianthemum dilatatum	false lily-of-the-valley			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Maianthemum racemosum ssp. *amplexicaule*	large false Solomon's seal			
Malus fusca	Oregon crabapple			
Matricaria discoidea	pineapple weed			
Medicago lupulina	black medick			
Mycelis muralis	mycelis			
Myosotis laxa	small-flowered forget-me-not			
Oemleria cerasiformis	Indian plum			
Osmorhiza berteroi	sweet-cicely			
Petasites frigidus	sweet coltsfoot			
Physocarpus capitatus	Pacific ninebark			
Plantago lanceolata	English plantain			
Plantago major	common plantain			
Plantago maritima	sea tongue			
Plectritis congesta	sea blush			
Polygonum paronychia	black knotweed			
Polystichum munitum	western swordfern			
Populus trichocarpa	black cottonwood			
Potentilla anserina	cinquefoil			
Prunella vulgaris	self-heal			
Prunus emarginata	bitter cherry			
Prunus laurocerasus	cherry laurel			
Pseudotsuga menziesii	Douglas fir			
Pteridium aquilinum	bracken fern			
Ranunculus repens	creeping buttercup			
Ranunculus uncinatus	little buttercup			
Ribes divaricatum	straggly gooseberry			
Ribes sanguineum	redflower currant			
Rosa gymnocarpa	little wild rose			
Rosa nutkana	Nootka rose			
Rubus bifrons	Himalayan blackberry			C
Rubus leucodermis	blackcap			
Rubus nutkanus	thimbleberry			
Rubus ursinus	Pacific blackberry			
Rumex acetosella	sheep sorrel			
Rumex crispus	curly dock			
Rumex occidentalis	western dock			
Salicornia depressa	low glasswort			
Salix sitchensis	Sitka willow			
Sambucus racemosa	red elderberry			
Senecio vulgaris	old-man-in-the-spring			
Senecio sylvaticus	wood groundsel			
Sonchus asper	prickly sow-thistle			
Spiraea douglasii	spirea			
Stellaria media	common chickweed			
Struthiopteris spicant	hard fern			
Symphoricarpos albus	common snowberry			
Taraxacum officinale	common dandelion			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Tellima grandiflora	fringecup			
Thuja plicata	western red cedar			
Tolmiea menziesii	youth-on-age			
Tragopogon dubius	yellow salsify			
Trifolium dubium	suckling clover			
Trifolium pratense	red clover			
Trifolium repens	white clover			
Triglochin maritima	seaside arrow-grass			
Triphysaria pusilla	dwarf owl-clover			
Tsuga heterophylla	western hemlock			
Urtica dioica	stinging nettle			
Vicia americana	American vetch			
Vicia cracca	bird vetch			
Vicia nigricans	giant vetch			
Vicia sativa	common vetch			

(a) Nomenclature according to Hitchcock, CL and A Cronquist. 2018. *Flora of the Pacific Northwest: An Illustrated Manual, 2nd Edition*. Edited by DE Giblin, BS Legler, PF Zika, and RG Olmstead. University of Washington Press, Seattle, Washington. 936pp.

(b) Noxious Weed Class: B = Prevent spread and contain or reduce existing populations; C = Weeds widespread, control methods available but not normally required; M = Monitor list.

Table B.2. Bird Species Observed on and in the Vicinity of the PNNL Sequim Campus Lands, 2010–2019

Species Name	Common Name	State Status	Federal Status
Accipiter cooperii	Cooper's hawk		
Agelaius phoeniceus	red-winged blackbird		
Accipiter striatus	sharp-shinned hawk		
Aechmophorus occidentalis	western grebe	Candidate	
Agelaius phoeniceus	red-winged blackbird		
Anas platyrhynchos	mallard		
Anthus rubescens	American pipit		
Ardea herodias	great blue heron		
Aythya marila	greater scaup		
Branta bernicla	brandt		
Branta canadensis	Canada goose		
Bubo virginianus	great-horned owl		
Bucephala albeola	bufflehead		
Bucephala clangula	common goldeneye		
Buteo jamaicensis	red-tailed hawk		
Calidris alpina	dunlin		
Callipepla californica	California quail		
Calypte anna	Anna's hummingbird		
Cardellina pusilla	Wilson's warbler		
Cathartes aura	turkey vulture		
Catharus ustulatus	Swainson's thrush		
Catharus guttatus	hermit thrush		
Cepphus columba	pigeon guillemot		

Species Name	Common Name	State Status	Federal Status
Cerorhinca monocerata	rhinoceros auklet		
Certhia americana	brown creeper		
Charadrius vociferus	killdeer		
Circus hudsoneus	northern harrier		
Cistothorus palustris	marsh wren		
Coccothraustes vespertinus	evening grosbeak		
Clangula hyemalis	long-tailed duck		
Colaptes auratus	northern flicker		
Columba livia	rock dove (pigeon)		
Contopus cooperi	olive-sided flycatcher		
Corvus brachyrhynchos	American crow		
Corvus corax	common raven		
Cyanocitta stelleri	Steller's jay		
Dryobates pubescens	downy woodpecker		
Dryobates villosus	hairy woodpecker		
Empidonax difficilis	Pacific-slope flycatcher		
Empidonax hammondii	Hammond's flycatcher		
Euphagus cyanocephalus	Brewer's blackbird		
Falco peregrinus	peregrine falcon		
Haematopus bachmani	black oystercatcher		
Haemorhous mexicanus	house finch		
Haliaeetus leucocephalus	bald eagle		
Hirundo rustica	barn swallow		
Histrionicus	harlequin duck		
Hydroprogne caspia	Caspian tern		
Ixoreus naevius	varied thrush		
Junco hyemalis	dark-eyed junco		
Larus glaucescens	glaucus-winged gull		
Larus glaucescens x L. occidentalis	Olympic gull		
Larus occidentalis	western gull		
Leiothlypis celata	orange-crowned warbler		
Lophodytes cucullatus	hooded merganser		
Megaceryle alcyon	belted kingfisher		
Melanitta deglandi	white-winged scoter		
Melospiza lincolnii	Lincoln's sparrow		
Melospiza melodia	song sparrow		
Mergus merganser	common merganser		
Mergus serrator	red-breasted merganser		
Molothrus ater	brown-headed cowbird		
Passerculus sandwichensis	savannah sparrow		
Passerella iliaca	fox sparrow		
Patagioenas fasciata	band-tailed pigeon		
Petrochelidon pyrrhonota	cliff swallow		
Phalacrocorax auritus	double-crested cormorant		
Phalacrocorax pelagicus	pelagic cormorant		
Phalacrocorax penicillatus	Brant's cormorant		
Pheucticus melanocephalus	black-headed grosbeak		

Species Name	Common Name	State Status	Federal Status
Pipilo maculatus	spotted towhee		
Piranga ludoviciana	western tanager		
Podiceps nigricollis	eared grebe		
Podilymbus podiceps	pied-billed grebe		
Poecile atricapillus	black-capped chickadee		
Poecile rufescens	chestnut-backed chickadee		
Progne subis	purple martin		
Psaltriparus minimus	bushtit		
Regulus calendula	ruby-crowned kinglet		
Regulus satrapa	golden-crowned kinglet		
Selasphorus rufus	rufous hummingbird		
Setophaga coronata	yellow-rumped warbler		
Setophaga townsendi	Townsend's warbler		
Sitta canadensis	red-breasted nuthatch		
Sphyrapicus ruber	red-breasted sapsucker		
Spinus tristis	American goldfinch		
Stelgidopteryx serripennis	northern rough-winged swallow		
Sterna caspia	Caspian tern		
Strix varia	barred owl		
Sturnus vulgaris	European starling		
Tachycineta bicolor	tree swallow		
Tachycineta thalassina	violet-green swallow		
Thryomanes bewickii	Bewick's wren		
Troglodytes pacificus	Pacific wren		
Turdus migratorius	American robin		
Zenaida macroura	mourning dove		
Zonotrichia leucophrys	white-crowned sparrow		

Table B.3. Other Vertebrate Species Observed on PNNL Sequim Campus Lands, 2013–2015

Species Name	Common Name	State Status	Federal Status
Anaxyrus boreas	western toad		
Canis latrans	coyote		
Odocoileus hemionus	black-tailed deer		
Rana aurora	northern red-legged frog		
Sorex sp.	shrew		
Tamiasciurus douglasii	Douglas squirrel		
Taricha granulosa	rough-skinned newt		

Appendix C

Ambient External Dose Surveillance Results CY 2019

Appendix C

Ambient External Dose Surveillance Results CY 2019

Table C.1. Definitions for Ambient Air External Dose Sampling Data

Column Heading	Data Type/Format	Content
Sample Site Name	Text	Location of monitoring station: PNNL Richland Campus Monitoring stations – PNL-1, PNL-2, PNL-3, PNL-4. Background Location – PNL-5 PNL-T – to measure exposure during field deployment/ retrieval Transit Control – to measure exposure during shipment to and from vendor (value is NOT subtracted from the monitoring station data shown in Table C.2)
Vendor Location ID	Number (#####)	Five-digit number assigned by dosimeter vendor.
Sample Method	Text	Optically stimulated luminescence dosimeter (OSLD).
Sample Date Time On	date (DD-MMM-YYYY HH:MM [24 hr])	Date and time when dosimeter sampling started (time field is truncated and is not displayed in Table C.2).
Sample Date Time	date (DD-MMM-YYYY HH:MM [24 hr])	Date and time when dosimeter sampling ended (time field is truncated in Table C.2).
Quarter	Text (Q#)	Calendar quarter when the dosimeter was deployed. This may differ from the quarter indicated by the vendor because the vendor may indicate the quarter when the dosimeter was purchased.
Value Reported	Integer number	Net dose (no control value subtracted) result millirem for the dosimeter deployment period.

Table C.2. Ambient External Dose Surveillance 2019 PNNL Richland Campus

Sample Site Name	Vendor Location ID	Sample Method	Sample Date Time On	Sample Date Time	Quarter	Value Reported (mrem)
PNL-1	00063	OSLD	19 Dec 2018	27 Mar 2019	Q1	27
PNL-2	00064	OSLD	19 Dec 2018	27 Mar 2019	Q1	30
PNL-3	00065	OSLD	19 Dec 2018	27 Mar 2019	Q1	28
PNL-4	00066	OSLD	19 Dec 2018	27 Mar 2019	Q1	28
PNL-5	00067	OSLD	19 Dec 2018	27 Mar 2019	Q1	30
PNL-T	00068	OSLD	19 Dec 2018	27 Mar 2019	Q1	21
Transit Control	00069	OSLD	19 Dec 2018	27 Mar 2019	Q1	21
PNL-1	00070	OSLD	27 Mar 2019	19 Jun 2019	Q2	26
PNL-2	00071	OSLD	27 Mar 2019	19 Jun 2019	Q2	28
PNL-3	00072	OSLD	27 Mar 2019	19 Jun 2019	Q2	27
PNL-4	00073	OSLD	27 Mar 2019	19 Jun 2019	Q2	27
PNL-5	00074	OSLD	27 Mar 2019	19 Jun 2019	Q2	31
PNL-T	00075	OSLD	27 Mar 2019	19 Jun 2019	Q2	21
Transit Control	00076	OSLD	27 Mar 2019	19 Jun 2019	Q2	19
PNL-1	00077	OSLD	19 Jun 2019	25 Sep 2019	Q3	40
PNL-2	00078	OSLD	19 Jun 2019	25 Sep 2019	Q3	37
PNL-3	00079	OSLD	19 Jun 2019	25 Sep 2019	Q3	39
PNL-4	00080	OSLD	19 Jun 2019	25 Sep 2019	Q3	40
PNL-5	00081	OSLD	19 Jun 2019	25 Sep 2019	Q3	42
PNL-T	00082	OSLD	19 Jun 2019	25 Sep 2019	Q3	36
Transit Control	00083	OSLD	19 Jun 2019	25 Sep 2019	Q3	34
PNL-1	00084	OSLD	25 Sep 2019	31 Dec 2019	Q4	25
PNL-2	00085	OSLD	25 Sep 2019	31 Dec 2019	Q4	29
PNL-3	00086	OSLD	25 Sep 2019	31 Dec 2019	Q4	29
PNL-4	00087	OSLD	25 Sep 2019	31 Dec 2019	Q4	26
PNL-5	00088	OSLD	25 Sep 2019	31 Dec 2019	Q4	31
PNL-T	00089	OSLD	25 Sep 2019	31 Dec 2019	Q4	20
Transit Control	00090	OSLD	25 Sep 2019	31 Dec 2019	Q4	19

OSLD = Optically stimulated luminescence dosimeter

Table C.3. 2019 PNNL Richland Campus Ambient External Dose Calculated for ANSI/HPS N13.37 91-d Normalized Quarters

2019 91-d Normalized Quarter Dose	PNL-1	PNL-2	PNL-3	PNL-4	PNL-5[(a)]
Normalized Q1 (mrem/Q)	5.57	8.36	6.50	6.50	8.36
Normalized Q2 (mrem/Q)	7.58	9.75	8.66	8.66	13.0
Normalized Q3 (mrem/Q)	5.58	2.79	4.65	5.58	7.43
Normalized Q4 (mrem/Q)	5.63	9.38	9.38	6.57	11.3
Total (mrem/yr)	**24.4**	**30.3**	**29.2**	**27.3**	**40.1**

(a) PNL-5 is the background station. No background values were subtracted from listed Campus perimeter stations (PNL-1 through PNL-4) results.

Appendix D

Helpful Information

Appendix D

Helpful Information

The following information is provided to assist readers in understanding this report. Included here is information about scientific notation, units of measurement, radioactivity units, radiological dose units, chemical and elemental nomenclature, and greater than or less than symbols. Definitions of technical terms can be found in Appendix E.

D.1 Scientific Notation

Scientific notation is used to express very large or very small numbers. For example, the number 1 billion can be written as 1,000,000,000 or, by using scientific or E notation, written as 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 the 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.

D.2 Units of Measurement

The primary units of measurement used in this report follow the International System of Units and are metric, but U.S. standard measurements are also provided. Table D.1 summarizes and defines the terms and corresponding symbols (metric and non-metric). A conversion table is provided in Table D.2.

D.3 Radioactivity Units

Much of this report deals with levels of radioactivity in various environmental media. Radioactivity in this report is usually discussed in units of curies (Ci), with conversions to becquerels (Bq), the International System of Units measure (Table D.3). The curie is the basic unit used to describe the amount of activity present, and activities are generally expressed in terms of curies per mass or volume (e.g., picocuries per liter). One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. One becquerel is equivalent to one disintegration per second. Nuclear disintegrations produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these. Figure D.1 includes selected conversions from curies to becquerels.

Table D.1. Names and Symbols for Units of Measure

Symbol	Name	Symbol	Name
Concentration		Area	
ppb	parts per billion	ha	hectare(s) (1×10^4 m^2)
ppm	parts per million	km^2	square kilometer(s)
ppmv	parts per million by volume	mi^2	square mile(s)
Length		ft^2	square foot (feet)
cm	centimeter(s) (1×10^{-2} m)	Mass	
ft	foot (feet)	g	gram(s)
in.	inch(es)	kg	kilogram(s) (1×10^3 g)
km	kilometer(s) (1×10^3 m)	mg	milligram(s) (1×10^{-3} g)
m	meter(s)	µg	microgram(s) (1×10^{-6} g)
mi	mile(s)	lb	pound(s)
mm	millimeter(s) (1×10^{-3} m)	Time	
µm	micrometer(s) (1×10^{-6} m)	d	day(s)
Rate		hr	hour(s)
cfs (or ft^3/sec)	cubic feet per second	min	minute(s)
cpm	counts per minute	sec	second(s)
gpm	gallon(s) per minute	yr	year(s)
mph	mile(s) per hour	Volume	
mR/hr	milliroentgen(s) per hour	cm^3	cubic centimeter(s)
mrem/d	millirem per day	ft^3	cubic foot (feet)
mrem/yr	millirem per year	gal	gallon(s)
µrem/hr	microrem per hour	L	liter(s)
Temperature		m^3	cubic meter(s)
°C	degrees Celsius	mL	milliliter(s) (1×10^{-3} L)
°F	degrees Fahrenheit	yd^3	cubic yard(s)

Table D.2. Conversion Table

Multiply	By	To Obtain	Multiply	By	To Obtain
cm	0.394	in.	in.	2.54	cm
m	3.28	ft	ft	0.305	m
km	0.621	mi	mi	1.61	km
kg	2.205	lb	lb	0.454	kg
L	0.2642	gal	gal	3.785	L
m^2	10.76	ft^2	ft^2	0.093	m^2
ha	2.47	acres	acre	0.405	ha
km^2	0.386	mi^2	mi^2	2.59	km^2
m^3	35.31	ft^3	ft^3	0.0283	m^3
m^3	1.308	yd^3	yd^3	0.7646	m^3
pCi	1,000	nCi	nCi	0.001	pCi
µCi/mL	10^9	pCi/L	pCi/L	10^{-9}	µCi/mL
Ci/m^3	10^{12}	pCi/m^3	pCi/m^3	10^{-12}	Ci/m^3
mCi/cm^3	10^{15}	pCi/m^3	pCi/m^3	10^{-15}	mCi/cm^3
nCi/m^2	1.0	mCi/km^2	mCi/km^2	1.0	nCi/m^2
Ci	3.7×10^{10}	Bq	Bq	2.7×10^{-11}	Ci
pCi	0.037	Bq	Bq	27	pCi
rad	0.01	Gy	Gy	100	rad
rem	0.01	Sv	Sv	100	rem
ppm	1,000	ppb	ppb	0.001	ppm
°C	(°C × 9/5) + 32	°F	°F	(°F -32) ÷ 9/5	°C
oz	28.349	g	g	0.035	oz
ton	0.9078	tonne	tonne	1.1	ton

Table D.3. Names and Symbols for Units of Radioactivity

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel
mCi	millicurie (1×10^{-3} Ci)	kBq	kilobecquerel (1×10^3 Bq)
µCi	microcurie (1×10^{-6} Ci)	mBq	millibecquerel (1×10^{-3} Bq)
nCi	nanocurie (1×10^{-9} Ci)	MBq	megabecquerel (1×10^6 Bq)
pCi	picocurie (1×10^{-12} Ci)	GBq	gigabecquerel (1×10^9 Bq)
fCi	femtocurie (1×10^{-15} Ci)	TBq	terabecquerel (1×10^{12} Bq)
aCi	attocurie (1 × 10-18 Ci)		

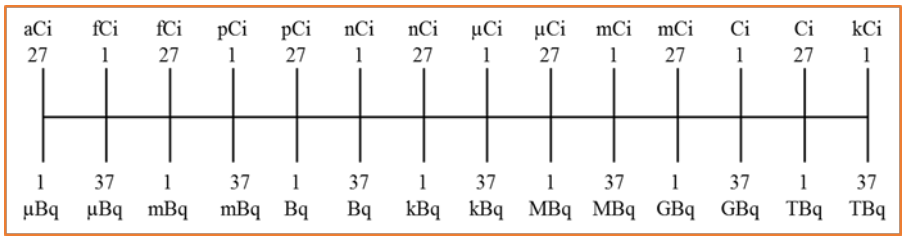


Figure D.1. Conversions for Radioactivity Units

D.4 Radiological Dose Units

Radiological dose in this report is usually written in terms of effective dose equivalent (EDE) and reported numerically in units of millirem (mrem), with the metric units millisievert (mSv) or microsievert (µSv) following in parentheses or footnoted. The EDE and effective dose (ED) units can be considered equivalent for the purposes of this report and reflect the units calculated by the software used.

Millirem (millisievert) is a unit of measurement that relates a given amount of absorbed radiation energy to its biological effectiveness or risk (to humans). For perspective, a dose of 0.01 mrem (1 mSv) would have a biological effect roughly the same as that received from 1 day's exposure to natural background radiation. An acute (short-term) dose to the whole body of 100 rem (1 Sv) would likely cause temporary radiation sickness in some exposed individuals. An acute dose of over 500 rem (5 Sv) would soon result in death in approximately 50% of those exposed. Exposure to lower amounts of radiation (10 mrem [100 µSv] or less) produces no immediate observable effects, but long-term (delayed) effects are possible. The average person in the United States receives an annual dose from exposure to naturally produced radiation of approximately 300 mrem (3 mSv). Medical and dental x-rays and air travel add to this total. Figure D.2 includes selected conversions from rem to sievert.

Also used in this report is the term rad, with the corresponding International System of Units, gray (Gy), in parentheses 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 Figure D.2 can also be used to convert grays to rads.

The names and symbols for units of radiation dose used in this report are listed in Table D.4.

Additional information about radiation and dose terminology can be found in Appendix E. A list of the radionuclides discussed in this report, their symbols, and their half-lives are included in Table D.5.

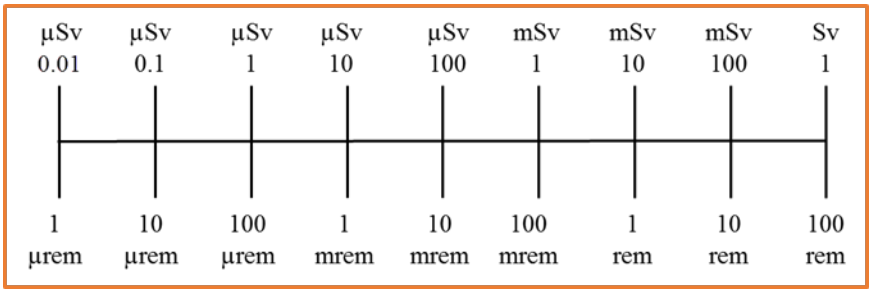


Figure D.2. Conversions for Radiological Dose Units

Table D.4. Names and Symbols for Units of Radiation Dose or Exposure

Symbol	Name
mrad	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
µrem	microrem (1×10^{-6} rem)
Sv	sievert (100 rem)
mSv	millisievert (1×10^{-3} Sv)
µSv	microsievert (1×10^{-6} Sv)
Gy	gray (100 rad)
mGy	milligray (1×10^{-3} Gy)

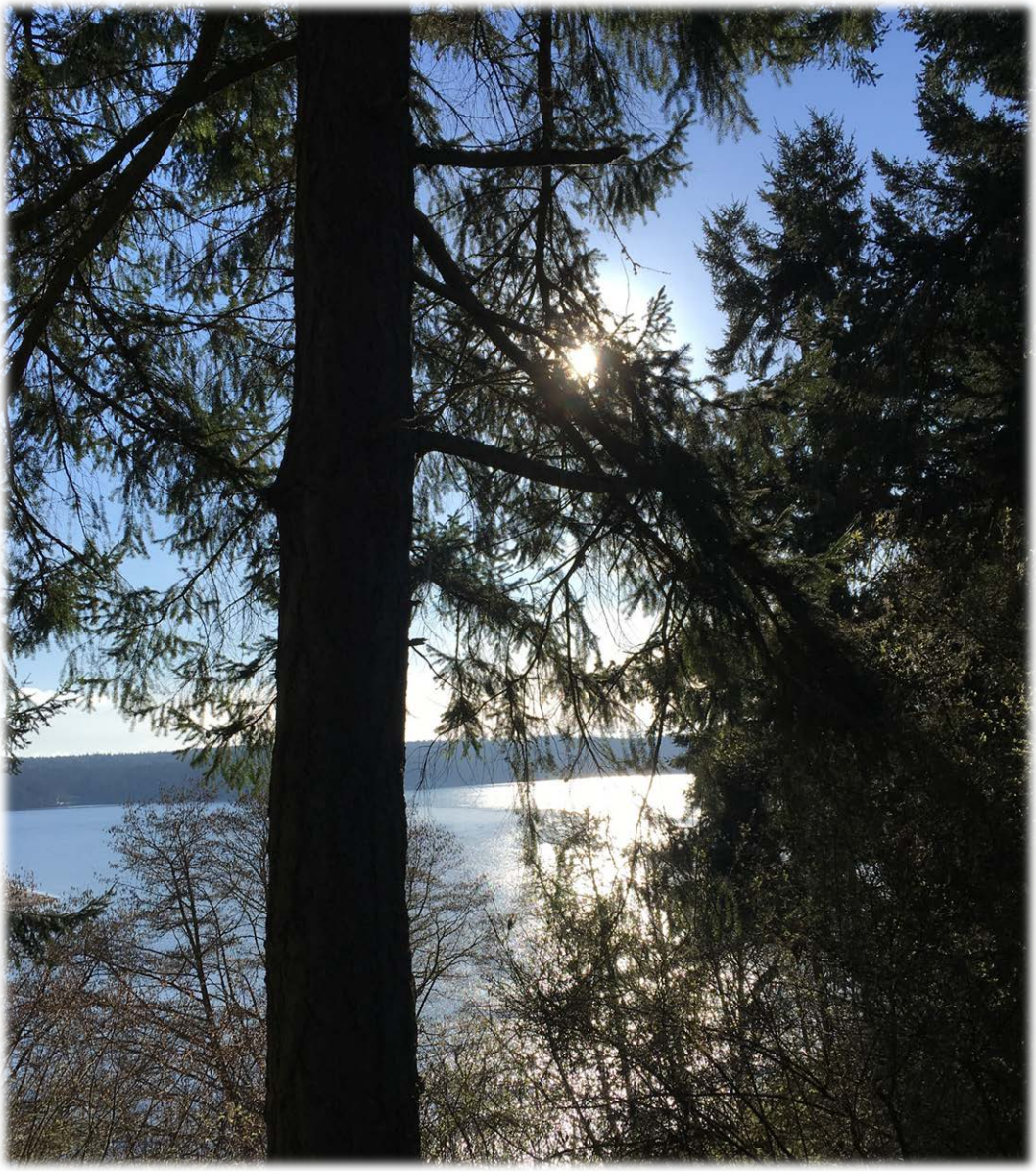
Table D.5. Radionuclides and Their Half-Lives[a]

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
^{3}H	tritium	12.32 yr	^{140}Ba	barium-140	12.7527 d
^{7}Be	beryllium-7	53.22 d	^{152}Eu	europium-152	13.517 yr
^{14}C	carbon-14	5,700 yr	^{154}Eu	europium-154	8.601 yr
^{24}Na	sodium-24	14.997 h	^{155}Eu	europium-155	4.753 yr
^{40}K	potassium-40	1.248×10^{9} yr	^{177}Lu	lutetium-177	6.647 d
^{37}Ar	argon-37	35.04 d	^{208}Po	polonium-208	2.898 yr
^{39}Ar	argon-39	269 yr	^{210}Pb	lead-210	22.20 yr
^{51}Cr	chromium-51	27.7025 d	^{212}Pb	lead-212	10.64 h
^{54}Mn	manganese-54	312.20 d	^{220}Rn	radon-220	55.6 sec
^{55}Fe	iron-55	2.744 yr	^{222}Rn	radon-222	3.8235 d
^{59}Fe	iron-59	44.495 d	^{226}Ra	radium-226	1600 yr
^{59}Ni	nickel-59	7.6×10^{4} yr	^{228}Ra	radium-228	5.75 yr
^{57}Co	cobalt-57	271.74 d	^{228}Th	thorium-228	1.9125 yr
^{60}Co	cobalt-60	5.275 yr	^{229}Th	thorium-229	7932 yr
^{63}Ni	nickel-63	101.2 yr	^{230}Th	thorium-230	7.54×10^{4} yr
^{65}Zn	zinc-65	243.93 d	^{232}Th	thorium-232	1.40×10^{10} yr
^{82}Br	bromine-82	35.282 h	U or uranium	natural uranium	~4.5×10^{9}[b]
^{85}Kr	krypton-85	10.739 yr	^{233}U	uranium-233	1.592×10^{5} yr
^{89}Sr	strontium-89	50.563 d	^{234}U	uranium-234	2.455×10^{5} yr
^{90}Sr	strontium-90	28.9 yr	^{235}U	uranium-235	7.04×10^{8} yr
^{88}Y	yttrium-88	106.626 d	^{238}U	uranium-238	4.468×10^{9} yr
^{90}Y	yttrium-90	64.053 h	^{236}Np	neptunium-236	1.53×10^{5} yr
^{95}Zr	zirconium-95	64.032 d	^{237}Np	neptunium-237	2.144×10^{6} yr
^{99}Tc	technetium-99	2.111×10^{5} yr	^{238}Pu	plutonium-238	87.7 yr
^{103}Ru	ruthenium-103	39.247 d	^{239}Pu	plutonium-239	2.411×10^{4} yr
^{106}Ru	ruthenium-106	371.8 d	^{240}Pu	plutonium-240	6.561×10^{3} yr
^{109}Cd	cadmium-109	461.4 d	^{241}Pu	plutonium-241	14.329 yr
^{113}Sn	tin-113	115.09 d	^{242}Pu	plutonium-242	3.75×10^{5} yr
^{125}Sb	antimony-125	2.75856 yr	^{244}Pu	plutonium-244	8.0×10^{7} yr
^{129}I	iodine-129	1.57×10^{7} yr	^{241}Am	americium-241	432.6 yr
^{131}I	iodine-131	8.0252 d	^{243}Am	americium-243	7,364 yr
^{132}I	iodine-132	2.295 h	^{243}Cm	curium-243	29.1 yr
^{133}Xe	xenon-133	5.2475 d	^{244}Cm	curium-244	18.1 yr
^{134}Cs	cesium-134	2.0652 yr	^{245}Cm	curium-245	8,423 yr
^{137}Cs	cesium-137	30.08 yr	^{250}Cf	californium-250	13.08 yr
^{137m}Ba	barium-137m	2.552 min	^{252}Cf	californium-252	2.645 yr

(a) From NuDat 2.8 at https://www.nndc.bnl.gov/nudat2/chartNuc.jsp.
(b) Natural uranium is a mixture dominated by uranium-238.

Appendix E

Glossary



Appendix E

Glossary

This glossary contains selected words and phrases used in this report that may not be familiar to readers. Words appearing in italic type within a definition are also defined in this glossary.

alpha particle – A positively charged particle composed of two protons and two neutrons ejected spontaneously from the nuclei of some *radionuclides* during radioactive decay. It has a low penetrating power and short range. The most energetic alpha particle will generally fail to penetrate the skin, but is hazardous when introduced into the body.

aquifer – Underground sediment or rock that stores and/or transmits water.

background radiation – *Radiation* in the natural environment, including cosmic rays from space and *radiation* from naturally occurring radioactive elements in the air, in the earth, and in human bodies. It also includes *radiation* from global fallout from historical atmospheric nuclear weapons testing. In the United States, the average person receives approximately 300 *millirem* of background radiation per year.

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) released from a nucleus during radioactive *decay*. At high enough intensities, some beta particles may cause skin burns and may be harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal or plastic.

Categorical Exclusion – A class of actions that DOE has determined are not likely to have significant environmental impacts under normal circumstances, and for which an environmental assessment or environmental impact statement is not normally needed. These are listed at 10 CFR Part 1021 Appendix D.

collective dose – Sum of the total *effective dose equivalent* for individuals composing a defined population. Collective dose units are *person-rem* or person-sievert.

composite sample – Sample formed by combining 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.

curie (Ci) – A unit of *radioactivity* equal to 37 billion (3.7×10^{10}) nuclear transformations per second (*becquerels*).

decay – The decrease in the amount of any radioactive material (disintegration) with the passage of time. See *radioactivity*.

decay product – The atomic nucleus or nuclei that are left after radioactive transformation of a radioactive material. Decay products may be radioactive or nonradioactive (stable). They are informally referred to as daughter products or progeny. See *radioactivity*.

dispersion – Process whereby *effluents* or *emissions* are spread or mixed when they are transported by *groundwater*, surface water, or air.

dose rate – The rate at which a dose is delivered over time (e.g., *millirem* per hour [mrem/h]).

effective dose equivalent (EDE) – Dose unit qualifier to indicate wholebody risk from ionizing radiation exposure. Calculated as the sum of critical human-tissue doses weighted for total health risk. Total health risk includes the risk of fatal and non-fatal cancers, severe hereditary effects, and lifespan.

effluent – Liquid material released from a facility.

effluent monitoring – Sampling or measuring specific liquid *effluent* streams for the presence of pollutants.

emission – Gaseous stream released from a facility.

exposure – The interaction of an organism with a physical agent (e.g., *radiation*) or a chemical agent (e.g., arsenic) of interest. Also used as a term for quantifying x- and *gamma-radiation* fields.

fission – The splitting or breaking apart of a nucleus into at least two other nuclei, accompanied by the release of a relatively large amount of energy.

gamma radiation – High-energy electromagnetic *radiation* (photons) originating in the nucleus of decaying *radionuclides*. Gamma radiation is substantially more penetrating than *alpha* or *beta emissions*, but comparatively the energy is not as readily absorbed.

grab sample – A short-duration sample (e.g., air, water, and soil) that is grabbed from the collection site.

gray (Gy) – Unit of absorbed dose in the International System of Units equal to the absorption of 1 joule per kilogram. The common unit of absorbed dose, the *rad*, is equal to 0.01 Gy.

groundwater – Subsurface water that is in the pores of sand and gravel or in the cracks of fractured rock.

high-level waste – Highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly from reprocessing and any solid material derived from such liquid waste that contains *fission* products and other *radioisotopes* in sufficient concentrations to require permanent isolation.

isotopes – *Nuclides* of the same chemical element with the same number of protons but a different number of neutrons.

low-level waste – Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, *transuranic waste*, byproduct material, or naturally occurring radioactive material.

maximum exposed individual – A hypothetical member of the public residing near the PNNL Richland Campus or PNNL Sequim Campus who, by virtue of location and living habits, would reasonably receive the highest possible *radiation* dose from radioactive materials originating from the site.

method reporting limit – The lowest amount of analyte in a sample that can be quantitatively determined with the stated acceptable precision and accuracy under controlled laboratory conditions.

millirem – A unit of *radiation dose* that is equal to one one-thousandth (1/1000) of a *rem*.

minimum detectable activity – The smallest amount or concentration of a chemical or radioactive material that can be reliably detected in a sample.

mitigation – Prevention or reduction of expected *risks* to workers, the public, or the environment.

mixed waste – A U.S. Environmental Protection Agency or state-designated dangerous, extremely hazardous, or acutely hazardous waste that contains both a nonradioactive hazardous component and a radioactive component.

monitoring – As defined in DOE Order 458.1, Admin Chg 3, the collection and analysis of samples or measurements of liquid *effluent* and gaseous *emissions* for purposes of characterizing and quantifying contaminants, assessing *radiation exposure* to the public, and demonstrating compliance with regulatory standards.

nuclide – A particular combination of neutrons and protons. A *radionuclide* is a radioactive nuclide.

operable unit – A discrete area for which an incremental step can be taken toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units, depending on the complexity of the problems associated with the site.

outfall – End of a drain or pipe that carries wastewater or other *effluent* into a ditch, pond, or river.

person-rem or **person-sievert (person-Sv)** – Unit of *collective dose*. 1 person-Sv = 100 person-rem.

plutonium – A heavy, radioactive, metallic element of several possible *isotopes*. One important *isotope* is plutonium-239, which is produced after a specific neutron reaction with uranium-238. Routine analysis cannot distinguish between the plutonium-239 and plutonium-240 *isotopes*; hence, the term plutonium-239/240 is used in this report to indicate the presence of one or both of these *isotopes* in the analytical results.

PNNL Richland Campus – Includes a mix of federal and private land and facility ownership north of Richland, Washington.

PNNL Sequim Campus – Consists of DOE-contracted facilities near Sequim, Washington.

quality assurance – Actions that provide confidence that an item or process meets or exceeds a user's requirements and expectations.

quality control – All actions necessary to control and verify that the features and characteristics of a material, process, product, or service meet specified requirements. Quality control is an element of *quality assurance*.

rad – The unit of absorbed dose. 1 rad = 0.01 gray (Gy).

radiation – The energy emitted in the form of photons or energetic *alpha* and *beta particles* subsequent to radioactive decay. 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.

radionuclide – An atom that has a particular number of protons (Z), a particular number of neutrons (A), and a particular atomic weight (N = Z + A) that happens to emit *radiation*. Carbon-14 is a radionuclide but carbon-12, which is not radioactive, is referred to simply as a *nuclide*.

rem – The unit of *effective dose equivalent*. 1 rem = 0.01 sievert (Sv).

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.

shrub-steppe – A drought-resistant shrub and grassland ecosystem.

sievert (Sv) – The unit of *effective dose equivalent* and its variants in the International System of Units. The common unit for *effective dose equivalent* and its variants, the *rem*, is equal to 0.01 Sv.

surveillance – As defined in DOE Order 458.1, Admin 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 assessing effects, if any, on the local environment.

transuranic element – An element with an atomic number greater than 92 (92 is the atomic number of uranium).

transuranic waste – Waste containing more than 100 nanocuries (10^{-9} *curies*) per gram of alpha-emitting transuranic isotopes that have half-lives longer than 20 years.

tritium – The heaviest radioactive isotope of hydrogen (hydrogen-3); it has a 12.3-year half-life.

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.

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; they are used in solvents and degreasing compounds as raw materials.

water table – The top of the *unconfined aquifer*.

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