

PNNL-33213

Pacific Northwest National Laboratory Annual Site Environmental Report for Calendar Year 2021

**Final Report
September 2022**

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Pacific Northwest National Laboratory
Richland, Washington 99354

Pacific Northwest National Laboratory Annual Site Environmental Report for 2021

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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.

In March 2020 and through 2021, PNNL on-site operations were curtailed due to the COVID-19 pandemic. PNNL operations impacted by implemented temporary COVID-19 work limitations are indicated, where appropriate.

Compliance with Federal, State, and Local Laws and Regulations in 2021

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 2021; 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. 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 exhibited 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 in 2021.

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 2021.

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 on-site wastewater treatment plant prior to being discharged to Sequim Bay under a permit issued by the Washington State Department of Ecology. In 2021, there were no unplanned releases of regulated pollutants or contaminated wastewater from PNNL facilities and effluent discharges were within permitted limits.

Drinking Water Monitoring. Drinking water quality at the PNNL Sequim Campus is monitored under a permit issued by the Washington State Department of Health. Drinking water is supplied by an on-site groundwater well and is untreated prior to distribution. In 2021, the PNNL Sequim Campus drinking water system complied with drinking water standards and there were no noncompliance issues regarding drinking water.

Radiological Release of Property. PNNL uses the pre-approved guideline limits derived from guidance in DOE Order 458.1, Admin Chg 4, *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 2021.

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 2021 dose rate estimates for aquatic, terrestrial, and riparian animals and plants for both the PNNL Richland and Sequim Campuses were well below the dose rate limits of DOE Order 458.1, Admin Chg 4 guidance (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).

Environmental Radiological Monitoring. Radioactive particulates in ambient air are monitored using a particulate air-sampling network located at the PNNL Richland Campus. No radiological releases to the environment exceeded permitted limits in 2021, and there was no indication that any PNNL activities increased the ambient air concentrations at the air-sampling locations.

Public Radiation Dose from All Pathways. The Richland Campus maximum exposed individual (MEI) location was 0.64 km (0.40 mi) south-southeast of the Physical Sciences Facility 3410 Building. The dose to the MEI from site radionuclide air emissions was 1.8×10^{-5} mrem (1.8×10^{-7} mSv). No other pathways contributed to MEI dose. In 2021, 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 9.7×10^{-5} person-rem (9.7×10^{-7} person-Sv).

The PNNL Sequim Campus MEI location for 2021 was 0.23 km (0.14 mi) west-northwest of the central emission location. The dose to the MEI from site emissions was 5.4×10^{-5} mrem (5.4×10^{-7} mSv). The 80 km (50 mi) collective dose for PNNL Sequim Campus emissions was 6.0×10^{-5} person-rem (6.0×10^{-7} person-Sv).

The total dose from radioactive air emissions 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). The total dose from all pathways (air emissions, liquid effluent releases, and other pathways) is well below the limit of 100 mrem/yr (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 was no nonradiological air emission permit exceedance or noncompliance occurrence at either the PNNL Richland Campus or PNNL Sequim Campus in 2021.

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.

Three endangered and threatened fish species, Upper Columbia River spring-run Chinook salmon, Upper Columbia River steelhead, and bull trout are known to occur or potentially occur in the Columbia River Hanford Reach, adjacent to the PNNL Richland Campus. Eleven federally endangered or threatened animal species are known to occur on or near the PNNL Sequim Campus: marbled murrelet, bull trout, Hood Canal summer-run chum salmon, North American green sturgeon, Pacific eulachon, Puget Sound bocaccio, Puget Sound Chinook salmon, Puget Sound steelhead, Puget Sound yelloweye rockfish, island marble butterfly, and Taylor's checkerspot butterfly.

All PNNL projects involving soil or vegetation disturbance or work outdoors are routinely evaluated to determine their potential to affect biological resources prior to implementation. Thirty-seven biological resource reviews were completed in 2021 at the Richland Campus (13), PNNL Sequim Campus (13), and other locations (11). Seventy-two environmental permits for PNNL research activities were acquired for CY 2021.

The PNNL cultural resources program supported 43 projects in 2021; 14 occurred at the PNNL Sequim Campus, where one undertaking identified in 2020 resulted in an Adverse Effect. Resolution of the Adverse Effect continued into 2021 due to the COVID-19 pandemic delays. NHPA Section 110 monitoring was also conducted at both Campuses in 2021. Small manmade disturbances resulting from human activities were identified at one PNNL location. Additional impacts were noted in the PNNL Richland Campus historic district during annual Section 110 monitoring.

Groundwater Protection

Groundwater monitoring is no longer required for environmental compliance at either the PNNL Richland or Sequim Campuses.

Quality Assurance

Sampling and monitoring activities performed under PNNL's Environmental Management Program in 2021 included collecting samples of water, wastewater, radiological air emissions, ambient air, and environmental dosimeters. Chain-of-custody procedures tracked the transfer of samples from points of collection to accredited analytical laboratories. The comprehensive quality assurance programs and plans at PNNL, which include various quality control procedures and method verification, assured reported data were reliable and met all quality control and quality assurance objectives.



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Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	microgram(s) per liter
µrem/hr	microrem(s) per hour
µSv	microsievert(s)
A	
ac	acre(s)
AFE	alternative fuel vehicle(s)
ALARA	as low as reasonably achievable
AQSS	Acquisition Quality Support Services
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASO	Analytical Support Operations (laboratory)
B	
Battelle	Battelle Memorial Institute
BCAA	Benton Clean Air Agency
BP	Before Present
Bq	becquerel(s)
BSF	Biological Sciences Facility
Btu	British thermal unit(s)
C	
C&D	construction and demolition
CAA	<i>Clean Air Act</i>
CBRMP	Cultural and Biological Resources Management Plan
CEQ	Council on Environmental Quality
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CFR	Code of Federal Regulations

CMP	coastal zone management program
CNGC	Cascade Natural Gas Corporation
Ci	curie(s)
cm	centimeter(s)
CSF	Computational Sciences Facility
CWA	<i>Clean Water Act</i>
CY	calendar year
CZMA	<i>Coastal Zone Management Act of 1972</i>
D	
d	day(s)
DoD	U.S. Department of Defense
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(s)
E	
ECM	Energy Conservation Measure(s)
ED	effective dose
EDE	effective dose equivalent
EISA	<i>Energy Independence and Security Act of 2007</i>
EM	Effluent Management
EMP	Environmental Management Plan
EMS	environmental management system
EMSL	William R. Wiley Environmental Molecular Sciences Laboratory
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPCRA	<i>Emergency Planning and Community Right-to-Know Act of 1986</i>
ERP	Environmental Research Permitting
ESA	<i>Endangered Species Act of 1973</i>
EV	electric vehicle(s)
EWTPG	Effluent, Waste, and Transportation Programs Group
F	
FEMA	Federal Emergency Management Agency
FEMP	Federal Energy Management Program
FR	Federal Register
FSOAA	<i>Forest Service Organic Administration Act</i>
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
GP	Guiding Principle(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GSA	General Services Administration
gsf	gross square foot (feet)
Gy	gray(s)
H	
ha	hectare(s)
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
HFC	hydrofluorocarbon
HDI	How Do I....?
I	
in.	inch(es)
ISO	International Organization for Standardization
ISO/IEC	International Organization for Standardization/ International Electrotechnical Commission
IT	information technology
K	
kg	kilogram(s) (1,000 grams)
km	kilometer(s)
km ²	square kilometer(s)
kW	kilowatt(s)
L	
L	liter(s)
L/min	liter(s) per minute
lb(s)	pound(s)
LNLM	Local Notice to Mariners
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
MBTA	<i>Migratory Bird Treaty Act of 1918</i>
MEI	maximum exposed individual
mGy/d	milligray(s) per day
mi	mile(s)
mi ²	square mile(s)
min	minute(s)
MMI	Modified Mercalli Intensity
MMPA	<i>Marine Mammal Protection Act of 1972</i>
MoU	Memorandum of Understanding
mph	mile(s) per hour
MRAD	Multi-Media Radiochemistry Proficiency Testing
mrem	millirem
mrem/yr	millirem per year
MSFCMA	<i>Magnuson–Stevens Fishery Conservation and Management Act</i>
mSv	millisievert(s)
mSv/yr	millisievert(s) per year
N	
NA	not applicable
NELAP	National Environmental Laboratory Accreditation Program
NEPA	<i>National Environmental Policy Act of 1969</i>
NESHAP	National Emission Standards for Hazardous Air Pollutants
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NQA	nuclear quality assurance
NRHP	National Register of Historic Places
NZERO	net-zero emissions and energy-resilient operations
O	
OAR	Oregon Administrative Rules
ORCAA	Olympic Region Clean Air Agency
OSL	Optically stimulated luminescence
OSLD	Optically stimulated luminescence dosimeter
P	
PCB	polychlorinated biphenyl(s)
pCi	picocurie(s)
pCi/L	picocurie(s) per liter
pCi/m ³	picocurie(s) per cubic meter
pCi/mL	picocurie(s) per milliliter

PFAS	per- and polyfluoroalkyl substances
PIC-5	Potential Impact Category 5
PNL	Pacific Northwest Laboratory
PNNL	Pacific Northwest National Laboratory
PNSO	Pacific Northwest Site Office
PSF	Physical Sciences Facility
Q	
QC	quality control
QA	quality assurance
QAP	quality assurance plan
R	
R&D	research and development
RAEL	radioactive air emission license
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
RCW	Revised Code of Washington
REC	Renewable Energy Credit
RESL	Radiological and Environmental Sciences Laboratory
RHA	<i>Rivers and Harbors Appropriations Act of 1899</i>
RPL	Radiochemical Processing Laboratory
RCW	Revised Code of Washington
RPL	Radiochemical Processing Laboratory
S	
s	second(s)
SDWA	<i>Safe Drinking Water Act of 1974</i>
SEPA	<i>State Environmental Policy Act</i>
SERC	State Emergency Response Commission
SMA	<i>Shoreline Management Act of 1971</i>
Sv	sievert(s)
T	
TNI	The NELAC Institute
TRN	Technical Resilience Navigator
U	
UESC	Utility Energy Services Contract
UIC	underground injection control
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 4, *Radiation Protection of the Public and the Environment*. DOE is committed to environmental protection, compliance, sustainability, and efforts to assure the validity and accuracy of compliance monitoring data.

This report provides a synopsis of calendar year (CY) 2021 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.

In late 2019, the coronavirus designated as SARS-CoV-2 was first identified. Commonly known as COVID-19, the virus developed to pandemic proportions in 2020, affecting both work and private lives. PNNL-specific COVID-19 workplace safety measures remained in place during 2021. Increased understanding of the disease, treatments, and the effectiveness of vaccines, first authorized for emergency use in December 2020, resulted in the easing of PNNL work restrictions after December 2021. A limited amount of information presented in this report may reflect operations in 2019 or 2020, if updated data were not available for 2021.

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 off-site 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.

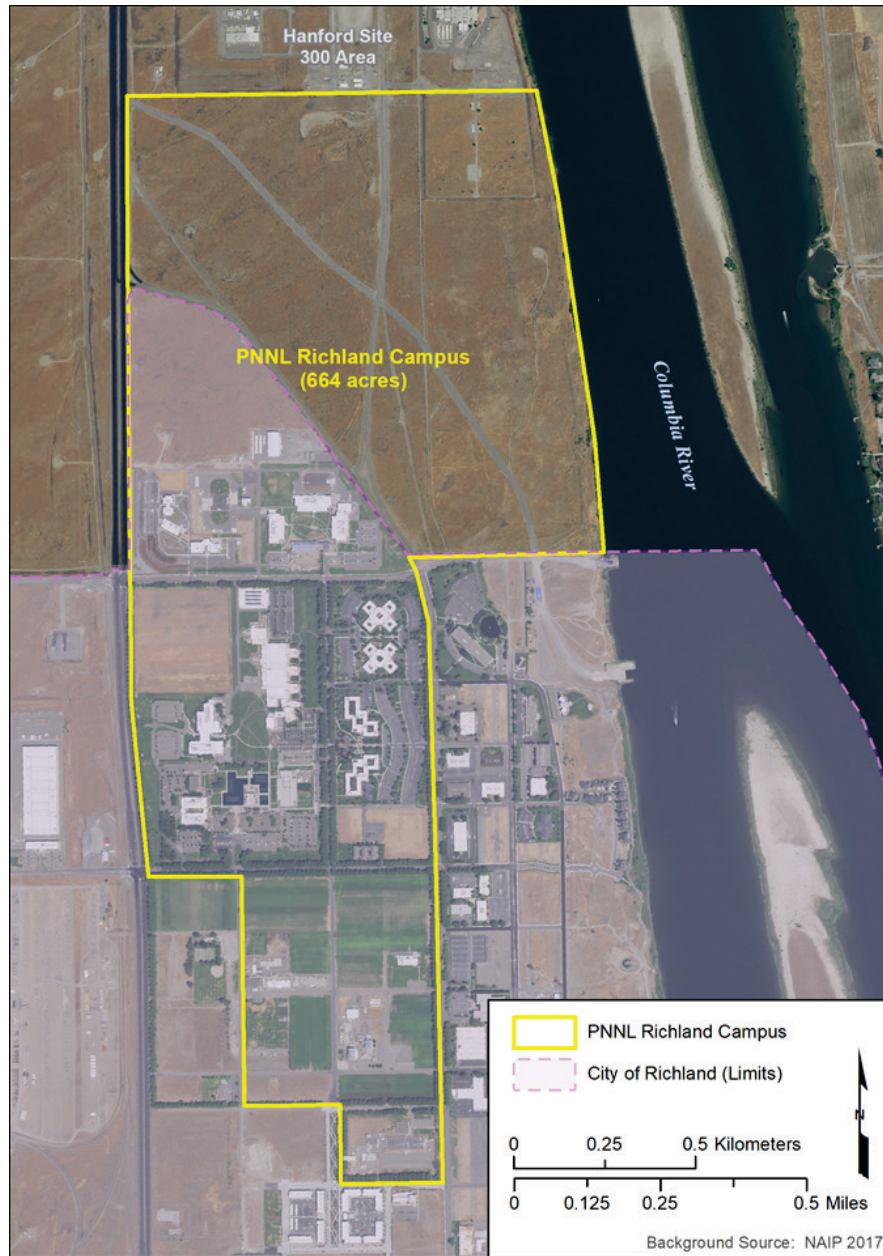


Figure 1.2. PNNL Richland Campus

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 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).

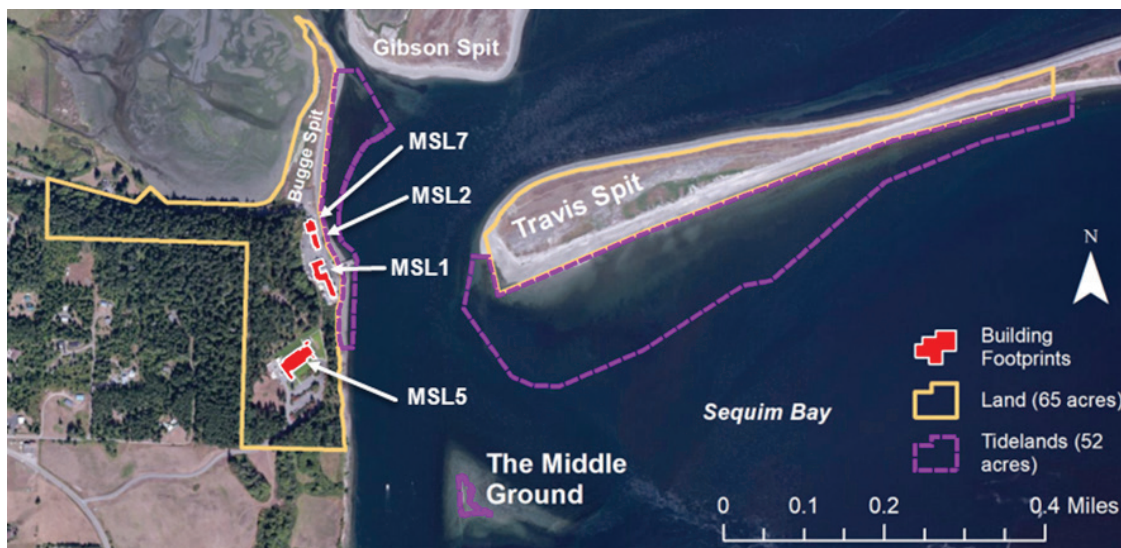


Figure 1.3. PNNL Sequim Campus and Nearby Environment

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 joined the DOE national laboratory system and 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, then Marine Sciences Laboratory. It 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 m² (15,000 ft²) 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, climate change, biofouling/biocorrosion, 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. Richland is the only community adjacent to the PNNL Richland Campus.

Demographic information from the 2020 U.S. Census Bureau indicates an estimated 206,873 people lived in Benton County and 96,749 people lived in adjacent Franklin County, increases of 18.1% and 23.8%, respectively, over 2010 figures (WOFM 2022a). During 2020, Benton and Franklin Counties accounted for 3.9% of Washington's population. Based on U.S. Census population data with adjustments for new nearby apartment construction, the population within an 80 km (50 mi) radius of the PNNL Richland Campus is estimated to be about 432,950. 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, on the Olympic Peninsula in the northwestern corner of Washington State. An estimated 76,482 people lived in Clallam County in 2020, an increase of approximately 6.9% over 2010 figures and equivalent to approximately 1% of Washington's population (USCB 2022). The City of Sequim, the nearest population center to the PNNL Sequim Campus, had a population of 8,024 people in 2020 (WOFM 2022b).

1.4 Environmental Setting – PNNL Richland Campus

The land and associated geology, hydrology, seismicity, and meteorology of the PNNL Richland Campus locale, as well as the flora and fauna and land and water habitats of the ecoregion, are described in the following sections.

1.4.1 Environmental Locale

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 portion of the Columbia River riparian zone on 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).

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 $21,000 \text{ m}^3/\text{s}$ ($742,000 \text{ ft}^3/\text{s}$) at the Hanford Site. The largest recent flood took place in 1948 and had an estimated peak discharge of $20,000 \text{ m}^3/\text{s}$ ($700,000 \text{ ft}^3/\text{s}$) (Duncan 2007). Exceptionally high runoff during the spring of 1996 resulted in a maximum discharge of nearly $11,750 \text{ m}^3/\text{s}$ ($415,000 \text{ ft}^3/\text{s}$) (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 $40,000 \text{ m}^3/\text{s}$ ($1.4 \text{ million ft}^3/\text{s}$) (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 $16,100 \text{ m}^3/\text{s}$ ($570,000 \text{ ft}^3/\text{s}$) (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 $12,500 \text{ m}^3/\text{s}$ ($440,000 \text{ ft}^3/\text{s}$) (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.

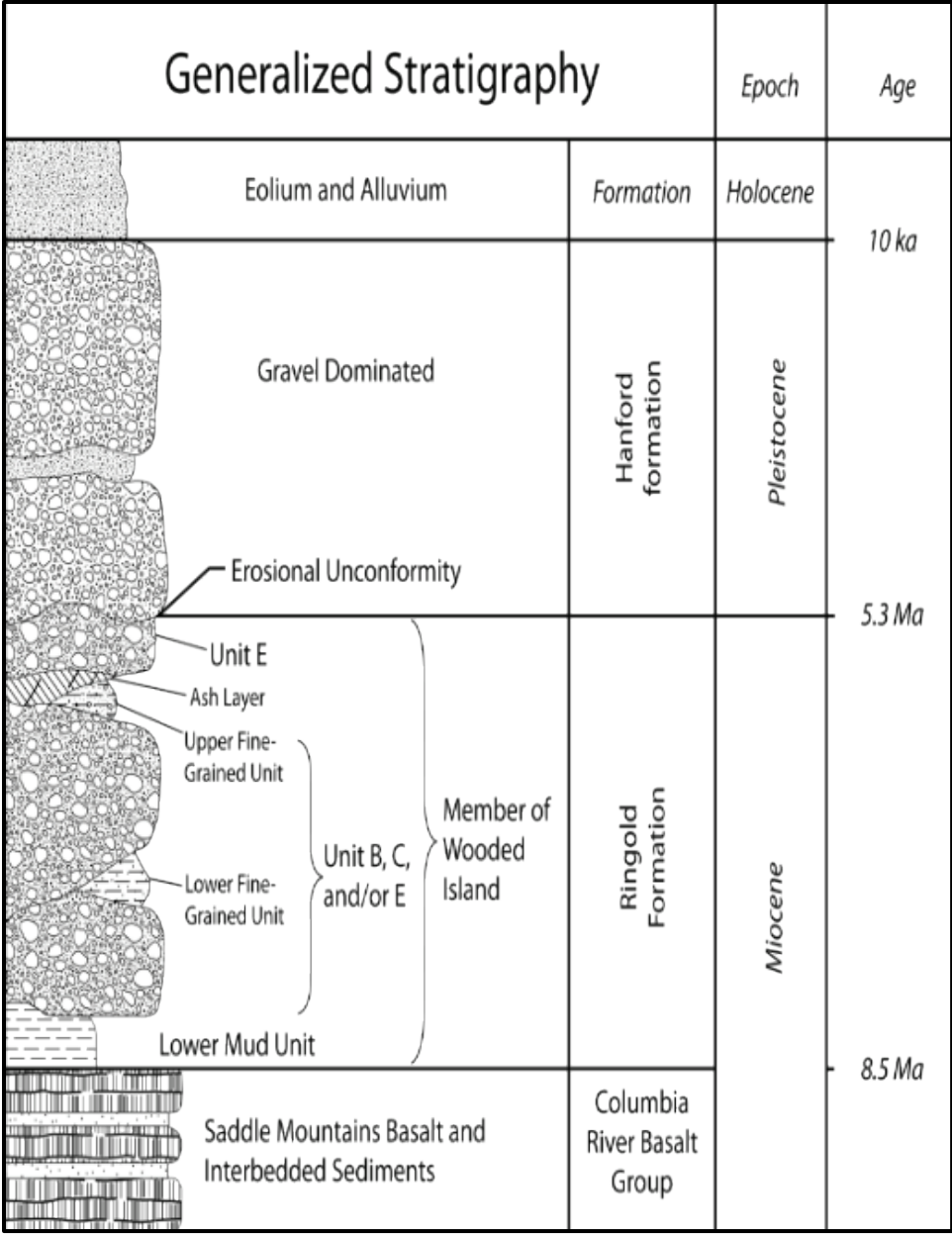


Figure 1.4. Generalized Stratigraphic Column Depicting the Stratigraphy Underlying the PNNL Richland Campus (modified from Reidel et al. 1992; Thorne et al. 1993; Lindsey 1995; Williams et al. 2000; DOE-RL 2002; and Williams et al. 2007)

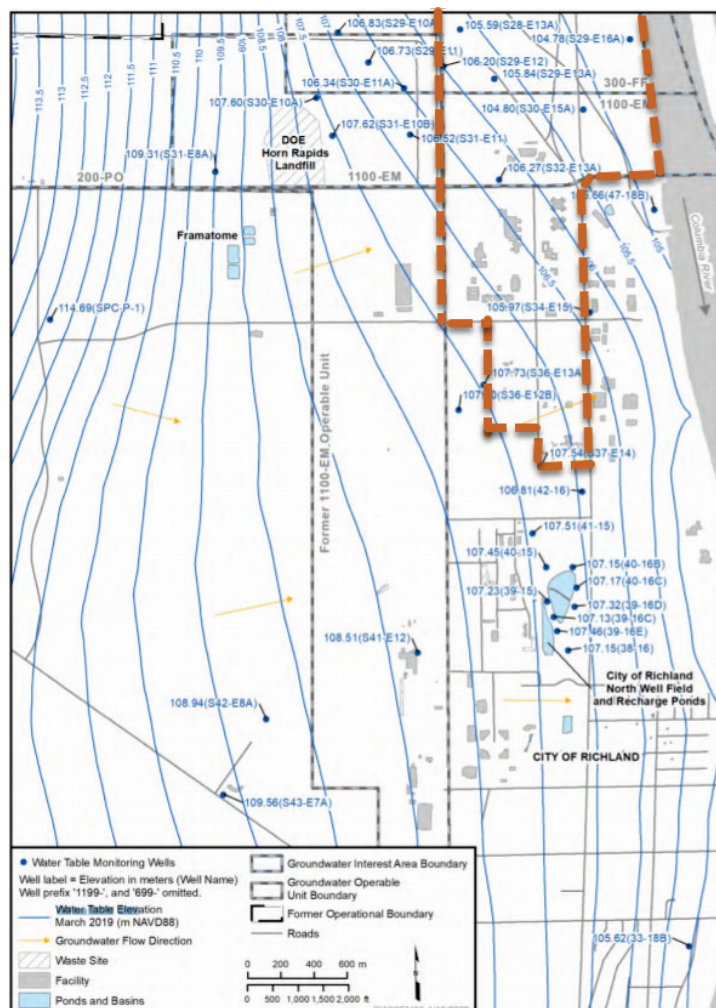


Figure 1.5. Water Table Elevations (m) in April 2020 (modified from DOE-RL 2020b). Groundwater flow direction is normal to the water table contour lines. The approximate PNNL Richland Campus is outlined in orange (northern portion not shown).

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 2021). The U.S. Geological Survey has identified ash as the only volcanic hazard in the vicinity of the PNNL Richland Campus (WDNR 2021).

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 a weather station maintained by the DOE Hanford Site meteorological staff, located just north of the PNNL Richland Campus.

Regional weather in CY 2021 was notable for being the second warmest on record, based on measurements at the Hanford Site's central monitoring station. The year was also drier and windier than

average. Significant meteorological events during 2021 included an extreme heat wave in June/July and numerous wildfires causing smoky days in August 2021, especially in the first half of the month (DOE 2022).

Normal regional monthly average temperatures (central Hanford Site station) range from a low of -4.3°C (24.2°F) in the winter to a high of 26.5°C (79.7°F) in the summer. The maximum high temperature in 2021 was 47.7°C (118°F), measured at the central Hanford monitoring station, was an all-time record; the minimum was -16°C (4°F). The average annual temperature near the PNNL Richland Campus in 2021 was 13.7°C (56.7°F), 2°C (3°F) above average 12°C (54°F). The annual relative humidity near the PNNL Richland Campus was 55% in 2021; humidity is generally higher in the colder months and lowest in the warmer months (DOE 2022). Precipitation for 2021 was 13.6 cm (5.35 in.), 75% below average (18.1 cm [7.14 in.]). Regional winds are primarily toward the northwest and south-southeast at the PNNL Richland Campus. Regional average wind speeds in 2021 were lowest during January and highest in April and May, averaging about 3.9 m/s (8.8 mph), above the average rate of 3.4 m/s (7.7 mph). The maximum regional wind gust recorded during 2021 was 27.3 m/s (61 mph).

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. In 2021, there were 41 days of regional fog. 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 (1945–2020).

1.4.2 Ecology

The PNNL Richland Campus is located in the lowest and most arid portion of the Columbia Plateau Ecoregion (LandScape Washington 2022; 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 171 plant species, 40 bird species, and 10 mammal species have been observed in upland portions of the PNNL Richland Campus (see species lists in Appendix A).

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).

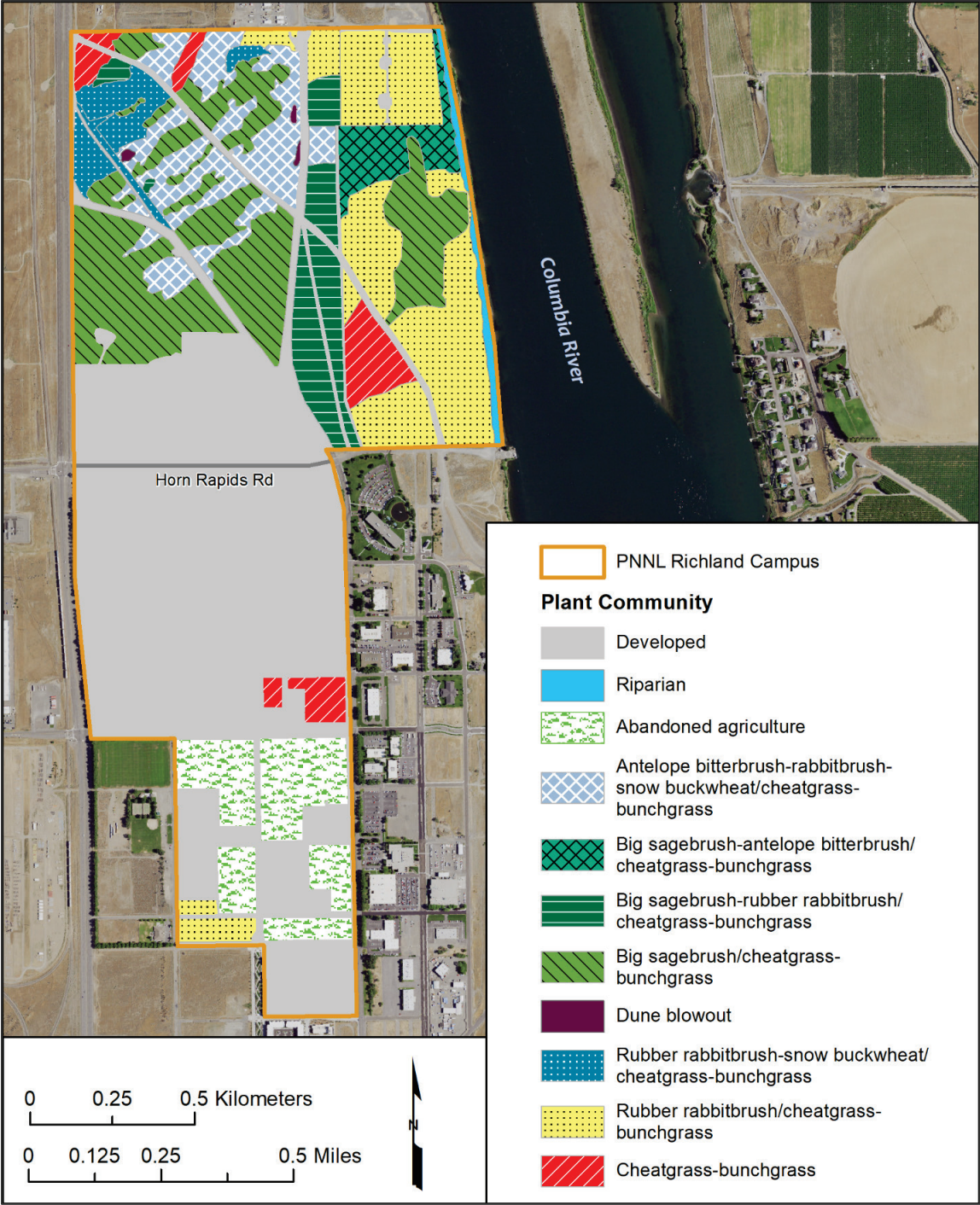


Figure 1.6. Habitat Polygons on the PNNL Richland Campus

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 2022a).

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 ([50 CFR 226.212](#); 75 FR 63898).

Federally 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 WDFW (2022b) and Washington Natural Heritage Program (WNHP 2021) 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	<i>Pelecanus erythrorhynchos</i>		Threatened
Black-tailed jackrabbit	<i>Lepus californicus</i>		Candidate
Burrowing owl	<i>Athene cunicularia</i>		Candidate
Loggerhead shrike	<i>Lanius ludovicianus</i>		Candidate
Northern sagebrush lizard	<i>Sceloporus graciosus</i>		Candidate
Sagebrush sparrow	<i>Artemisiospiza nevadensis</i>		Candidate
Desert striped whipsnake	<i>Coluber taeniatus</i>		Candidate
Townsend ground squirrel	<i>Urocitellus townsendii</i>		Candidate
Fish			
Bull trout	<i>Salvelinus confluentus</i>	Threatened	Candidate
Upper Columbia River spring Chinook salmon	<i>Oncorhynchus tshawytscha</i>	Endangered	
Upper Columbia River steelhead	<i>Oncorhynchus mykiss</i>	Threatened	Candidate
Plants			
Awned halfchaff sedge	<i>Lipocarpa aristulata</i>		Sensitive
Walking spike-rush	<i>Eleocharis rostellata</i>		Sensitive
Large St. Johns-wort	<i>Hypericum majus</i>		Sensitive
Columbian yellowcress	<i>Rorippa columbiae</i>		Threatened
Grand redstem	<i>Ammania robusta</i>		Sensitive
Great Basin gilia	<i>Aliciella leptomeria</i>		Sensitive
Spreading pygmyleaf	<i>Loeflingia squarrosa</i>		Sensitive
Rosy pussypaws	<i>Calyptidium roseum</i>		Sensitive
Suksdorf monkeyflower	<i>Erythranthe suksdorfii</i>		Sensitive

Sources: WDFW (2022b) and WNHP (2021)

- (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 2022).
- (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 2022b). 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 2022b). 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 2021).

1.5 Environmental Setting – PNNL Sequim Campus

The land and associated geology, seismicity, and meteorology of the PNNL Sequim Campus locale, as well as the flora and fauna and land and water habitats of the ecoregion, are described in the following sections.

1.5.1 Environmental Locale

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 Sequim Bay and Puget Sound.

In the vicinity below the PNNL Sequim Campus are Quaternary-age unconsolidated glacial and interglacial deposits to depths greater than 366 m (1,200 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 (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); the nearest fault trace is about 3.2 km (2 mi) to the southwest (WDNR 2021). The region is subject to significant seismic hazards, as evidenced by the estimated peak ground acceleration of 3.92 to 7.85 m/s² (0.4 to 0.8 g) and 2% 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 that 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 2021). The shoreline area of the PNNL Sequim Campus and Travis Spit are subject to tsunami hazards (inundation) for the Cascadia Subduction Zone scenario (WDNR 2021). 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 2021), suggesting a potential landslide hazard at the site. No volcanic hazard has been identified in the PNNL Sequim Campus region (WDNR 2021).

Daily meteorological data are collected at an automated weather station near Sequim, Washington, maintained by AgWeatherNet, an affiliate of Washington State University (WSU 2022). 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; rainfall in 2021 was 47.9 cm (18.9 in.). The region experiences cool, wet winters and warm, dry summers. From January 2009 to December 2020, average temperatures ranged from 4.6°C to 14.7°C (40.3°F to 58.5°F). The annual average temperature in 2021 was 9.7°C (49.5°F). Regional winds are primarily from the west to northwest. Wind speed averaged 1.4 m/s (3.1 mph) in 2021 (Snyder et al. 2022b).

1.5.2 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 2022; EPA 2013). The PNNL Sequim Campus is located in 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 (WDFW 2005). Today, the region consists mostly of second-growth coniferous forest and agricultural fields; little of the original forest habitat remains (EPA 2013; LandScope Washington 2022).

The PNNL Sequim Campus includes 26 ha (65 ac) of land and 21 ha (52 ac) of tidelands. Tideland habitat includes shoals, intertidal wetlands, and subtidal wetlands. The Middle Ground (Figure 1.7) is a sandy shoal, which is submerged except during lower tides, and does not support vegetation (DOE-PNSO 2020).

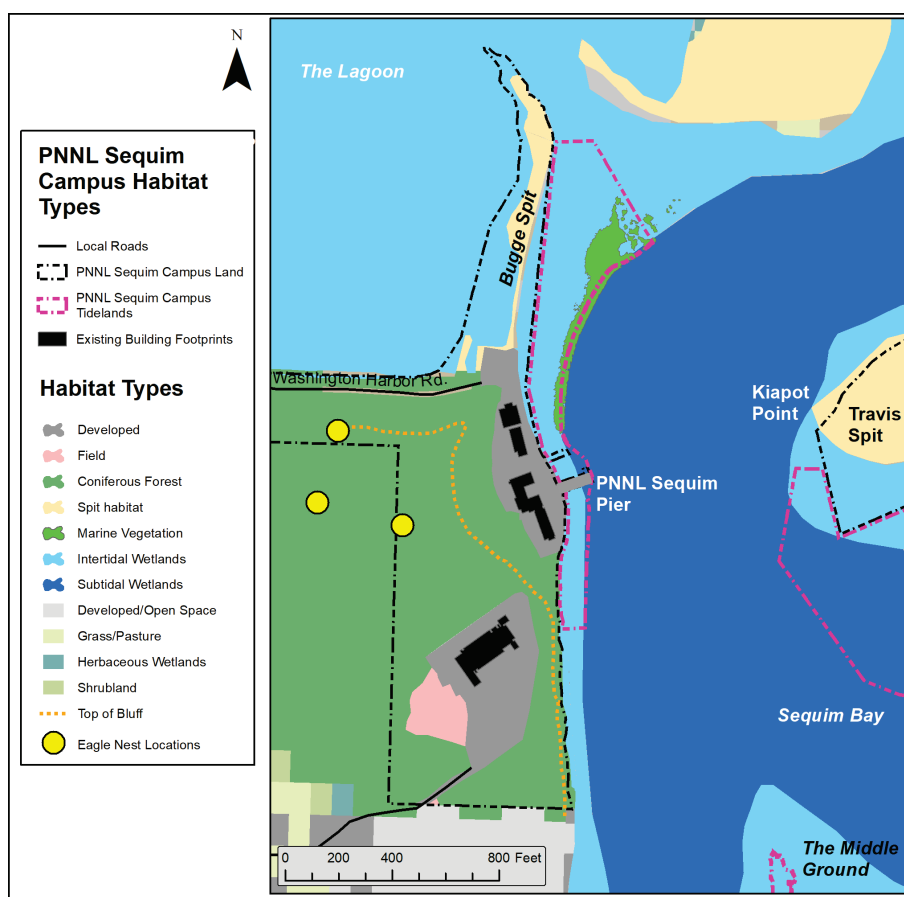


Figure 1.7. Habitat Types at the PNNL Sequim Campus

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 (labeled marine vegetation in 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 (*Parophrys 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 1.7) 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 verbenia (*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, 104 bird species, and 7 other wildlife species have been observed on the PNNL Sequim Campus (see species lists in 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 2022a) 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 2022a).

The tideland and land habitats provide potential habitat for several federally listed threatened, endangered, and/or candidate species (Figure 1.2) (DOE-PNSO 2020). Two avian species of conservation concern, as well as eight aquatic and three invertebrate species of conservation concern, are known to occur or potentially occur near PNNL Sequim Campus facilities (Figure 1.2). No plant species of state or federal concern are currently known to occur near the PNNL Sequim Campus (Figure 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*) ([50 CFR 226.212](#); 70 FR 52630) (Figure 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). Each of these mammals is considered a priority species by the state, and priority areas comprise haul-outs used by California sea lions and harbor seals, and foraging areas and migration routes used by harbor porpoises and Dall's porpoises. Kipap 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 haul-out 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			
Marbled murrelet	Brachyramphus marmoratus	Threatened	Endangered
Fish			
Bull trout	Salvelinus confluentus	Threatened	Candidate
Hood Canal summer-run chum salmon	Oncorhynchus keta	Threatened	
North American green sturgeon	Acipenser medirostris	Threatened	
Pacific eulachon	Thaleichthys pacificus	Threatened	
Puget Sound bocaccio	Sebastes paucispinis	Endangered	
Puget Sound Chinook salmon	Oncorhynchus tshawytscha	Threatened	
Puget Sound steelhead	Oncorhynchus mykiss	Threatened	
Puget Sound yelloweye rockfish	Sebastes ruberrimus	Threatened	
Invertebrates			
Island marble butterfly	Euchloe ausonides	Endangered	Candidate
Sand-verbena moth	Copablepharon fuscum		Candidate
Taylor's checkerspot butterfly	Euphydryas editha taylori	Endangered	Endangered

Source: WDFW (2022b)

- (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 2022).
- (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 2022b). 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 2022b).

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 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. 2002).



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 during the subsequent Cold War Era.



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 in the National Register of Historic Places (NRHP) 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 Fraser 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 as 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 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 2021 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.

PNNL operations were curtailed due to the COVID-19 pandemic starting in March 2020 and remained in effect for the remainder of the CY 2021. Teleworking was maximized and the health and safety of all on-site and off-site staff were tracked. PNNL operations impacted by the temporary COVID-19 requirements are indicated, where appropriate.

Per- and polyfluoroalkyl substances (PFASs) and several other persistent contaminants (perfluorooctane sulfonate, perfluorooctanoic acid, perchlorates, 1,4-dioxane) are acknowledged to require a comprehensive approach by DOE. DOE established a policy (Turk 2021) for addressing these emerging contaminants. Most significantly recognized as a potential water quality issue, PNNL sources and applicable regulation of these chemicals are addressed in Sections 2.5.4 and 6.0.

The Enforcement & Compliance History Online (ECHO) database at <https://echo.epa.gov/> is the EPA's official record of the current compliance status of a DOE site or particular facilities within the site except where the Washington State Department of Ecology has been delegated responsibility for a program area. The ECHO-designated locations in Table 2.1 apply to the PNNL Richland Campus and PNNL Sequim Campus.

The Washington State Department of Ecology has been delegated oversight of the wastewater program area by EPA. A search of the ECHO database for the "Battelle Marine Sciences Lab" indicates noncompliances for "failure to report." EPA acknowledges that the reports were received by the Washington State Department of Ecology and that these records are tracked within an Ecology database rather than the ECHO database. The Battelle Marine Sciences Lab wastewater and *Resource Conservation and Recovery Act of 1976* (RCRA) program areas are in compliance.

Table 2.1. EPA ECHO Database Listing for PNNL Campuses

ECHO Facility Name	Facility Registry Service (FRS) ID	Program Area
Pacific Northwest National Laboratory Stevens	110025329133	RCRA
Pacific Northwest National Laboratory	110006473440	RCRA
Battelle Marine Sciences Laboratory ^(a)	110000828230	Wastewater, RCRA
^(a) Synonymous with the PNNL Sequim Campus.		

Table 2.2 and Table 2.3 summarize PNNL's compliance with federal and state laws and regulations, respectively, and subsequent sections provide brief descriptions of each statute or regulation.

Table 2.2. Status of Federal Environmental Laws and Regulations Applicable to PNNL, 2021

Statute/Regulation	2021 Status	Report Section(s)
Air Quality and Protection		
The <i>Clean Air Act</i> (CAA) 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
The hydrofluorocarbon (HFC) phasedown requirements of the American Innovation and Manufacturing (AIM) Act of 2020 seek to reduce HFC consumption and production to 15% of a 2011-2013 baseline by 2036.	PNNL uses HFCs primarily as refrigerants in chillers and other refrigeration appliances. Cleaning solvents used at PNNL also may contain HFCs. Refrigerants and products containing HFCs will be replaced by EPA-approved substitutes as they become available.	2.4.5
Cultural and Historic Resources		
The <i>National Historic Preservation Act of 1966</i> (NHPA) requires 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 43 projects. Fourteen of the 43 projects were undertaken on PNNL's Sequim Campus. One undertaking resulted in an Adverse Effect in calendar year (CY) 2020; consultation to resolve the Adverse Effect has been delayed into CY 2021 due to the COVID-19 pandemic. NHPA Section 110 monitoring was also conducted; some small impacts were identified at existing sites in CY 2021.	2.7.3
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, 2.7.2
Energy Independence		
The <i>Energy Independence and Security Act of 2007</i> (EISA) encourages U.S. 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
Predominantly, Executive Order 14008 establishes environmental sustainability goals that protect public health and the environment and requirements related to energy and environmental performance with respect to facilities, vehicles, and overall operations.	PNNL prepared the <i>Pacific Northwest National Laboratory FY 2022 Site Sustainability Plan</i> (PNNL 2021), which addressed the goals and requirements of Executive Orders.	2.1, 3.0
Environmental Safety and Health Reporting		

Statute/Regulation	2021 Status	Report Section(s)
DOE Order 231.1B, <i>Environment, Safety, and Health Reporting</i> , requires the gathering, analysis, and reporting of information about environmental safety and health issues.	PNNL monitors and conveys information via reports, emails, <i>LabWeb</i> news articles, and staff meetings. The PNNL Annual Site Environmental Report is a requirement of this Order.	1.0
DOE Order 414.1D, <i>Quality Assurance</i> , states the roles and requirements for providing quality assurance (QA) for work performed by DOE and its contractors.	A PNNL internal document, <i>Quality Assurance Program Description/Quality Management M&O Program Description</i> , 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 <i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i> (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.	2.6.1, 2.6.2
The <i>Emergency Planning and Community Right-to-Know Act of 1986</i> 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 about potential hazards. PNNL was not required to submit a Toxic Release Inventory Report.	2.6.8
The <i>Federal Facility Compliance Act of 1992</i> amends the <i>Resource Conservation and Recovery Act of 1976</i> (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 <i>Federal Insecticide, Fungicide, and Rodenticide Act</i> 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
The <i>Resource Conservation and Recovery Act of 1976</i> (RCRA) requires hazardous waste to be tracked 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 six RCRA facilities (EPA Site ID#s). The single CY 2021 inspection performed at the PNNL-managed 325RPL Building Radiochemical Processing Laboratory (325RPL) facility on the Hanford Site found one violation (i.e., failure to mark the accumulation date on two containers in storage) and no areas of concern.	2.6.4
The <i>Superfund Amendments and Reauthorization Act of 1986</i> 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 groundwater is no longer required to be monitored for Hanford Site contaminant migration. No contamination was identified at the PNNL Sequim Campus that would require response under CERCLA or the <i>Superfund Amendments and Reauthorization Act</i> .	2.6.2

Statute/Regulation	2021 Status	Report Section(s)
The <i>Toxic Substances Control Act</i> requires the control and tracking of regulated hazardous chemicals, primarily polychlorinated biphenyls (PCBs).	PNNL contributed to the 2021 PCB annual document log report for the Hanford Site and 2021 PCB annual report; both were published in 2022 and submitted to the U.S. Environmental Protection Agency as required.	2.6.6
Radiation Protection		
DOE Order 435.1, <i>Radioactive Waste Management</i> , establishes requirements for managing high-level waste, transuranic waste, low-level waste, and mixed wastes.	PNNL's Radioactive Waste Management Basis report identifies and staff implement radioactive waste-management controls through internal workflows and procedures.	2.8.2, 2.8.3
DOE Order 458.1, <i>Radiation Protection of the Public and the Environment</i> , 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, 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 <i>Clean Water Act</i> (CWA) seeks to maintain and improve surface water quality through criteria and permitting, including point-source discharges to U.S. 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. Three Nationwide Permits were acquired or extended for off-site scientific research studies.	2.5.1, 2.5.2, 2.7.1, 7.3, 7.4
The <i>Safe Drinking Water Act of 1974</i> (SDWA) 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 SDWA. At the PNNL Sequim Campus, water is provided exclusively from on-site wells and PNNL is considered the water purveyor under a Group A drinking water operating permit.	2.5.2, 2.5.3, 7.3, 7.4
PFAS (Per- and polyfluoroalkyl substances) Emerging Contaminants	There are currently no enforceable federal standards for PFAS chemicals, but in 2021, the EPA issued a roadmap for developing regulations for PFAS chemicals under the SDWA, RCRA, CWA, and other U.S. environmental laws.	2.5.4, 6.0
Wildlife and Ecosystems		
The <i>Bald and Golden Eagle Protection Act of 1940</i> 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

Statute/Regulation	2021 Status	Report Section(s)
The <i>Coastal Zone Management Act of 1972</i> (CZMA) 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 the associated habitats when evaluating proposed actions. One federal consistency determination was made for an off-site research study.	2.7.1
The <i>Endangered Species Act of 1973</i> (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. Nine ESA authorizations were acquired, and six no-effect determinations were made or extended for off-site scientific studies.	2.7.1
The <i>Forest Service Organic Administration Act of 1897</i> (FSOAA) provides for the protection and administration of U.S. Forest Service lands.	Three authorizations under the FSOAA were acquired in 2021 for off-site scientific research studies.	2.7.1
The <i>Magnuson–Stevens Fishery Conservation and Management Act of 1976</i> (MSFCMA) governs marine fisheries management.	Six essential fish habitat authorizations were acquired, and three no-effect determinations were made for off-site scientific research studies.	2.7.1
The <i>Marine Mammal Protection Act of 1972</i> provides for the protection of all marine mammals.	One <i>Marine Mammal Protection Act</i> no-effect determination was made for off-site scientific research studies.	2.7.1
The <i>Migratory Bird Treaty Act of 1918</i> (MBTA) 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 15 inquiries concerning migratory birds on the PNNL Richland Campus and PNNL Sequim Campus.	2.7.1
The <i>National Environmental Policy Act of 1969</i> (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 1,897 NEPA reviews during CY 2021 for research and support activities. DOE-PNSO approved no new activity-specific categorical exclusions in 2021.	2.3
The <i>National Park Service Organic Act of 1916</i> provides for the management of national parks and monuments.	No scientific research and collecting permits were acquired for off-site studies.	2.7.1
The <i>National Wildlife Refuge System Administration Act of 1966</i> provides administrative and management directives for refuges under the jurisdiction of the U.S. Fish and Wildlife Service (USFWS).	One special use permit was acquired for an off-site scientific research study.	2.7.1

Statute/Regulation	2021 Status	Report Section(s)
The <i>Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990</i> 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.	2.7.1.1
The <i>Rivers and Harbors Appropriation Act of 1899</i> (RHA) prohibits obstruction or alteration of navigable waters.	One Section 10 permit was extended for an off-site scientific research study.	2.7.1
Executive Order 11988, <i>Floodplain Management</i> (42 FR 26951), requires federal agencies to evaluate the potential effects of any actions within a floodplain.	Compliance was achieved through the biological resource review process at PNNL.	2.7.1
Executive Order 11990, <i>Protection of Wetlands</i> (42 FR 26961), requires federal agencies to minimize the loss or degradation of wetlands and to preserve and enhance their natural and beneficial values.	Compliance was achieved through the biological resource review process at PNNL.	2.7.1

Table 2.3. Status of Washington State Environmental Laws and Regulations Applicable to PNNL, 2021

Statute/Regulation	2021 Status	Report Section(s)
The <i>Hazardous Waste Management Act of 1976</i> 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 <i>Shoreline Management Act of 1971</i> establishes guidelines for shoreline use, environmental protection, and public access.	One Shoreline Letter of Consistency was obtained for an off-site scientific research study.	2.7.1
The <i>Washington Clean Air Act</i> implements and supplements the federal CAA, 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 emissions of regulated substances or substances of concern to the outside air.	2.4.1
The <i>Washington Pesticide Application Act</i> provides for the control of pesticide application and use to protect public health and welfare.	Licensed PNNL staff or certified commercial applicators were used to apply pesticides.	2.6.7
The <i>Washington Pesticide Control Act</i> establishes guidelines for proper use and control of pesticides.	Licensed PNNL staff or certified commercial applicators were used to apply pesticides.	2.6.7
The <i>Washington State Environmental Policy Act (SEPA)</i> requires the identification and analysis of the environmental impacts of state and local decisions, giving agencies the authority to deny a proposal when adverse environmental impacts are identified.	PNNL environmental compliance representatives and staff review research and support activities and complete SEPA checklists as required.	2.3
Washington Administrative Code (WAC) 246–290, “Group A Public Water Supplies,” establishes drinking water State Action Levels and monitoring requirements for five PFAS chemicals in Washington State.	No PFAS monitoring was required or performed at the PNNL Richland Campus or the PNNL Sequim Campus. Under WAC 246–290, drinking water sampling and monitoring at the PNNL Sequim Campus for PFAS chemicals will be required no later than December 31, 2025. The City of Richland is responsible for monitoring for PFAS in drinking water at the PNNL Richland Campus.	2.5.3, 2.5.4

2.1 Sustainability and Environmental Management System

The DOE-Battelle Prime Contract for the management and operation of PNNL (DOE-PNSO 2022) continues to implement applicable sustainability and Environmental Management System (EMS) requirements from Executive Orders, including associated performance goals, objectives, and systems.

The DOE-Battelle Prime Contract requires the development of a Site Sustainability Plan (e.g., PNNL 2021), and maintain an EMS that is certified to the International Organization for Standardization (ISO) 14001:2015 standards. Prepared and submitted to DOE annually in accordance with DOE Sustainability Performance Division (SPD) guidance, the Site Sustainability Plan highlights accomplishments and continuous improvement opportunities related to DOE's sustainability goals. Section 3.0 of this report provides a summary of PNNL's Fiscal Year (FY) 2022 Site Sustainability Plan (PNNL 2021) and the EMS.

Executive Order 13834 of May 17, 2018, *Efficient Federal Operations*, ([83 FR 23771](#)) required that federal agencies meet statutory requirements to increase energy efficiency, improve performance, eliminate resource use when unnecessary, and protect the environment. This Executive Order established 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.

In January 2021, Executive Order 13990, *Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis* ([86 FR 7037](#)), was issued, which directed "... all executive departments and agencies to immediately review, and, as appropriate and consistent with applicable law, take action to address the promulgation of Federal regulations and other actions... that conflict with... important national objectives, and to immediately commence work to confront the climate crisis." This Executive Order partially revoked some provisions in Executive Order 13834. Later in January 2021, Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad* ([86 FR 7619](#)), was issued to place the climate crisis at the forefront of foreign policy and national security planning.

Subsequently in December 2021, Executive Order 14057, *Catalyzing Clean Energy and Industries and Jobs Through Federal Sustainability* ([86 FR 70935](#)), was issued to establish a new, broader federal policy of leading by example "... to achieve a carbon pollution-free electricity sector by 2035 and net-zero emissions economy-wide by not later than 2050." This Executive Order fully revoked Executive Order 13834 and set new federal-level sustainability goals. In response to the federal guidance, PNNL has developed detailed plans and milestones for achieving energy efficiency objectives and goals, details of which are available in Section 3.0 of this report. In FY 2021, PNNL was one of four national laboratories participating in a DOE net-zero pilot, an initiative to achieve net-zero emissions and resilient operations by 2030 (PNNL 2021).

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, reduction of stormwater runoff, water conservation and protection, 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 FY 2020, PNNL completed an evaluation of four buildings that are subject to EISA Section 432 continuous (4-year cycle) comprehensive energy and water requirements. To date, approximately 46% of buildings (49% by

total square footage) have met the criteria for DOE Federal Energy Management Program Guiding Principles for high-performance sustainable buildings, far exceeding the 2025 goal of 17% (PNNL 2021).

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 (PV) array continued operation in 2021, contributing to on-site energy generation and, together with a solar water heater, additional small PV arrays on monitoring stations, and renewable energy certificate purchases, it offset 7.5% of PNNL's electrical use and 5.4% of its total electric and thermal energy (PNNL 2021). In 2021, an inverter malfunction of the 125 kW PV array significantly reduced the array's output. Repairs have been completed, and production is expected to be back within the normal range in CY 2022.

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. For the first time since 1978, in July 2020 the Council on Environmental Quality (CEQ) comprehensively updated its regulations for Federal agencies to implement NEPA ([85 FR 43304](#)). The update modernizes and clarifies the regulations to facilitate more efficient, effective, and timely NEPA reviews. 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 1,897 NEPA reviews during CY 2021 for research and support activities (1,479 Electronic Prep and Risk System reviews, 375 William R. Wiley Environmental Molecular Sciences Laboratory [EMSL] user proposals, and 43 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 all cases, activities were adequately addressed in previously approved NEPA documentation, including generic categorical exclusions, environmental assessments, environmental impact statements, and supplement analyses. All NEPA reviews conducted in CY 2021 were covered with existing NEPA documentation.

A draft environmental assessment for future development of the PNNL Sequim Campus was published by PNSO during 2020. Stakeholder comments have been received and dispositioned. Finalization of the environmental assessment is pending completion of federal agency consultations.

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 2021. A total of 20 generic categorical exclusions have been approved by PNSO to cover PNNL research and operations activities to date. When projects clearly are within the definition of a categorical exclusion, but a generic categorical exclusion is not applicable, a new project- or activity-specific categorical exclusion is prepared. No new project- or activity-specific PNSO-approved categorical exclusions were finalized in

2021. 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* (CAA; 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. It authorized EPA to establish National Ambient Air Quality Standards for the protection of public health and welfare. Establishment of these pollutant standards was combined with state implementation plans to facilitate attainment of the standards. The *Washington Clean Air Act* (Revised Code of Washington [RCW] [70A.15](#)), 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* (CFR) 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](#), "General Regulations for Air Pollution Sources;" [WAC 173-441](#), "Reporting of Emissions of Greenhouse Gases;" [WAC 173-460](#), "Controls for New Sources of Toxic Air Pollutants;" and [WAC 173-480](#), "Ambient Air Quality Standards and Emission Limits For Radionuclides."

The Benton Clean Air Agency (BCAA) implements and enforces most federal and state requirements on the PNNL Richland Campus through [BCAA Regulation 1](#) (BCAA 2021). 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 2022). PNNL requirements applicable to the PNNL Sequim Campus include Regulation 4, "Registration;" Regulation 6, "Required Permits and Notifications;" 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 CAA 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 complies 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](#)), "Radiation Protection – Air Emissions," that require the calculation and reporting of the EDE to the maximum exposed individual (MEI) 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 off-site 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) has 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 2021 are available in the *PNNL Richland Campus Radionuclide Air Emissions Report for Calendar Year 2021* (Snyder et al. 2022a). The PNNL Sequim Campus has one sitewide 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 2021* (Snyder et al. 2022b). During CY 2021, 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 100,000 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 Notice of Construction and are incorporated into the Radioactive Air Emissions License (RAEL). For the PNNL Richland Campus, WDOH issued RAEL-005, which was last renewed on January 1, 2021; 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:

- PNNL Site – William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), PSF Complex, Energy Sciences Center, Life Sciences Laboratory 2 Halogenated Solvent Degreaser Operations (Order of Approval No. 2019-0005, Revision 1)
- Life Sciences Laboratory 2 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).

¹ As a group of research buildings, the PSF is expected to accommodate emerging research over time.

The PNNL Sequim Campus has two air permits for airborne emissions: RAEL-014 issued effective on January 1, 2018, by the WDOH and a nonradiological regulatory order issued by the ORCAA (Order of Approval 13NOI968).

2.4.5 Hydrofluorocarbon Phasedown

PNNL uses hydrofluorocarbons (HFCs) primarily as refrigerants in chillers and other refrigeration appliances. Cleaning solvents that may contain HFCs also are used at PNNL. Refrigerants and products containing HFCs will be replaced with EPA-approved substitutes as they become available.

2.5 Water Quality and Protection

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

2.5.1 Clean Water Act

The *Clean Water Act* (CWA; 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 CWA was enacted in 1948 and was officially named the *Federal Water Pollution Control Act*. Substantially reorganized and expanded with amendments in 1972, it became commonly known as the CWA. Under the CWA, 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 CWA made it unlawful to discharge any pollutant from a point source into navigable waters unless a permit is obtained. EPA's NPDES permit program controls these point-source discharges. Point sources are discrete conveyances such as pipes or constructed ditches. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. 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 make sure 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 No. 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 No. CR-IU005 regulates discharges from EMSL to Outfall 001. Permit No. CR-IU011 regulates process wastewater discharged from PSF. 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 to an on-site wastewater treatment system before being discharged to Sequim Bay under the authorization of Washington State Department of Ecology NPDES Permit No. WA0040649. 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

The *Clean Water Act* (CWA; 33 U.S.C. § 1251 *et seq.*) also regulates the discharge of stormwater to the surface waters of the United States from point sources. Stormwater discharges from specific industries or industrial categories are governed by general permits or individual permits issued under the NPDES program. Stormwater discharges to the ground through certain types of engineered structures (e.g., dry wells, French drains, etc.) are regulated by the SDWA (42 U.S.C. § 300f *et seq.*) under the Underground Injection Control well program. EPA has delegated responsibility for both of these stormwater programs to the Washington State Department of Ecology.

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, “Underground Injection Control Program.” Best management practices, in accordance with the *Stormwater Management Manual for Eastern Washington* (Ecology 2019), are used to minimize pollution in stormwater. These practices include using catch basins to remove solids, storing chemicals inside or under cover, when possible, to prevent contact with stormwater, routinely sweeping and cleaning parking lots, promptly notifying the 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 catch basins for paved areas and parking lots. The catch basins provide basic treatment for solids removal. In addition, catch basins in the boat storage yard and in the wastewater treatment system area contain multimedia filtration systems for oil control. Stormwater from the uplands area of the PNNL Sequim Campus drains to an infiltration pond, which is an engineered stormwater collection basin with an overflow trench. Stormwater from the beach area drains to outfalls located near the shoreline.

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 (42 U.S.C. § 17001) Section 438 are considered and implemented as part of PNNL sustainability practices (PNNL 2021). The registration of underground injection control wells for stormwater have been completed as required by the SDWA and WAC 173-218.

2.5.3 Safe Drinking Water Act of 1974

The *Safe Drinking Water Act* (SDWA; 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, EPA sets primary and secondary standards for drinking water quality and oversees the states, municipalities, and water suppliers who implement those standards. The SDWA 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 SDWA focuses on all waters actually or potentially designated for use as drinking water, whether from aboveground or underground sources. The Act authorizes 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. The Washington State Department of Health has been approved to implement these rules for EPA under WAC 246-290, which also addresses compliance with water quality and implementation of secondary standards. Under the SDWA, 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 the city is responsible for meeting water quality standards under the SDWA.

Water for PNNL Sequim Campus facilities is provided exclusively from an on-site well. PNNL is considered the water purveyor and is responsible for all monitoring and sampling of the drinking water 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 wells and discharged to the ground via underground injection control wells. Registrations of these injection control wells for ground-source heat pump return flow water have been completed as required by the SDWA.

2.5.4 Emerging Contaminants

Per- and polyfluoroalkyl substances (PFASs) 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, as well as some cleaning products and engineered coatings, and certain types of firefighting foam. There are currently no enforceable federal standards for PFAS chemicals, but in 2021, the EPA issued a roadmap (EPA 2021) for developing regulations for PFAS chemicals under the SDWA, RCRA, CWA, and other U.S. environmental laws.

In 2021, Washington State passed legislation to monitor certain PFASs in drinking water and establish approved analytical methods for testing for PFASs. Under WAC 246-290, effective January 2023, all public water systems will be required to perform initial PFAS sampling for five specific PFAS chemicals no later than December 31, 2025.

An initial review of PNNL properties and activities was conducted to determine if the potential for PFAS contamination exists. There are no active fire suppression systems at PNNL facilities that contain aqueous film-forming foam or other PFAS chemicals. 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.

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 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 Tri-Party Agreement (1) defines RCRA and CERCLA cleanup commitments, (2) establishes responsibilities, (3) provides a basis for budgeting, and (4) reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones.

The Tri-Party Agreement is available on the DOE Hanford Site website.¹ Printed copies, current as of May 12, 2022, 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 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 2021* (DOE-RL 2022).

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 products, 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 off-site 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.

¹ <http://www.hanford.gov/?page=81>

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 wastes 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 2021, no spills or non-permitted discharges that posed a threat to human health or the environment occurred at PNNL facilities in the 300 Area, on the PNNL Richland Campus, or on 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 (Ecology 2022). This unit group is located in the 325RPL Radiochemical Processing Laboratory (325RPL) in the Hanford Site 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 full documentation of the Hanford RCRA Permit may be viewed at <https://fortress.wa.gov/ecy/nwp/permitting/hdwp/rev/8c/index.html>. PNNL, in coordination with DOE-RL, has been in active negotiations with the Department of Ecology for renewal of the 325 Hazardous Waste Treatment Units portion of the Hanford Facility RCRA Permit, which would be issued as Revision 9.

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 2021, PNNL facilities followed the generator requirements for waste management and shipped nonradioactive waste to off-site facilities for proper disposal.

RCRA and WAC 173-360A also include requirements for the proper management of underground storage tanks. In CY 2021, Battelle administered two underground storage tanks for the storage of diesel fuel for backup generators on the PNNL Richland Campus—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.

The Washington State Department of Ecology performed one RCRA compliance inspection of a PNNL facility during 2021. The inspection covered the 325 Hazardous Waste Treatment Units and generator areas in the 325RPL facility. The inspection found one violation for failure to mark the accumulation date on two containers in storage and no areas of concern.

2.6.5 Federal Facility Compliance Act of 1992

The *Federal Facility Compliance Act of 1992* (FFCA; 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 also are given authority to conduct inspections of federal facilities to enforce compliance with state hazardous waste programs. DOE also is required to provide mixed waste information to EPA and the states under the FFCA. PNNL provides this information as part of an annual Hanford Site Mixed Waste Land Disposal Restrictions Report pursuant to Tri-Party Agreement Milestone M-26. Submissions of the 2020 and 2021 reports have been delayed pending resolution of Washington Department of Ecology comments on the 2019 report (DOE-RL 2020a). As of the date of publication of this report, PNNL has provided 2020 data and is prepared to provide 2021 data when requested.

2.6.6 Toxic Substances Control Act

Requirements of the *Toxic Substances Control Act* (TSCA; 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." PNNL generates very small quantities of waste regulated by [40 CFR Part 761](#), and any of these wastes are stored and/or disposed of in accordance with this regulation.

The *2021 Hanford Site Polychlorinated Biphenyl Annual Report* (Weyns 2022a) and the *2021 Hanford Site Polychlorinated Biphenyl Annual Document Log* (Weyns 2022b) were published in 2022. These documents describe the PCB waste-management and disposal activities that occur on the Hanford Site, including PNNL activities in the 300 Area. The annual reports are provided to EPA as required by 40 CFR 761.180. The PNNL Richland and Sequim Campuses did not generate PCB waste in 2021.

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 requirements of this Act 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 2021, 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:

1. Emergency planning
2. Emergency release notification
3. Hazardous chemical inventory reporting
4. 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).

On February 22, 2021, the Annual Tier Two inventory report for the PNNL Richland Campus was submitted 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 PNNL 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 Clallam County Fire District 3 on February 23, 2021. 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 2021, 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 2021.

Table 2.4. 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

OSHA = Occupational Safety and Health Administration

LEPC = Local Emergency Planning Committee

SERC = State Emergency Response Commission

Table 2.5. *Emergency Planning and Community Right-to-Know Act of 1986 Compliance Reporting, 2021*

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 2021 Tier Two reports for the PNNL Richland Campus and PNNL Sequim Campus were submitted to the Washington State Department of Ecology, LEPC, and local fire departments in February 2022.
313	Toxic release inventory	Not required	No releases were greater than the reporting threshold requirement.

2.7 Natural and Cultural Resources

The *Pacific Northwest Site Office Cultural and Biological Resources Management Plan* (CBRMP; DOE-PNSO 2021a) provides 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 and elsewhere in the United States 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 and Environmental Permitting

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 2021.

Table 2.6. Environmental Research Permits Obtained in 2021 for PNNL Research Activities

Issuer	Permit Type	Regulatory Driver	Number of Permits
Bonneville Power Administration	No Effects Determination	ESA	1
California Coastal Commission	Coastal Development Permit Waiver	CCR	1
California Fish and Wildlife	Scientific Collection - Specific Use Permit	CCR	1
City of Tacoma	Shoreline Letter of Consistency	SMA	1
Columbia Land Trust	Access Permit	NA	1
Cowiche Canyon Conservancy	Access Permit	NA	1
DOE-RL	Hanford Site Access Permit	NA	2
Washington Department of Ecology	Access Permit	NA	1
Hancock Forest Management	Access Permit	NA	1
National Marine Fisheries Service/NOAA Fisheries	Informal Consultation	ESA, MMPA, MSFCMA	6
New York Department of State	Coastal Zone Consistency Concurrence	CZMA	1
Oregon Department of Fish and Wildlife	Access Permit	OAR	1
Oregon Department of Fish and Wildlife	Scientific Taking Permit – Fish	OAR	2
Ohio Department of Natural Resources	Research Permit	OAC	1
PNNL for DOE-PNSO	No Effects Determination	ESA, MMPA, MSFCMA	6
Port of Astoria	Access Permit	NA	1
Private Landowner	Access Permit	NA	1
Puyallup Tribe of Indians	Tribal Development Permit	NA	1
U.S. Army Corps of Engineers	Nationwide Permit 5 – Scientific Measurement Devices	RHA, CWA	2
U.S. Army Corps of Engineers	Individual Permit	RHA	1
U.S. Coast Guard	Local Notice to Mariners	CFR	1
U.S. Coast Guard	Private Aids to Navigation Permit	CFR	1
U.S. Forest Service	Nominal Effects Letter	FSOAA	1
U.S. Forest Service	Special Use Permit	FSOAA	2
USFWS	Informal Consultation	ESA	3
USFWS	Special Use Permit	NWRSAA, CFR	1
Washington State Parks and Recreation Commission	Scientific Research Permit	WAC	1
Washington Department of Fish and Wildlife	Fish Transport Permit	WAC	6
Washington Department of Fish and Wildlife	Hydraulic Project Approval	WAC	2
Washington Department of Fish and Wildlife	Right of Entry	WAC	3
Washington Department of Fish and Wildlife	Scientific Collection Permit	WAC	1

Issuer	Permit Type	Regulatory Driver	Number of Permits
Washington Department of Natural Resources	Aquatic Lands Right of Entry License	WAC	4
Confederated Tribes and Bands of the Yakama Nation	Closed Area Work Permit	NA	12
Confederated Tribes and Bands of the Yakama Nation	Project Approval	NA	1
Total Environmental Research Permits			72

CCR = *California Code of Regulations*
 MMPA = *Marine Mammal Protection Act of 1972*
 MSFCMA = *Magnuson–Stevens Fishery Conservation and Management Act*
 NWRSA = *National Wildlife Refuge System Administration Act of 1966*
 OAC = *Ohio Administrative Code*
 OAR = *Oregon Administrative Rules*
 SMA = *Shoreline Management Act of 1971*
 WAC = *Washington Administrative Code*
 NA = not applicable

2.7.1.1 Federal Statutes and Regulations

The ESA (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. Section 7(a)(2) of the ESA requires federal agencies to evaluate actions that they perform, fund, or permit to determine whether they would affect any species listed as endangered or threatened or affect 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 of 1918* (MBTA; 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. The MBTA prohibits incidental take and applies enforcement discretion ([86 FR 54642](#)). PNNL projects that have a potential to affect avian species listed under the MBTA use the PNNL biological resource review process, as described in the CBRMP (DOE-PNSO 2021a) and implemented by PNNL's internal biological resource protection procedures to protect migratory birds regardless of intent. In 2021, PNNL biologists resolved 15 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 of 1940* (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.

The *Magnuson–Stevens Fishery Conservation and Management Act* (MSFCMA; 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 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 MSFCMA, 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 (MMPA; 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 MMPA 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 RHA 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 CWA 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 ERP program.

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 2.7.2.1 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. It states that federal agencies should avoid undertaking or assisting in 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 Executive Order 11990, as well as the wetland provisions of the CWA (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 2.7.2.2 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 USFWS regarding implementation of Executive Order 11386, identifies specific areas in which enhanced collaboration between DOE and 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 2021) and implemented by PNNL’s internal biological resource protection procedures.

The *Coastal Zone Management Act of 1972* (CZMA; 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 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 is necessary. The USCG also publishes the *Local Notice to Mariners* weekly, which provides information about the location of structures to facilitate navigational safety in marine environments. Permits, private organizations or individuals, and *Local Notices to Mariners* (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* (FSOAA; 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 of 1916* established the National Park Service 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. No permits were acquired under the CRGNSAA in 2021. PNNL maintains compliance through its ERP program.

2.7.1.2 State Statutes and Regulations

PNNL conducts research at locations throughout the United States 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 m³/s (21 ft³/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 2021) 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 Plans through PNNL's ERP program.

Several chapters and sections of the WAC govern activities that affect fish and wildlife or their habitat, aquatic lands, and excavation activities in Washington State. 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 in 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.

Research that PNNL undertakes in the state of California must comply with state regulations in place to protect fish and wildlife and their habitat. The California Code of Regulations (CCR) requires a permit from the California Department of Fish and Wildlife (CCR, Title 14, Section 650) to conduct scientific collections or to conduct research in marine managed areas. In addition, a permit or waiver from the California Coastal Commission (CCR, Title 14, Section 13050.5) is required for certain deployments within the coastal zone.

For research conducted in Ohio on natural areas and preserves, a permit issued by the Ohio Department of Natural Resources is required under the Ohio Administrative Code (Rule 1501:17-3-02).

2.7.2 PNNL Programs

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

PNSO prepared the CBRMP (DOE-PNSO 2021a) 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 2021a), projects involving soil or vegetation disturbance or work outdoors are routinely evaluated to determine their potential to affect biological resources prior to implementation. Thirty-seven biological resource reviews were completed for PNNL projects in CY 2021—13 on the Richland Campus, 13 at the PNNL Sequim Campus, and 11 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 May through August 2021, 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 2021, and at the PNNL Sequim Campus from 2006 to 2021 and their status are provided in Appendix A and Appendix B, respectively.

2.7.2.1 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 Species” 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 2021).

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 (Elwell and Phillips 2016). 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 subsequent boat operators of watercraft condition and status relative to completion of decontamination and quarantine requirements prior to launch.

2.7.2.2 Noxious Weed Control

Several non-native plant species listed in the State noxious weed list "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. 2021; see Appendix A. Class B noxious weeds are species designated for control where they are not yet widespread to prevent new infestations (WNWCB 2021). On the PNNL Richland Campus, Class B species include the following:

- 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*)
- 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, a perennial that spreads by seed and root, occurs in seasonally moist areas (e.g., low areas or near the river). 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 2021). These species are not typically targeted for control on the PNNL Richland Campus. Known Class C species on the PNNL Richland Campus are as follows:

- 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*)
- Tree-of-heaven (*Ailanthus altissima*).



PNNL has carried out a noxious weed control program on the PNNL Richland Campus since 2010. Areas treated in 2021 are indicated in Figure 2.1. 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 Milestone™ herbicide is generally used (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).

In 2021, the primary weed species targeted for herbicide applications were rush skeletonweed, diffuse knapweed, and Russian knapweed. Herbicide applications were conducted on six days between April 27 and May 13, 2021. In addition, mechanical control of yellow starthistle and cotton thistle was conducted when those species were observed outside of the spray period.

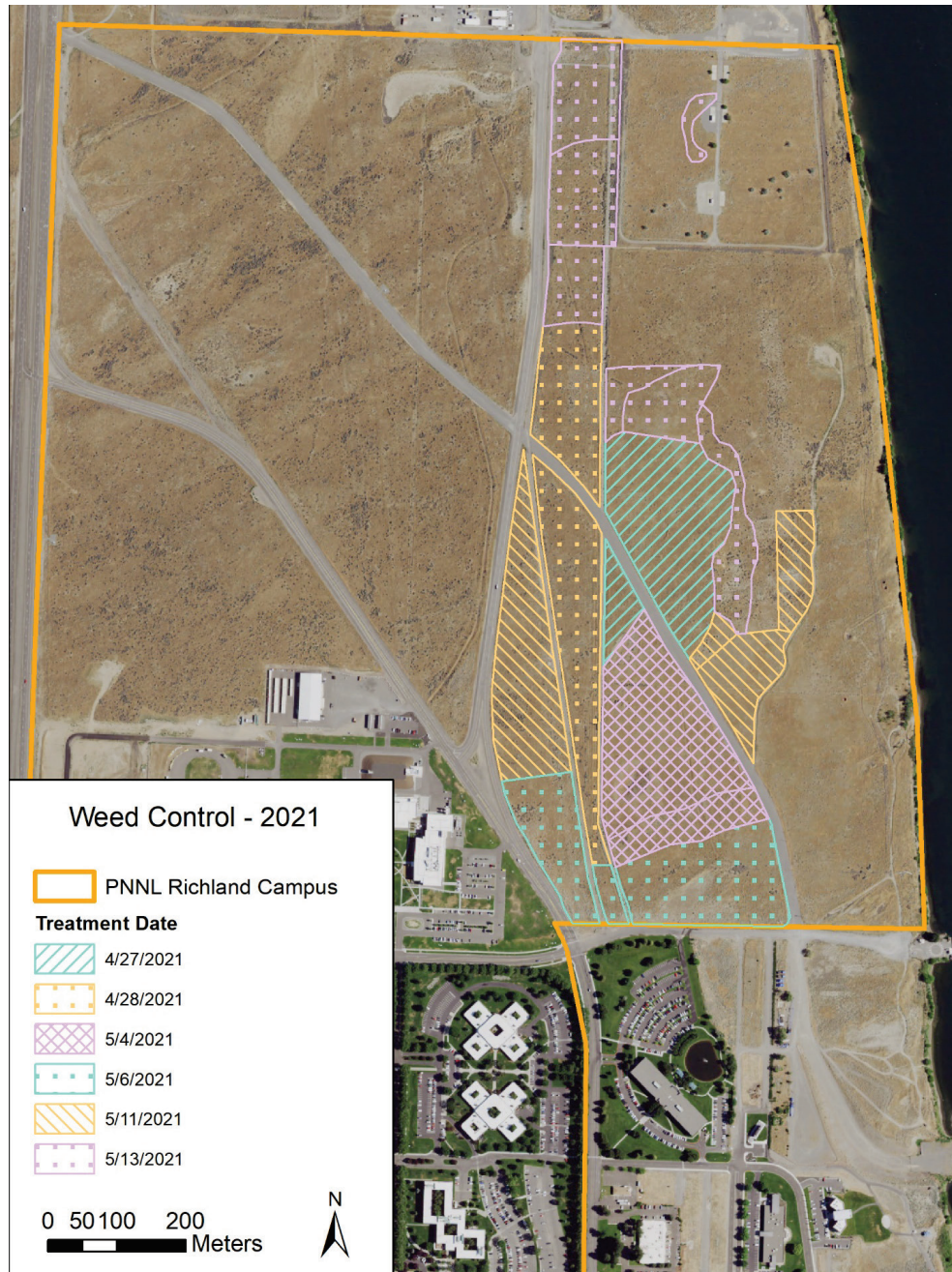


Figure 2.1. Areas Treated for Noxious Weeds on the PNNL Richland Campus in 2021

2.7.3 Cultural Resources

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. Most of the work completed by the cultural resources program at PNNL is focused on Section 106 compliance, as required by the *National Historic Preservation Act of 1966* (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 to avoid, minimize, or mitigate these impacts. This section summarizes PNNL's compliance activities in 2021.

The PNNL cultural resources program supported 43 projects by performing desktop reviews and field surveys and monitoring of cultural resources for projects with archaeological monitoring requirements. Seven of the 43 projects were activities exempt under existing agreement documents. One undertaking off-site resulted in the identification and recording of one precontact isolate. This finding was reported to the Washington State Department of Archaeology and Historic Preservation and described in the report sent to consulting Tribes.



Fourteen of the 43 projects were undertakings at PNNL's Sequim Campus. Consultation for the 2020 project that resulted in an Adverse Effect resumed in 2021. A Memorandum of Agreement was signed between DOE-PNSO (DOE-PNSO 2021b), the Washington State Department of Archaeology and Historic Preservation, and the Jamestown S'Klallam Tribe.

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 also are consulted regularly.

2.7.3.1 NHPA 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 the PNNL Richland Campus during the first quarter of FY 2021. Monitoring was conducted by the PNNL cultural resources staff 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 impacts. In addition, information was collected and added to file records to update the current knowledge of the sites.

Some small manmade disturbances resulting from human activities were recorded in one site during the FY 2021 monitoring trip. The area is now protected by a fence that was installed in late 2021. Animals continue to use 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. More impacts were noted in the PNNL Richland Campus historic district. The district comprises six buildings—four that were part of the original Battelle campus and two facilities completed in the 1970s. Deterioration of staircases and other infrastructure was noted, along with other general deterioration. The historic properties will continue to be monitored annually.

For the first time, Section 110 monitoring occurred on the PNNL Sequim Campus in 2021. The monitoring established baseline condition assessments for the three precontact historic properties at the campus. Results were documented in a report and sent to consulting Tribes. Section 110 monitoring will continue at the PNNL Sequim Campus.

2.8 Radiation Protection

PNNL is subject to radiation protection statutes and regulations that are 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, Chg 4 (September 2020). 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 incorporated into 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 2.2). The ALARA process must be applied to the design or modification of facilities and to the conduct of radiological work activities.

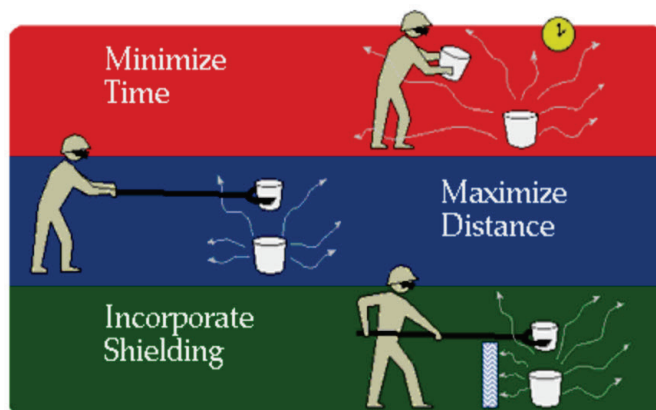


Figure 2.2. Elements of the As Low As Reasonably Achievable (ALARA) Principle

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. 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.

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 2021.

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 3, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees*
- DOE Order 458.1, Chg 4, *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).

PNNL's Radioactive Waste Management Basis¹ 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* (AEA; 42 U.S.C. § 2011 *et seq.*) was passed 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 and DOE Order 458.1) to protect public health and the environment from potential risks associated with radioactive materials. PNNL complies with the AEA through its Radiation Protection Management and Operation Program and Radioactive Waste Management Basis.

¹ CM Anderson to RE Snyder. July 23, 2020. "Contract NO. DE-AC05-76RL01830-Transmittal of Radioactive Waste Management Basis Report and Request Re-approval of Exemptions to DOE Order 435.1." OUT-0298-2020, PNNL, Richland, Washington.

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 2021.

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 2021.

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 2021.

2.10 Summary of Permits

Table 2.7 summarizes air, liquid, and hazardous waste permits for the PNNL Richland Campus and PNNL Sequim Campus during CY 2021. Project-specific permits are also acquired but are not reflected in the table because they are usually of limited term and scope.

Table 2.7. PNNL Air, Liquid, and Hazardous Waste Permits, 2021

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	1/1/2026
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, Rev. 1	PNNL Site – W.R. Wiley Environmental and Molecular Sciences Laboratory, Physical Sciences Facility Complex, Energy Sciences Center, Life Sciences Laboratory II 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	8/15/2025
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 (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	3/6/2023
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	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
<p>(a) Expired permits generally remain in force while renewal applications are processed by the issuing agency.</p> <p>(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. The ST 4511 permit has expired but has been administratively extended by Ecology.</p> <p>(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.</p>				

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.

In early 2020, PNNL successfully renewed its ISO 14001:2015 Certificate of Registration through 2023 (Figure 3.1).



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

The EMS program is audited annually to verify that it is operating as intended and in conformance with ISO 14001 standards. The 2021 audit was performed virtually because of site access restrictions imposed by the COVID-19 pandemic. The results of the 2021 audit showed that PNNL continues to meet the requirements of the ISO 14001 standard, despite the disruptions and workplace access challenges imposed by the pandemic. In addition, the 2021 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.

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 described below:

1. *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 to reduce PNNL’s chemical waste.
2. *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, work controls and procedures for biological material use, and adequate safety requirements.
3. *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.
4. *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, special training requirements for staff requiring access, and restricting the amount and location of where radioactive materials can be used to within permitted levels.
5. *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.

6. *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.
7. *Energy Use.* Using energy judiciously is a prime objective at PNNL. Energy reduction goals are established and activities to reduce energy consumption are implemented.
8. *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.
9. *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.
10. *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.
11. *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.”

3.1 Environmental Operating Experience and Performance Measurement

Despite the unprecedented disruptions and challenges of the ongoing COVID-19 pandemic, staff at PNNL have remained productive. Key accomplishments and initiatives in advancing PNNL sustainability are highlighted in the following sections. Select sustainability goals, PNNL’s FY 2021 performance status, and planned actions are detailed in Table 3.1. Additional details are provided in PNNL’s FY 2022 Site Sustainability Plan. The plan was prepared in accordance with the DOE/Sustainability Performance Division (SPD) FY 2022 Site Sustainability Plan guidance and is available upon request.

Table 3.1. Select PNNL Sustainability Goals through FY 2021 and Planned Actions

Prior DOE Goal	Current Performance Status	Planned Actions & Contribution	Overall Risk of Non-Attainment
Energy Management			
Reduce energy use intensity (Btu per gross	5% increase versus last year.	PNNL is in the process of developing several plans to	Medium Risk

Prior DOE Goal	Current Performance Status	Planned Actions & Contribution	Overall Risk of Non-Attainment
square foot) in goal-subject buildings.		significantly reduce energy use by electrification of heating systems, investing in district energy systems, and implementing general Energy Conservation Measures (ECMs). PNNL's NZERO planning, when fully implemented, would see 50% reduction in energy use, before factoring renewable energy production.	
Energy Independence and Security Act (EISA) Section 432 continuous (4-year cycle) energy and water evaluations.	Compliant with EISA Section 432 requirements.	PNNL will continue to complete EISA requirements.	Low Risk
Meter all individual buildings for electricity, natural gas, steam, and water, where cost effective and appropriate.	All individual buildings are metered for electricity, natural gas, steam, water, and chilled water, where cost effective and appropriate.	PNNL will continue implementing metering for applicable buildings. PNNL intends to update and document progress once the new metering guidance is issued.	Low Risk
Water Management			
Reduce potable water use intensity (WUI) (gal per gross square foot).	57% reduction in WUI from FY 2007 baseline; a 20% increase in WUI compared to FY 2020.	PNNL will continue to reduce potable water intensity as much as possible.	Low Risk
Reduce non-potable freshwater consumption (gal) for industrial, landscaping, and agricultural.	19% increase compared to FY 2020.	Hot, dry, windy summer this year increased landscaping needs. Trending shows possible impact due to climate change. New buildings will impact industrial, landscaping, and agricultural aspects.	Medium Risk
Waste Management			
Reduce nonhazardous solid waste sent to treatment and disposal facilities.	Diverted 61% through recycling.	Continue to implement and improve recycling program. Conduct assessment for waste reduction opportunities.	Low Risk
Reduce construction and demolition (C&D) materials and debris sent to treatment and disposal facilities.	Diverted 94% through recycling.	Continue monitoring C&D recycling performance and raising awareness of waste diversion requirements.	Low Risk
Fleet Management			
Reduce petroleum consumption.	An increase of over 1,000 gallons compared to FY 2020 usage.	Primary strategy is to move away from petroleum-based vehicles. Also, education will continue for petroleum-based vehicle custodians on the importance of avoiding extra idling time and combining trips	Low Risk

Prior DOE Goal	Current Performance Status	Planned Actions & Contribution	Overall Risk of Non-Attainment
		with other staff members, when feasible.	
Increase alternative fuel consumption.	957% increase in annual alternative fuel consumption.	Continue periodic checks on the local availability for alternative fuels. As older vehicles are replaced, PNNL will continue to work with General Services Administration (GSA) to determine whether an alternative fuel vehicle or electric vehicle (EV) is an option for replacement.	Low Risk
Acquire alternative fuel and electric vehicles.	PNNL achieved 33% in FY 2021, limited by GSA due to options available.	PNNL will continue to work closely with GSA to assure that all applicable PNNL vehicle orders are for alternatively fueled vehicles when available.	Low Risk
Clean & Renewable Energy			
Increase consumption of clean and renewable electric energy.	7.5% of electricity consumption is renewable.	PNNL will evaluate the feasibility of clean and renewable energy systems as part of NZERO planning.	Low Risk
Increase consumption of clean and renewable non-electric thermal energy.	5.4% of total electricity and thermal energy is renewable.	PNNL will evaluate the feasibility of clean and renewable energy systems as part of NZERO planning.	Low Risk
Sustainable Buildings			
Increase the number of owned buildings that are compliant with the Guiding Principles for Sustainable Buildings.	11 of the 24 (46%) applicable buildings are Sustainable Buildings per the Guiding Principles (GPs) or Leadership in Energy and Environmental Design principles.	All new construction of owned buildings will meet the GPs.	Low Risk
Acquisition & Procurement			
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring all sustainability clauses are included as appropriate.	100% of eligible contracts contains the sustainable acquisition clause.	Continue to be proactive with sustainable acquisition.	Low Risk
Efficiency & Conservation Measure Investments			
Implement life-cycle cost effective efficiency and conservation measures with appropriated funds and/or performance contracts.	PNNL partnered with CNGC to explore potential energy savings projects for funding under a Utility Energy Services Contract (UESC).	Implement approved energy conservation projects under UESC.	Low Risk
Electronic Stewardship & Data Centers			
Electronics stewardship from acquisition, to operations, to end of life.	100% of electronic products procured in FY 2021 are Electronic Product	Continue to reuse and recycle electronics.	Low Risk

Prior DOE Goal	Current Performance Status	Planned Actions & Contribution	Overall Risk of Non-Attainment
	Environmental Assessment Tool (EPEAT). 100% of electronic waste was recycled.		
Increase energy and water efficiency in high-performance computing and data centers.	The normalized (weighted by total data center load) power usage effectiveness at PNNL is 1.29 for FY 2021. The WUI is 4.02 (EMSL), 2.99 (3820 building), and 1.73 (CSF).	Continuing server and storage improvements along with removal of older devices in ISB II Data Center to reduce IT load.	Low Risk
Adaptation & Resilience			
Implement climate adaptation and resilience measures.	Currently conducting a pilot to identify improvement opportunities in energy/water resilience using the Federal Energy Management Program (FEMP) Technical Resilience Navigator (TRN) tool.	Leverage the TRN pilot to identify opportunities to improve resilient operations. Evaluate and implement opportunities as part of NZERO planning.	Low Risk
Multiple Categories			
Reduce Scope 1 and 2 greenhouse gas (GHG) emissions.	An increase of 72% from FY 2020.	Implement ECMs and NZERO projects.	Medium Risk
Reduce Scope 3 GHGs.	A reduction of 54% from FY 2020.	Implement Hybrid Workplace.	Medium Risk

3.1.1 Reducing Energy Use

In FY 2021, PNNL's energy intensity for "Goal Subject" buildings was 177.4 kBtu/gross square foot (gsf), a net increase of approximately 6.4% compared to the FY 2015 baseline and a 6.7% increase versus last year. For "Excluded" buildings, energy intensity was 357.4 kBtu/gsf, a 5.7% decrease compared to the FY 2015 baseline and a 0.3% increase versus last year.

Some of the increase in energy use can be explained by local weather. In FY 2021, a 30% increase in cooling degree days was observed compared to FY 2020. This is due to record-setting weather conditions in Richland, Washington, during the summer season, which set both a new all-time record for highest daily temperature of 118°F and a record for the number of days (35) on which temperatures exceeded 100°F. The sweltering temperatures greatly impacted energy consumption. Not only was load and use high, but heat-rejection equipment has a reduced efficiency at these elevated temperatures. For reference, PNNL's typical design temperature for the summer is 101°F. Heating degree days were roughly the same. Also, PNNL is transitioning from COVID-19 curtailed operation to limited operation, so facility energy usage steadily increased compared to last year.

Figures 3.2 provides PNNL's total energy use (in million British thermal unit [MMBtu]) from FY 2017 through FY 2021.

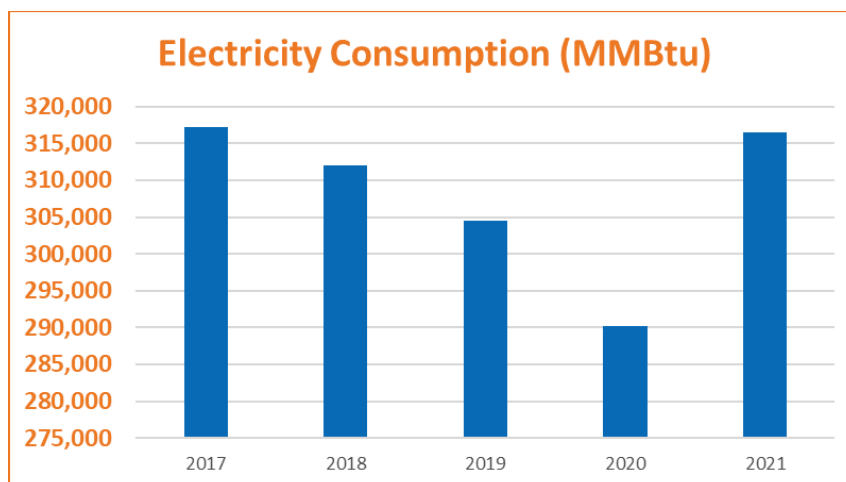


Figure 3.2. Electricity Consumption

3.1.2 Reducing Water Use Intensity

By the end of FY 2021, PNNL's potable water use intensity (WUI) had increased by approximately 20% compared to FY 2020, primarily due to record high-temperature setting weather conditions in Richland, Washington, as described in Section 3.1.1. Additionally, PNNL noticed a marked reduction of water usage in FY 2020 compared to FY 2019, due to a reduction in the number of people on-site because of COVID-19 workplace restrictions. As restrictions eased to enable limited campus operation, the additional people on campus contributed to an increase in water usage. PNNL continues to perform line flushing (especially in the 300 Area) to control chlorine levels in the water distribution systems.

The current WUI, 29.8 gallons per gross square foot (gal/gsf), is 57.5% less than the FY 2007 baseline WUI of 70.1 gal/gsf. Potable water usage from FY 2017 through FY 2021 is provided in Figure 3.3.

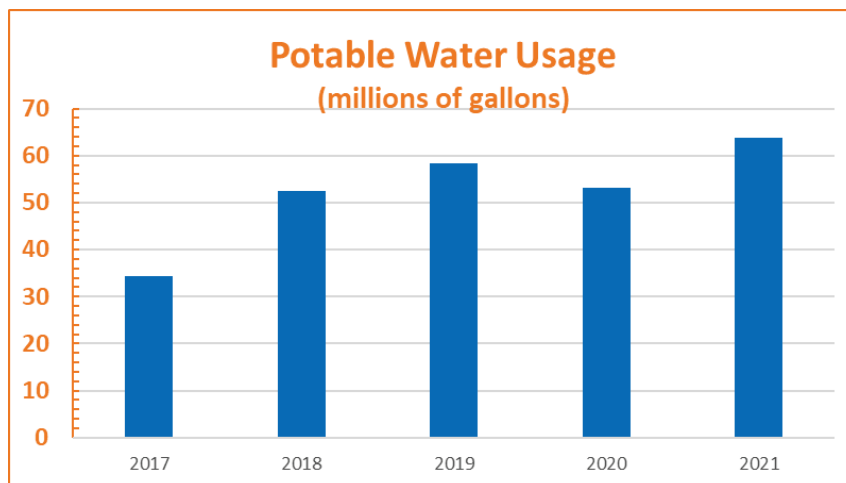


Figure 3.3. Potable Water Usage

3.1.3 Sustainable Buildings

Currently, PNNL has 11 (or 517,841 gsf) of 24 (or 1,065,666 gsf) applicable buildings compliant with DOE's Federal Energy Management Program Guiding Principles (GPs). Federal new construction and modernization projects greater than 10,000 gross square feet are required to comply with the *Guiding*

Principles for Sustainable New Construction and Modernization (CEQ 2020). PNNL applicable buildings comprise 46% by building count, or 49% by total square footage.

At PNNL, all new construction, major renovations, and alterations of buildings greater than 10,000 gsf will comply with the GPs. This commitment is institutionalized by incorporating the GPs, including the energy-reduction requirements per the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1, into PNNL's engineering design standards and the general specification for new construction and major renovation projects.

Currently, two buildings are under construction. The Energy Sciences Center building is expected to complete commissioning in FY 2022. This will be the first new facility at PNNL to use the 2016 GPs as a path toward sustainable building status. The Grid Storage Launchpad building is designed to consolidate and enhance the grid energy storage research capability and will meet the 2020 GP requirements.

3.1.4 Solid Waste Management

In FY 2021, PNNL generated 350 metric tons of nonhazardous waste and diverted 538 metric tons (i.e., 61%) of nonhazardous sanitary waste through recycling (459 metric tons) and composting (79 metric tons). This success is attributed to innovative program communication and infrastructure/process improvements, as highlighted below.

Recycling at PNNL has become easier with "single-stream recycling," which was launched in late FY 2016. Prior to single-stream recycling, routine recyclables were separated into several different bins; the intention is to improve the recycling culture with this zero-sort recycling. Since then, PNNL has been using single-stream recycling and we continue to promote this important recycling program.

- A nitrile glove recycling program was initiated in FY 2015 to divert this high-volume, yet hard-to-recycle waste stream from laboratory spaces. Over 500 lb of gloves have been collected each year during FY 2019 through FY 2021. During FY 2021, the program was expanded to include additional PNNL laboratory spaces, and shipping practices were expanded to improve the ability to support point source generation of nitrile gloves for recycling.
- During FY 2021, PNNL's recycling programs remained strong, and quantities of materials recycled returned to pre-pandemic levels.
- In FY 2021, PNNL implemented opportunities for improvement from a Pollution Prevention program assessment. Improvements were applied to the laboratory glassware recycling and PNNL's sustainable acquisition policy, including identification of a new biobased hand soap that will be promoted for PNNL research laboratories during FY 2022.

Figure 3.4 presents PNNL's solid waste recycling levels since FY 2017, excluding construction waste, which is covered in the next section.

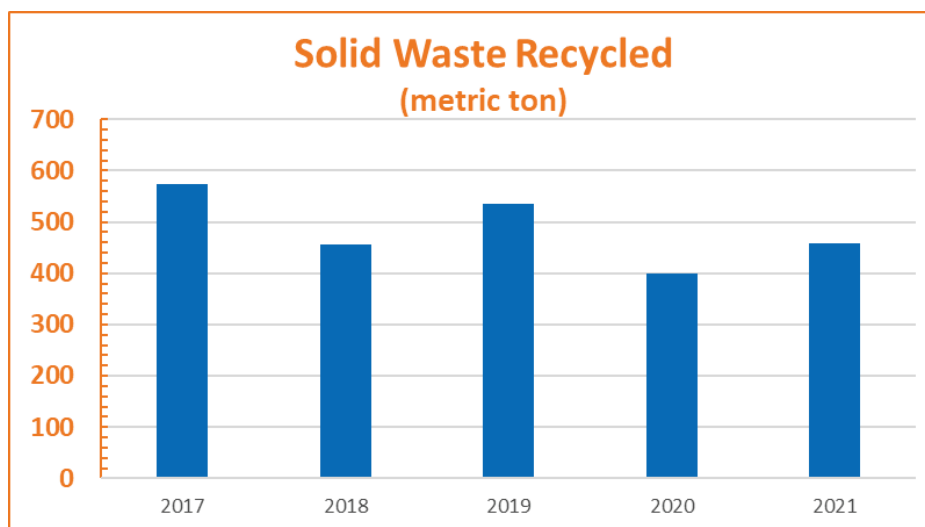


Figure 3.4. Solid Waste Recycling, 2017–2021

3.1.5 Construction Waste Management

PNNL has a wide variety of construction and demolition (C&D) work activities that vary from large construction projects to smaller scopes of work. Opportunities for reuse and recycling of such waste depends on annual C&D activities. Reuse and recycling strategies are integrated with project planning, enabling continued success in C&D waste diversion. During FY 2021, PNNL generated 5.2 metric tons and diverted 4.9 metric tons (i.e., 94%) of C&D waste through recycling or reuse.

3.2 Site Resiliency

Site resilience planning is an iterative process for PNNL, and is revisited as external hazards and threats, site missions and priorities, and local systems and conditions change. In FY 2020 and FY 2021, PNNL piloted the DOE Federal Energy Management Program Technical Resilience Navigator (DOE/FEMP TRN) tool, which examined risk to PNNL operations from energy and water systems conditions, operations, procedures, and plans. As a part of this process, PNNL identified potential resilience solutions that would be complementary to its NZERO initiative effort. PNNL will use the findings from the TRN assessment to develop the Vulnerability Assessment and Resilience Plan (VARP).

The internal stakeholder team for the TRN effort included a cross-cutting group of program managers and technical personnel with responsibility for employee safety, energy and water resource management, continuity planning, and facility engineering and design. The members of this group have direct responsibility for implementing energy and water management that must be maintained to assure successful laboratory operations.

PNNL has shared lessons learned from our experience with the TRN with other DOE offices and sites and also helped them enhance their facility resilience plans. Specific actions PNNL has taken in FY 2021 under the TRN actions include the following:

1. Reviewing the vulnerabilities of energy and water critical loads identified in the TRN study, including the availability and capacity of backup generators and the operations and planning capabilities for mission restoration in the event of a disruption to the primary energy and water supply.
2. Reviewing potential hazards at the PNNL Richland campus and identifying which could be affected by climate change (either in increasing severity or frequency). PNNL used the TRN, which draws data from the Department of Homeland Security's National Risk Index, in addition to reviewing county-

level risk assessments and previous site risk assessments required for operations of specific facilities and research to develop the short-list of hazards examined in the assessment.

3. Reviewing the results of the risk assessment with PNNL staff across the research, building operations, and emergency management divisions.
4. Identifying institutional, operational, and technological solutions that address site risk and support PNNL's NZERO initiatives.
5. Prioritizing resilience solutions for their potential risk reduction at the PNNL Richland campus and alignment with PNNL's resilience goals.

In FY 2022, PNNL will close out its pilot and coordinate the prioritized resilience solutions with key stakeholders to formally define and implement cost-effective options. Under its partnership with FEMP, PNNL will continue to share lessons learned from its experience with the TRN with other DOE facilities.

3.2.1 Risks to Mission, Operations, and People

In 2022, PNNL will update its FY 2015 *Climate Resilience Action Plan* (PNNL 2015) following the VARP guidance. PNNL will be reviewing the previously established high-priority areas, shown in (Table 3.2), to see if there are changes to the identified potential impacts from current and changing climate exposures on PNNL's core systems, considering current levels of preparedness.

Table 3.2. Potential Climate Exposures and Impacts on Core Systems

Climate Exposure/Core System	High Temperatures	Intense Precipitation	Wildfire	Drought	Storms and Winds	Ice Storms
Buildings	Higher	Higher	Medium	Medium	Medium	Medium
Energy	Higher	Lower	Lower	Medium	Medium	Lower
IT Services	Medium	Medium	Lower	Lower	Medium	Lower
Worker, Safety, & Health	Lower	Lower	Medium	Lower	Lower	Lower
Water Resources & Infrastructure	Lower	Lower	Lower	Lower	Lower	Lower
Transportation	Lower	Lower	Lower	Lower	Lower	Lower

The two climate exposures previously identified as the highest concern to PNNL's operations are the projected increase in the number of high-temperature days and the intense precipitation events that are experienced each year. PNNL plans to address several of these risks via resilience solutions for buildings and critical loads identified in the TRN. Additionally, PNNL plans to re-examine the potential climate exposure risks of previously identified medium impact hazards (e.g., wildfire, drought, etc.). See the Climate Resilience Action Plan (PNNL 2015) on the PNNL Sustainability website for more information about climate exposures and core system vulnerabilities rated medium or low priority.

3.2.2 Impacts on Risk Management Processes

The PNNL Emergency Management and Business Continuity Plans address most hazards that could result from long-term climate variability and change through the Emergency Preparedness hazards surveys, conducted on a triennial basis, which cover a multitude of natural phenomena events (e.g., flood, wildfire, etc.). The PNNL Emergency Management and Business Continuity Plans employ an all-hazards-based approach to include response processes that are flexible and adaptable to a multitude of scenarios. The TRN Pilot at the PNNL Richland Campus identified several opportunities to improve existing processes to help collect additional resilience information as a part of its normal activities.

3.2.3 Plans and Projected Performance

PNNL will develop the VARP in accordance with the VARP guidance; the results of the TRN pilot will be incorporated into the FY 2022 VARP, including the lessons learned and best practices identified from the TRN pilot assessment. The Sustainability Program team members responsible for resiliency planning will continue to consult with internal subject matter experts as warranted.

3.2.4 Accomplishments, Awards, and Recognition

Recent PNNL sustainability and resiliency noteworthy accomplishments that recognize organizational accomplishments:

- DOE's FEMP TRN tool provides a systematic approach to examining resilience needs and goals, assessing on-site energy and water systems, evaluating risk, identifying resilience gaps, and developing and prioritizing solutions to resolve those gaps.

In FY 2020, PNNL was selected by FEMP to pilot its TRN tool to determine the effectiveness of the methodologies and provide lessons learned and improvement opportunities. PNNL plans to use the results from the TRN pilot to develop its VARP. The PNNL TRN project won the 2021 DOE Sustainability award in the Innovative Approach to Sustainability category.

- In FY 2020, PNNL signed an agreement to support the DOE's 50001 Ready Cohort initiative. This [50001 Ready](#) Energy Management System, when implemented fully, will improve PNNL's ability to continually identify, monitor, track, and improve energy conservation measures. The 50001 Ready program is an ISO 50001:2018-based energy management system. PNNL completed the initial internal audit in 2021 and is positioned to obtain the 50001 Ready recognition from DOE by the end of CY 2021.

4.0 Environmental Radiological Protection Program and Dose Assessment

This section describes the environmental monitoring programs for radiological constituents and the associated estimated dose assessments for the PNNL Richland and Sequim Campuses. 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 to a permitted waste treatment facility that is authorized to receive radiological material. Further evaluation is then performed to determine the source of the radiological component in the discharge.

If a waste stream is identified as containing very low levels of radioactive material, a request to authorize the discharge of this waste stream to the sewer system would be submitted to the City of Richland. The City of Richland can authorize the discharge of individual waste streams that contain very low levels of radiological material to the sewer system, as appropriate. As described in Section 4.1.1, there is currently only one authorized discharge of a liquid waste stream potentially 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 potentially 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 the PSF (Physical Sciences Facility).

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 2021, the fume hoods were washed down an estimated total of 27 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 routinely tracked at the PNNL Sequim Campus. Regulatory compliance reporting and monitoring results are reported in an annual air emission report for each location (Snyder et al. 2022a, 2022b). CY 2021 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 2021, the PNNL Richland Campus MEI location was 0.64 km (0.40 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 2021.



nonroutine emissions
Richland Campus in

Table 4.1. PNNL Richland Campus Emissions and Dose Contributions by Radionuclide, 2021 (Snyder et al. 2022a)

Radionuclide ^(a)	Releases (Ci)	Campus MEI Dose (mrem EDE)	Percent of Total EDE
Gross Alpha ^(b)	1.4×10^{-7}	4.8×10^{-6}	27%
Gross Beta ^(c)	1.2×10^{-6}	4.0×10^{-6}	22%
Hydrogen-3 (tritium)	1.2×10^{-4}	1.4×10^{-8}	<1%
Aluminum-26	7.8×10^{-9}	1.1×10^{-7}	1%
Cobalt-60	1.2×10^{-8}	3.3×10^{-8}	<1%
Krypton-83m	3.2×10^{-1}	7.1×10^{-9}	<1%
Rubidium-83	1.4×10^{-6}	3.3×10^{-7}	2%
Strontium-90	3.4×10^{-8}	9.0×10^{-8}	1%
Cesium-137	1.7×10^{-8}	6.5×10^{-8}	<1%
Lead-210	2.4×10^{-9}	4.5×10^{-8}	<1%
Radon-222	1.0×10^{-6}	2.1×10^{-9}	<1%
Radium-226 ^(d)	1.2×10^{-9}	8.0×10^{-8}	<1%
Uranium-232	1.3×10^{-10}	7.0×10^{-9}	<1%
Uranium-233/234	5.1×10^{-7}	5.3×10^{-6}	29%
Plutonium-238	1.0×10^{-8}	4.1×10^{-7}	2%
Plutonium-239/240	2.1×10^{-9}	7.8×10^{-8}	<1%
Plutonium-241	2.6×10^{-8}	7.9×10^{-8}	<1%
Plutonium-242	4.0×10^{-9}	6.3×10^{-7}	3%
Americium-241	4.0×10^{-9}	1.7×10^{-7}	<1%
Americium-243	2.6×10^{-10}	7.6×10^{-9}	<1%
Curium-243/244	3.8×10^{-8}	8.3×10^{-7}	5%
All other nuclides	6.0×10^{-5}	6.7×10^{-9}	<1%
PIC-5 emissions – VRRM	NA	$9.4 \times 10^{-7(e)}$	5%
PIC-5 emissions – NDRM	NA	$6.6 \times 10^{-8(e)}$	<1%
PIC-5 emissions – Facilities Restoration ^(e)	NA	0	0%
PIC-5 emissions – SOIC ^(e)	NA	0	0%
Total ^(f)	3.2×10^{-1}	1.8×10^{-5}	100%

(a) Release information available in Snyder et al. (2022a).

(b) Gross alpha from PSF emission units sampling assumed to be Pu-239.

(c) Gross beta from PSF emission units sampling assumed to be Cs-137.

(d) Dose includes progeny isotope Rn-222.

(e) The PIC-5 emission doses are assigned based on permit value. The SOIC and Facilities Restoration emission sources were not implemented in 2021.

(f) Totals may not add up to value indicated due to rounding.

NA = not applicable

NDRM = non-dispersible radioactive material

PIC-5 = Potential Impact Category

PSF = Physical Sciences Facility

SOIC = sources for instrument/operational checks

VRRM = volumetrically released radioactive material

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

Emissions were determined from both sampling and, for non-sampled emissions, using the 40 CFR Part 61, Appendix D method. The CAP88-PC Version 4.0 code was used for estimating dose. The MEI dose of 1.8×10^{-5} mrem (1.8×10^{-7} mSv) effective dose⁴ is more than 100,000 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 2021, modeling was done to determine the location of the maximum off-site radioactive material air concentration. A 2.1×10^{-5} mrem (2.1×10^{-7} mSv) effective dose was estimated for the maximum off-site radioactive material air concentration location at 0.72 km (0.45 mi) on the western PNNL Richland Campus boundary (i.e., PNL-1 ambient air surveillance station).

The regional collective dose from PNNL's Richland Campus air emissions in CY 2021 also was 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 432,950 people residing within an 80 km (50 mi) radius of the Hanford Site 300 Area (Hamilton and Snyder 2011), with adjustments to add 640 and 190 residents south and south-southeast, respectively, of the PNNL Richland Campus to account for recent apartment units constructed near the PNNL Richland Campus. The near 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 2021 total collective dose from radionuclide air emissions estimated from nuclides that originated from the PNNL Richland Campus was 9.7×10^{-5} person-rem (9.7×10^{-7} person-Sv).

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 2021, the PNNL Sequim Campus MEI location was 0.23 km (0.14 mi) west-northwest 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 2021, which are summarized as gross alpha and gross beta emissions. There were no unplanned emissions or radon 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, 2021 (Snyder et al. 2022b)

Radionuclide	Releases ^(a) (Ci)	Dose to MEI (mrem EDE)	Percent of Total EDE (Percent)
Gross Alpha (as Americium-241)	2.26×10^{-8}	5.1×10^{-5}	94
Gross Beta (as Cesium-137)	3.88×10^{-8}	3.5×10^{-6}	6
Total	6.1×10^{-8}	5.4×10^{-5}	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 mSv, multiply mrem by 0.01.

⁴ 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.

The dose to the PNNL Sequim Campus MEI was 5.4×10^{-5} mrem (5.4×10^{-7} 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 of 310 mrem (3.1 mSv) (NCRP 2009). In 2021, modeling was done to determine the location of the maximum off-site radioactive material air concentration near the PNNL Sequim Campus. The maximum modeled air concentration location results in a 6.4×10^{-4} mrem (6.4×10^{-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 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 2021 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 6.0×10^{-5} person-rem (6.0×10^{-7} person-Sv). If the release were dispersed only to the maximum Canadian sector (north-northwest), the maximum estimated Canadian collective dose would be 2.4×10^{-5} person-rem (2.4×10^{-7} person-Sv).

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, Chg 4, *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 2021.

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 2021.

Table 4.3. Pre-Approved Surface Activity Guideline Limits

Radionuclides	Allowable Total Residual Surface Contamination Limits (dpm/100 cm ²)		
	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	NA	NA

(a) All transuranic elements except plutonium-241, which is treated as a beta/gamma-emitter.
dpm = disintegrations per minute
NA = not applicable

4.3.2 Property Potentially Contaminated in Volume

PNNL uses pre-approved volumetric release limits when releasing small-volume research samples and wastewater potentially contaminated in volume (Table 4.4). 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 2021, PNNL released hundreds of liquid research samples with a total volume on the order of 38 L (10 gal), using the pre-approved release limits in Table 4.4. Generally, 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. 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 directs that DOE sites establish procedures and practices to protect biota, while DOE-STD-1153-2019, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019), provides a graded approach for evaluating the doses to 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 2019, DOE Order 458.1 Chg 4 (LtdChg)). 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 amounts 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 2021—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 4.5). The dose rates are based on the PNNL-reported total particulate radionuclide emissions for CY 2021 (Snyder et al. 2022a).

Calculations are based on conservative assumptions that all the particulate radioactive material is concentrated into either 2,500 m³ (8.8 × 10⁴ ft³) of contaminated water (equivalent to the volume of an Olympic swimming pool) or 50 m² (538 ft²) of contaminated soil or sediment, with a soil density of 224 kg/m² (14 lb/ft²) to a depth of 15 cm (6 in.) (equivalent to a representative garden area) (Napier 2006). For comparison, an average of 3.34 × 10³ m³/s (1.18 × 10⁵ ft³/s) of Columbia River water flows below Priest Rapids Dam (USGS 2021) and past the PNNL Campus on a daily basis, and the PNNL Richland Campus occupies approximately 3.1 × 10⁶ m² (3.34 × 10⁷ ft²) 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 4.5. Absorbed Biota Dose Rates for the PNNL Richland Campus, 2021

	Particulate Emissions ^(a) (Bq/yr)	Terrestrial Animal to Contaminated Soil ^(b) (mGy/d)	Terrestrial Plant to Contaminated Soil ^(b) (mGy/d)	Aquatic Animals to Contaminated Water ^(c) (mGy/d)	Riparian Animal to Contaminated Sediment ^(b) (mGy/d)
Totals	4.6 × 10 ⁶	1.2 × 10 ⁻²	1.7 × 10 ⁻³	9.0 × 10 ⁻²	9.6 × 10 ⁻³
Dose Limit mGy/d	-	1	10	10	1

(a) Total particulate emissions determined from Snyder et al. (2022a).

(b) The terrestrial animals may include deer, bee, earthworm, and rat. The terrestrial plants may include pine tree and wild grass. The riparian animals may include duck and frog. The contaminated soil area is 50 m² (538 ft²) to a depth of 15 cm (6 in.) (Napier 2006).

(c) The aquatic animals may include trout, bass, and salmon and steelhead. The contaminated water volume is 2,500 m³ (8.8 × 10⁴ ft³).

Conversion factors: 1 Ci = 3.7 × 10¹⁰ 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 2021—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 0.1 rad/d (1 mGy/d) for both riparian and terrestrial animals (Table 4.6). These conservative dose rates are well below dose rate limits, which are based on the PNNL-reported total particulate radionuclide emissions for CY 2021 (Snyder et al. 2022b). Conservative assumptions are that all the particulate radioactive material is concentrated into either 2,500 m³ (8.8 × 10⁴ ft³) of contaminated water (equivalent to the volume of an Olympic swimming pool) or 50 m² (538 ft²) of contaminated soil or sediment, with a soil density of 224 kg/m² (14 lb/ft²) 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 × 10⁸ m³ (4.66 × 10⁹ ft³) of seawater with continuous tidal flow past Travis Spit, and the PNNL Sequim Campus developed land occupies approximately 3 × 10⁴ m² (3.2 × 10⁵ ft²) of area.

Table 4.6. Absorbed Biota Dose Rates for the PNNL Sequim Campus, 2021

	Particulate Emissions ^(a) (Bq/yr)	Terrestrial Animal to Contaminated Soil ^(b) (mGy/d)	Terrestrial Plant to Contaminated Soil ^(b) (mGy/d)	Aquatic Animals to Contaminated Water ^(c) (mGy/d)	Riparian Animal to Contaminated Sediment ^(b) (mGy/d)
Totals	2.3 × 10 ³	2.1 × 10 ⁻⁴	8.7 × 10 ⁻⁵	9.2 × 10 ⁻³	6.1 × 10 ⁻⁴
Dose Limit mGy/d	-	1	10	10	1

(a) Total particulate emissions determined from Snyder et al. (2022b).
(b) The terrestrial animals may include deer, bee, earthworm, and rat. The terrestrial plants may include pine tree and wild grass. The riparian animals may include duck and frog. The contaminated soil area is 50 m² (538 ft²) to a depth of 15 cm (6 in.) (Napier 2006).
(c) The aquatic animals may include crab, shrimp, and saltwater fish. The contaminated water volume is 2,500 m³ (8.8 × 10⁴ ft³).
Conversion factors: 1 Ci = 3.7 × 10¹⁰ Bq; 1 Gy = 100 rad

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.

4.5 Unplanned Radiological Releases

No radiological releases to the environment exceeded permitted limits at the PNNL Richland Campus or PNNL Sequim Campus in 2021. There were no unplanned releases reported at either the PNNL Richland Campus or PNNL Sequim Campus in 2021 (Snyder et al. 2022a, 2022b), nor were there any unplanned release events via liquid effluents or to soil.

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. This section summarizes environmental radiological monitoring activities conducted by PNNL for both the PNNL Richland Campus and PNNL Sequim Campus.

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 PNNL Richland Campus boundary was expanded by 35 ha (85.6 ac) to the north, necessitating that the particulate air-sampling network again be evaluated (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), one background sampler (PNL-5), and co-located ambient external dose monitors. Air surveillance station locations for the PNNL Richland Campus are shown in Figure 4.1.

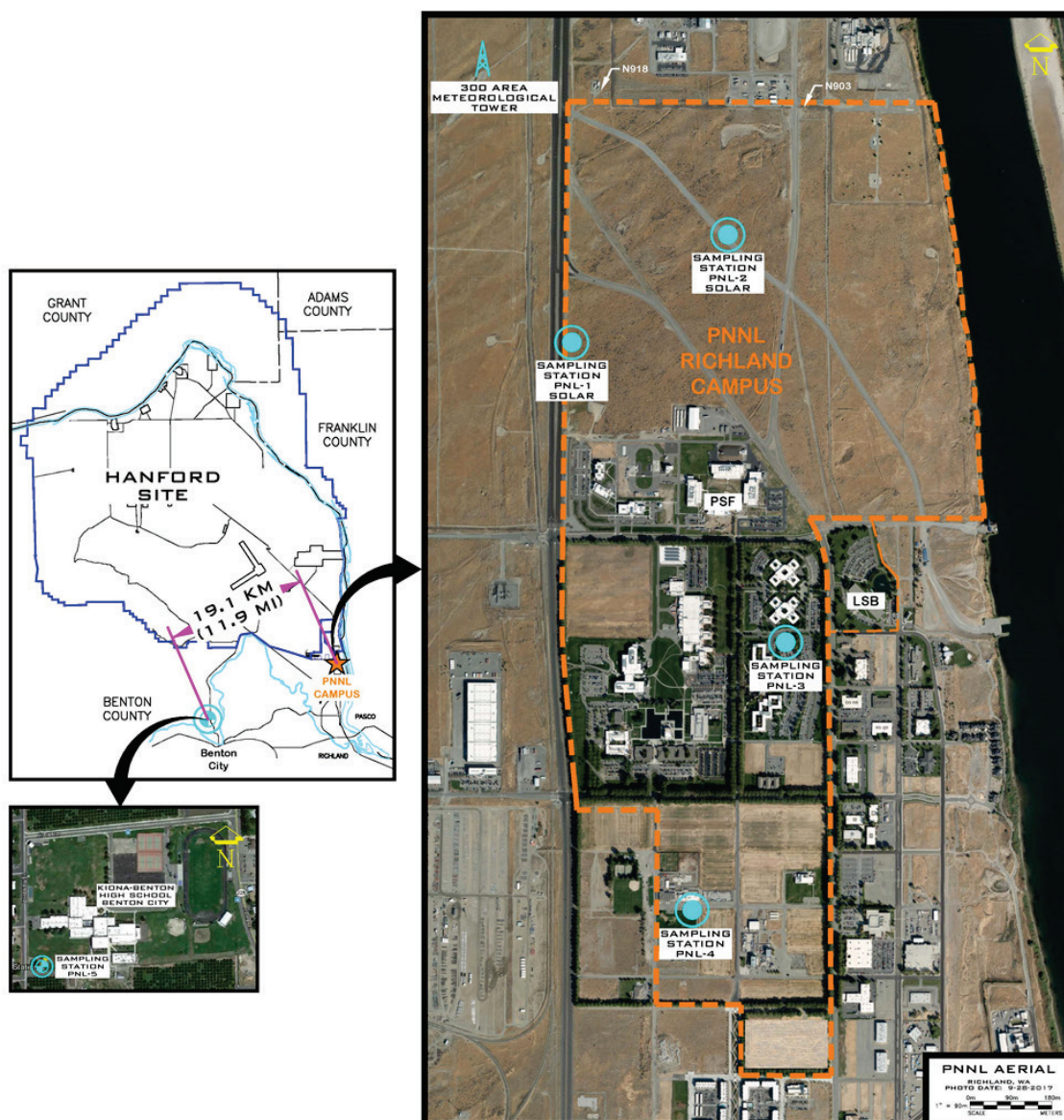


Figure 4.1. Air Surveillance Station Locations for the PNNL Richland Campus (based on Snyder et al. 2022a)

4.6.1.1 Environmental Air Surveillance – PNNL Richland Campus

During CY 2021, 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 would indicate potential unexpected increases in emissions. Semi-annually, filters are composited for specific radionuclide analysis. The required composite analyses include cobalt-60, uranium-233,⁵ plutonium-238 and plutonium-239/240, americium-241 and americium-243, and curium-244.⁶ Starting in CY 2021, gross alpha and gross beta analyses were also added to the list of reported composite analyses. See Snyder et al. (2022a) for additional details regarding environmental air surveillance in CY 2021.

Prior to performing the second-half 2021 semiannual composite sample analyses, the analytical laboratory informed PNNL that they were unable to locate the air particulate filters collected in August 2021. As a result, the sample volume(s) reported for the particulate samples collected in August 2021 and analyzed for gross alpha and gross beta are not part of the composite sample volume used to determine average air concentrations (Table 4.7). Although reduced, the second-half composite sample volume was determined to be sufficient for performing the requested composite analyses and air concentration determinations. There was no significant impact on the annual composite results or station operational frequency for CY 2021 because of this event.

Table 4.7. Summary of 2021 Air-Sampling Results for the PNNL Richland Campus (Snyder et al. 2022a)

Nuclide	Location ^(a)	No. of Samples Analyzed	No. of Detections	Value ± Error (pCi/m ³) ^(b)		
Gross Alpha	PNL-1	28	24	8.4E-04	±	2.5E-03
	PNL-2	28	23	7.7E-04	±	2.4E-03
	PNL-3	26	23	6.3E-04	±	1.7E-03
	PNL-4	26	21	5.2E-04	±	1.6E-03
	PNL-5	26	25	6.9E-04	±	1.8E-03
Gross Beta	PNL-1	28	28	1.7E-02	±	7.9E-03
	PNL-2	28	28	1.5E-02	±	7.0E-03
	PNL-3	26	26	1.4E-02	±	5.4E-03
	PNL-4	26	26	1.3E-02	±	5.5E-03
	PNL-5	26	26	1.4E-02	±	5.7E-03
Gross Alpha ^(c)	PNL-1	2	1	1.3E-03	±	1.1E-03
	PNL-2	2	2	9.8E-04	±	9.6E-04
	PNL-3	2	2	1.4E-03	±	1.1E-03
	PNL-4	2	1	1.6E-03	±	1.2E-03
	PNL-5	2	1	1.7E-03	±	1.1E-03
Gross Beta ^(c)	PNL-1	2	2	1.3E-02	±	2.0E-03
	PNL-2	2	2	1.5E-02	±	2.1E-03
	PNL-3	2	2	1.5E-02	±	2.0E-03
	PNL-4	2	2	1.5E-02	±	2.5E-03
	PNL-5	2	2	1.4E-02	±	1.8E-03
Co-60 ^(c)	PNL-1	2	0	1.9E-05	±	1.1E-04

⁵ 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.

⁶ Only curium-244 is required, but it is reported as curium-243/244 because the curium-243 emission peak overlaps with curium-244.

Nuclide	Location ^(a)	No. of Samples Analyzed	No. of Detections	Value \pm Error (pCi/m ³) ^(b)		
	PNL-2	2	0	1.4E-06	\pm	1.1E-04
	PNL-3	2	0	2.1E-05	\pm	1.0E-04
	PNL-4	2	0	3.1E-05	\pm	1.2E-04
	PNL-5	2	0	7.4E-05	\pm	1.2E-04
	PNL-1	2	0	1.1E-05	\pm	1.0E-04
Cs-137 ^(c)	PNL-2	2	0	1.3E-05	\pm	1.6E-04
	PNL-3	2	0	3.7E-05	\pm	1.1E-04
	PNL-4	2	0	1.1E-05	\pm	5.2E-05
	PNL-5	2	0	5.1E-05	\pm	1.2E-04
	PNL-1	2	2	5.0E-05	\pm	3.4E-05
U-233/234 ^(c)	PNL-2	2	2	3.5E-05	\pm	2.7E-05
	PNL-3	2	1	2.8E-05	\pm	2.5E-05
	PNL-4	2	1	3.5E-05	\pm	3.9E-05
	PNL-5	2	1	3.7E-05	\pm	3.5E-05
	PNL-1	2	0	1.1E-06	\pm	6.9E-06
Pu-238 ^(c)	PNL-2	2	0	1.1E-06	\pm	4.9E-06
	PNL-3	2	0	6.0E-06	\pm	8.6E-06
	PNL-4	2	0	8.3E-06	\pm	1.1E-05
	PNL-5	2	0	5.3E-06	\pm	1.3E-05
	PNL-1	2	0	3.4E-06	\pm	9.0E-06
Pu-239/240 ^(c)	PNL-2	2	0	1.6E-06	\pm	5.9E-06
	PNL-3	2	0	3.4E-07	\pm	6.2E-06
	PNL-4	2	0	4.3E-06	\pm	1.2E-05
	PNL-5	2	0	-5.3E-07	\pm	1.1E-05
	PNL-1	2	0	6.0E-06	\pm	1.3E-05
Am-241 ^(c)	PNL-2	2	0	5.4E-06	\pm	1.6E-05
	PNL-3	2	0	2.9E-06	\pm	1.3E-05
	PNL-4	2	0	5.9E-06	\pm	1.1E-05
	PNL-5	2	0	7.8E-06	\pm	2.0E-05
	PNL-1	2	0	1.1E-05	\pm	2.0E-05
Am-243 ^(c)	PNL-2	2	0	1.4E-05	\pm	2.5E-05
	PNL-3	2	0	3.6E-06	\pm	2.2E-05
	PNL-4	2	1 ^(d)	8.1E-06	\pm	1.6E-05
	PNL-5	2	0	4.8E-06	\pm	2.0E-05
	PNL-1	2	0	1.6E-06	\pm	1.3E-05
Cm-234/244 ^(c)	PNL-2	2	0	-8.9E-07	\pm	1.1E-05
	PNL-3	2	0	-3.3E-06	\pm	1.3E-05
	PNL-4	2	0	-3.9E-06	\pm	8.8E-06
	PNL-5	2	0	-1.2E-05	\pm	1.7E-05

To convert pCi/m³ to Bq/m³, multiply pCi/m³ by 0.037.

(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, with no background (PNL-5) results subtracted.

(c) Semiannual composite analyses.

(d) The detected value is greater than the 2-sigma error; however, the result was flagged by the analytical laboratory as biased high due to possible interference.

No PNNL activities resulted in increased ambient air concentrations at the air-sampling locations in CY 2021 (Table 4.7). The gross alpha and gross beta results were comparable to background levels. These nuclide-specific results were less than the 40 CFR Part 61, Appendix E, Table 2 values, 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.

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 2021. 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 2021.

Ambient external dose monitoring is done with aluminum oxide dosimeters read by optically stimulated luminescence, using the Landauer⁷ InLight® System. The system has a 5 mrem (50 μ Sv) minimum detection level with one sigma uncertainty of 12% for each measurement period. Additional quality assurance information regarding dosimeters is found in Section 7.3.

Optically stimulated luminescence dosimeter (OSLD) results for the 2021 monitoring periods are presented in Appendix C. After adjusting for control dosimeter results, daily and hourly reported results were determined to evaluate dose rates by the number of days monitored each quarter. Daily average dose rates and total 2021 annual background are provided in Figure 4.2. Hourly average dose rates are provided in Table 4.8. Background values at PNL-5 are not subtracted from the PNL-1 through PNL-4 values in the figure and table data.

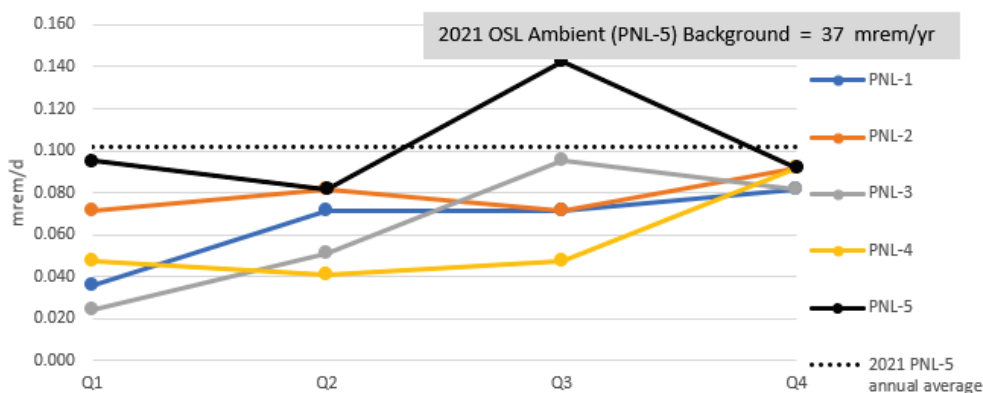


Figure 4.2. Average Daily Ambient External Dose Rates at Each PNNL Richland Campus Sampling Location for Each Calendar Quarter in 2021

⁷ Landauer, 2 Science Rd, Glenwood, Illinois 60425-1586. Accessed at <https://www.landauer.com>.

Table 4.8. Average Hourly Ambient External Dose Rates at Each PNNL Richland Campus Sampling Location ($\mu\text{rem/hr}$)

2021 Quarter	PNL-1	PNL-2	PNL-3	PNL-4	PNL-5 ^(a)
First (Q1)	1.5	3.0	1.0	2.0	4.0
Second (Q2)	3.0	3.4	2.1	1.7	3.4
Third (Q3)	3.0	3.0	4.0	2.0	5.9
Fourth (Q4)	3.4	3.8	3.4	3.8	3.8
Average annual ($\mu\text{rem/hr}$)	2.7	3.3	2.6	2.4	4.3

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

To convert mrem to mSv, multiply mrem by 0.01.

CY 2021 annual dose rates at each campus monitoring location are less than the PNL-5 background (37 mrem/yr [370 $\mu\text{Sv/yr}$] with normalized 91-day quarters). The 2021 normalized results at all stations ranged from 20.7–37.4 mrem (207–374 μSv). For this fifth year of ambient external dose monitoring, the PNNL Richland Campus measurements remained similar to previous regional average background levels from 2017–2020 (32–40 mrem [320–400 μSv]).

In addition to the boundary and background station ambient external dose monitoring discussed above, the PNNL Radiation Protection organization performs 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 2021, survey results were at background levels ($<20 \mu\text{R/hr}$ [$<0.2 \mu\text{Sv/hr}$]) in areas that could be occupied by the public.

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 $\mu\text{Sv/yr}$]) (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 external dose rate surveys at MSL-1 and MSL-5 exterior door locations as well as direct contamination surveys of the ground within 6 m (20 ft) of these building perimeters. For CY 2021, survey results were at background levels ($<20 \mu\text{R/hr}$ [$<0.2 \mu\text{Sv/hr}$]) in areas that could be occupied by the public.

4.7 Public Dose Pathway Summary

The total public dose includes air, water, and other contributions from facility operations. DOE limits the all-pathway public dose limit to 100 mrem/yr (1,000 $\mu\text{Sv/yr}$) in DOE Order 458.1, Section 4.b.1. Components of the total public dose can include contributions from the radiological air emissions pathway, which is limited to 10 mrem/yr (100 $\mu\text{Sv/yr}$) under [40 CFR Part 61, Subpart H](#). Radiological liquid effluents for community water systems are limited to 4 mrem/yr (40 $\mu\text{Sv/yr}$) beta/gamma under [40 CFR 141.26](#). Other dose pathways may be addressed through environmental surveillance activities (e.g., ambient air monitoring, environmental dosimetry, biota [e.g., native plant and wildlife] surveys, and farm product surveys [e.g., local milk, produce, and meat]; DOE 2015). The 100 mrem (1,000 $\mu\text{Sv/yr}$) public dose limit is about one-third of the typical background exposure of 310 mrem/yr (3,100 $\mu\text{Sv/yr}$) (NCRP 2009).

In 2021, the only radiological public dose pathway was from the air pathway (i.e., resulting from permitted operations on the PNNL Richland Campus and the PNNL Sequim Campus). The radiological dose summary to the public by pathway and total is provided in Table 4.9.

Table 4.9. Radiological Dose Summary for PNNL Locations, 2021

Dose Source	PNNL Richland Campus		PNNL Sequim Campus	
	MEI Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose (mrem/yr)	Collective Dose (person-rem/yr)
Air Pathway	1.8E-05	9.7E-05	5.4E-05	6.0E-05
Water Pathway	0	0	0	0
Other Pathway ^(a)	0	NA	NA	NA
Total Dose	1.8E-05	9.7E-05	5.4E-05	6.0E-05
All-Pathways Dose Limit	100	NA	100	NA
Natural Background Radiation	310	1.3E+05	310	7.3E+05

(a) Direct external exposure based on maximum ambient environmental dose result.

NA = not applicable

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

4.8 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 or ambient surveillance, the revised DQO (Snyder et al. 2019) recommended 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 were recommended. DQO results further recommended that this sampling be performed at on-site locations; sampling is acceptable at on-site 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 but has suffered delays due to the onset of and ongoing status of the COVID-19 pandemic as well as the limited availability of technical staff.

5.0 Environmental Nonradiological Program Information

The Effluent, Waste, and Transportation Programs Group (EWTPG) 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.

EWTPG 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* (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 facility. Wastewater discharges are regulated by the City of Richland under three industrial wastewater discharge permits (see Table 2.7). 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, monitoring, and reporting of the wastewater discharges to the City of Richland's system are done as required in accordance with the permits.

Process wastewater from the PNNL Sequim Campus is discharged to an on-site 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 2021 are listed in Table 5.1. Grab samples were taken 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.



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.

Table 5.1. PNNL Sequim Campus NPDES Monitoring Results for Outfall 008, 2021^(a)

Parameter	Total Samples	Quantity Found Below Method Reporting Limit	Method Reporting Limit ^(b)	Maximum Value
Maximum flow (gpd)	NA	NA	NA	53,000
Chlorine, total residual ^(c) (µg/L)	10	10	50	<50
Antimony (µg/L)	5	5	1.0	<1.0
Arsenic (µg/L)	5	5	5.0	<5.0
Beryllium (µg/L)	5	5	0.20	<0.20
Cadmium (µg/L)	5	5	0.20	<0.20
Chromium (µg/L)	5	4	2.0	2.6
Copper (µg/L)	12	5	1.0	44.4
Lead (µg/L)	12	9	0.20	0.42
Mercury (µg/L)	5	1	0.0005	0.00142
Nickel (µg/L)	5	4	2.0	7.4
Selenium (µg/L)	5	5	10.	<10
Silver (µg/L)	5	5	0.20	<0.20
Thallium (µg/L)	5	4	0.20	0.29
Zinc (µg/L)	12	12	20.	<20
pH ^(d)	12	12	NA	7.4

(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) Chlorine analysis was discontinued November 2021 after sampling indicated chlorine was not a pollutant of concern.

(d) The current permit specifies pH limits of 6–9 standard units.

gpd = gallons per day

NA = not applicable

µg/L = micrograms per liter



6.0 Groundwater Protection Program

PNNL does not currently have any requirements to monitor groundwater. PNNL Richland Campus groundwater monitoring was required up to March 2020 and earlier years for temperature and other parameters associated with the re-injection of groundwater from a ground-source heat pump system. Currently, no temperature monitoring or any other groundwater monitoring is required by the Washington State Department of Ecology. No groundwater monitoring or testing for PFAS chemicals has occurred or been required for PNNL facilities. An initial review of PNNL properties and activities was conducted and none were identified as having potential PFAS contamination.

PNNL is not required to have a Groundwater Protection Program.

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 American Society of Mechanical Engineers (ASME) 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).

An internal PNNL document, *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 EWTPG (formerly, 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 Quality Assurance Plan (QAP) has been developed to demonstrate how the EWTPG is meeting QA requirements specified in environmental regulations and permits; assist EM staff in identifying applicable requirements and procedures (i.e., workflows, work controls, or process lifecycles) that are delivered through the HDI standards-based management system; and to 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 Order 414.1D, so that identical requirement sections align. Sections 1–10 of the document discuss each of the 10 criteria in 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, reference standard material providers) were closely evaluated before contracts were awarded.

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.

Table 7.1. PNNL Effluent Management Quality Assurance Requirements Documents

Document Titles
<i>Effluent Management Quality Assurance Plan (EM-QA-01)</i>
<i>Quality Requirements for Air Chemical Emissions Management</i>
<i>Quality Requirements for Facility Effluent Management Planning</i>
<i>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)</i>
<i>Quality Requirements for Marine Sciences Laboratory Monitoring to National Pollutant Discharge Elimination System Permit WA 0040649</i>
<i>Quality Requirements for Radionuclide Air Emissions Sampling and Monitoring</i>
<i>Quality Requirements for Radionuclide Air Environmental Surveillance Monitoring</i>

Radiological environmental air monitoring activities were determined using the DQO process described in *EPA Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA 2006) for operations on the PNNL Richland Campus (Snyder et al. 2017) and PNNL Sequim Campus (Snyder et al. 2019). 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 EMP (Snyder et al. 2020) with its attachments—the *Sampling and Analysis Plan*, *Data Management Plan* and *Dose Assessment Guidance*—documents the environmental radioactive air monitoring program.

PNNL Richland Campus radioactive air emissions are permitted under RAEL-005, which was issued by the WDOH. PNNL-owned facilities in the 300 Area are also subject to the Hanford Site Air Operating Permit. Regulatory standards/bodies include *National Emissions Standards for Hazardous Air Pollutants* (NESHAP) ([40 CFR Part 61, Subpart H](#) and [WAC 246-247](#)), [WAC 173-480](#), and Facility Use Agreements. Radiological air emissions are monitored by several different means, including the analysis of air filters; calculations of potential releases that are based on radioactive inventory using 40 CFR Part 61, Appendix D, calculations; and using the recorded releases documented in the PNNL Radioactive Gas Inventory database.

Environmental air surveillance and ambient external dose surveillance were performed at the five particulate air monitoring stations associated with the PNNL Richland Campus. The environmental air surveillance meets the requirements of the RAEL-005. The program also collects baseline ambient external dose levels at the perimeter and background sampling stations (Appendix C); the PNNL Richland Campus currently has no significant quantities of external dose contributors. Dose monitoring is done using aluminum oxide dosimeters read by optically stimulated luminescence.

Potential PNNL Sequim Campus radioactive air emissions are permitted under the current RAEL and compliance is demonstrated through calculated emission rates using 40 CFR Part 61, Appendix D, calculations. The renewed PNNL Sequim Campus license (RAEL-014, Renewal 1) became effective on January 1, 2018, and is renewed every 5 years. This RAEL provides a permit for PNNL Sequim Campus radioactive air emissions as a single sitewide emission unit. The PNNL Sequim Campus DQO (Snyder et al. 2019) notes radioactive air emissions from operations at the campus do not require emission unit sampling or monitoring, or ambient surveillance under the RAEL-014, Renewal 1. Snyder et al. (2019) recommended that baseline radioactive air background surveillance be performed. No baseline radioactive air background data are currently available for the PNNL Sequim Campus or for the local area. Determination of site radiation background for ambient external dose and for particulate gross alpha and gross beta in air is, therefore, recommended. It is suggested that this sampling be performed at on-site locations. Sampling is acceptable at on-site locations because of the historical and continued minimal radiological operations at the PNNL Sequim 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. 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.

In lieu of monitoring, chemical air emissions are managed by complying with PNNL's air permits. Permits for nonradiological air emissions are issued by the BCAA for the PNNL Richland Campus and the ORCAA for the PNNL Sequim Campus. Applicable regulatory statutes include the CAA and NEPA. PNNL limits its chemical air emissions 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, etc.) 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 to generate nonradiological 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. These procedures are based on standards, regulatory requirements, and guidance produced by NESHAP, WAC, EPA, WDOH, and the American National Standards Institute/Health Physics Society (ANSI/HPS). 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. Requests for sample analysis are also a means of sample tracking and provide specific instructions for completing analyses of specific samples. QA program requirements in terms of sample receipt, handling, control, and identification of samples are integrated into the statement of work for subcontracted analytical laboratories.

Typically, samples are collected then analyzed in a laboratory. However, some water and wastewater 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, temperature, and conductivity) are completed by staff at both the PNNL Richland and Sequim Campuses using portable calibrated equipment (e.g., pH probe), approved standards, and controlled procedures based on EPA-approved methods or methods specified by the applicable regulatory agency.

7.3 Quality Assurance Analytical Results

Analyses are performed according to a statement of work or contract, which describes the activities necessary to assure that the analytical results are of high and verifiable quality. These activities include 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 EWTPG. Each analytical data package is validated prior to using and reporting the data. Data packages include the analytical results of quality control (QC) samples/analysis, which help determine the adequacy of the entire analysis. These QA requirements, which are disseminated to subcontractors, may include the analyses of laboratory method blanks to evaluate sources of contamination, laboratory duplicates to evaluate method precision, laboratory control samples/blank spike samples, and sometimes matrix spikes and/or surrogates to assess accuracy. A description of these QC terms is provided in Table 7.2. For cases where identified quality issues result in invalid data, the issues are documented, and corrective actions are taken.

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	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.

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 2021:

- Radiological air emission filter samples were analyzed by PNNL's Analytical Support Operations (ASO) laboratory located on the Hanford Site in the 325RPL Building.
- Ambient air filter samples were analyzed for radioactivity by GEL Laboratories, 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
 - Spectra Laboratories, Port Orchard, Washington.

Information about each laboratory is summarized below:

- The ASO laboratory analyzed all airborne filter samples for radioactivity according to criteria in their statements of work and contracts. 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 analysis samples and were analyzed for specific isotopes in addition to alpha and beta activity to assure quality control. ASO's QAP (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 staff and management to maintain a high level of analytical testing rigor, giving special attention to radiological safety and environmental protection. ASO performs assessments that address analytical instrument maintenance, checking data traceability and validity, undergoing independent DOE performance testing, and communicating results to the client. Any corrective actions are addressed by the ASO quality engineer and laboratory management.
- 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 optically stimulated luminescence technology, and providing dose results for the deployment period. 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. Control or background values were not subtracted from the PNNL Richland Campus value in Landauer-reported results, but these values are subtracted when dosimeter results are evaluated for reporting. The environmental dosimeter external dose reporting information is expected to follow the ANSI/HPS Standard N13.37-2014, Environmental Dosimetry—Criteria for System Design and Implementation (HPS 2019).
- GEL analyzed all particulate ambient air filters for radioactivity according to criteria in their 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 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).
- 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 2021. 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 undergo periodic inspection 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 laboratory is either accredited or currently listed on PNNL's Evaluated Supplier List. ALS Environmental and the in-house laboratory on the PNNL Sequim Campus also are accredited by the National Environmental Laboratory Accreditation Conference Institute (NELAP), which requires adherence to a uniform and robust laboratory program that has been implemented consistently nationwide. All wastewater and drinking water analyses are performed using approved CWA or SDWA methods specified by EPA in "Guidelines Establishing Test Procedures for the Analysis of Pollutants" (40 CFR Part 136) and "National Primary Drinking Water Regulations" (40 CFR Part 141). 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, holding times, sample containers, and sample preservation laboratory activities must meet regulatory requirements and are verified for each sample collected.

7.4 Interlaboratory 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 a laboratory accredited by ISO/IEC (International Organization for



Standardization/International Electrotechnical Commission) 17043, 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 provides samples of environmental media for assessing air filters, 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 2021, two studies—MAPEP-44 and MAPEP-45—were issued to participating laboratories; results are as follows:

- GEL participated in both MAPEP 44 and 45 performance evaluation studies as well as Multi-Media Radiochemistry Proficiency Testing (MRAD) studies 34 and 35 in 2021. MRAD is provided by ERA-Waters Corporation, which is also accredited to ISO 9001:2015 and ISO/IEC 17025:2017. For MAPEP-44, radiological filter results for gross alpha, beta, select gamma, and alpha spectroscopy results were acceptable or acceptable with warning (Zn-65 only). For MAPEP-45, radiological filter results for gross beta, select gamma, and alpha spectroscopy results were acceptable or acceptable with warning (Sr-90 only); however, gross alpha was unacceptable with GEL issuing a Corrective Action Report. For

MRAD-34, radiological filter results for gross beta, gamma, and select alpha spectroscopy samples were acceptable for MRAD-34; however, gross alpha was unacceptable with GEL issuing a Corrective Action Report. For MRAD-35, radiological filter results for gross alpha, gross beta, gamma, and select alpha spectroscopy samples were acceptable; however, U-234 was unacceptable with GEL issuing a Corrective Action Report. GEL reported U-234 by two methods; the "HASL 300 Method U-02 (28th Ed 1997)" was deemed acceptable, whereas the "ASTM C1345-08 (Mod 2008)" method was not acceptable. GEL uses the HASL 300 Method U-02 to analyze and report results for PNNL radiological air filters, so this was a non-issue for PNNL radiological air monitoring analyses. The DOE Consolidated Audit Program (DOECAP) Accreditation Body contractual auditing organization A2LA (American Association for Laboratory Accreditation) performed the 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. The latest certification, Certificate Number 2567.01, was originally authorized in July 2019, and prior to expiring on June 30, 2021, was reauthorized in June 2021 and expires in June 2023. GEL also maintained TNI National Environmental Laboratory Accreditation Program (NELAP) accreditation for 2021 with the state of Washington (Certificate Number: C780-21, which expires November 25, 2022).

- In 2021, the ASO 325RPL at PNNL participated in MAPEP-44 and MAPEP-45 testing studies. As mentioned in last year's PNNL Annual Site Environmental Report (Duncan et al. 2021), Sr-90 was the only constituent 325RPL reported for MAPEP-42 radiological filter analysis and for MAPEP-43 all of the constituents were reported for radiological filter analysis with the exception of Co-57 and Sr-90 due to a false positive result (Co-57) and quality control issues (Sr-90). Both issues were documented in internal discrepancy reports. Both Co-57 and Sr-90, along with Cs-134, Cs-137, Co-60, Mn-54, and Zn-65, were analyzed and submitted for MAPEP-44 testing with acceptable results for all radioisotopes. ASO did not report gross alpha, gross beta, Am-241, Pu-238, Pu-239/240, U-234, and U-238 for MAPEP-44; however, these constituents were reported in MAPEP-43 in 2020, all with acceptable results. For the MAPEP-45 study in 2021, gross alpha, gross beta, Am-241, Cs-134, Cs-137, Co-57, Co-60, Mn-54, Pu-238, Pu-239/240, Sr-90, U-234/233, U-238, and Zn-65 were reported, all with acceptable results except for gross alpha. The non-acceptable result for gross alpha was documented in an internal discrepancy report. It should be noted that ASO analyzes air filters for additional constituents, however, these analytes are not offered on the MAPEP studies. In addition to participating in performance testing, it should be noted that on a periodic basis, the ASO laboratory is audited relative to the requirements of the Hanford Analytical Services Quality Assurance Requirements Document (HASQARD) (DOE-RL 2014), so that it can remain on the Hanford Evaluated Suppliers List; the most recent audit was performed in October 2021.

The requirements for interlaboratory performance do not apply to dosimetry.

Participation in interlaboratory performance programs for the analysis of water and wastewater samples is not required pursuant to permits issued under the SDWA or CWA. PNNL considers the following standards in their review of commercial analytical laboratories for use: ISO/IEC Standard 17025 and Standard 17043.

- ISO/IEC 17025 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 8, 2022, at which time the scope of their accreditation will be re-evaluated. ALS also was accredited by Perry Johnson Laboratory Accreditation, Inc., as being certified to the ISO/IEC 17025:2017 standard, the DoD Environmental Laboratory Accreditation Program for ISO/IEC 17025:2017, and the DoD Quality Systems Manual Version 5.3 on

July 10, 2020; this accreditation expires on June 10, 2022. Spectra Labs and the Benton-Franklin Health District Laboratory also are accredited by the Washington State Department of Ecology to [WAC 173-50](#) ("Accreditation of Environmental Laboratories") and [WAC 246-290](#) ("Group A Public Water Supplies") criteria. These accreditations are renewed annually; Spectra Labs accreditation expires October 23, 2022, and the Benton-Franklin Health District accreditation expires August 23, 2022. The in-house laboratory on the PNNL Sequim Campus is nationally accredited by the New Jersey Department of Environmental Protection to perform certain analytical methods with TNI requirements until June 30, 2022, and with guidance from EPA QA/R-5, *EPA Quality Requirements for Quality Assurance Project Plans* (EPA 2001). The PNNL Sequim Campus maintained its accreditation with Washington State Department of Ecology, which is applicable until October 23, 2022. Implementation of the policies and requirements are specified in the *PNNL Marine Sciences Laboratory Quality Assurance Management Plan* (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

QA 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 2021, 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, 2009–2021



Table A.1. Plant Species Observed on the Undeveloped Upland Portions of the PNNL Richland Campus, 2009–2021

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class [2021] ^(b)
<i>Achillea millefolium</i>	common yarrow			
<i>Achnatherum hymenoides</i>	Indian ricegrass			
<i>Agoseris glauca</i>	pale agoseris			
<i>Agoseris grandiflora</i>	large-flowered agoseris			
<i>Agoseris heterophylla</i>	annual agoseris			
<i>Agropyron cristatum</i>	crested wheatgrass			
<i>Ailanthus altissima</i>	tree-of-heaven			C
<i>Allium schoenoprasum</i>	chives			
<i>Amaranthus albus</i>	white pigweed			
<i>Ambrosia acanthicarpa</i>	bur ragweed			
<i>Amsinckia lycopsoides</i>	tarweed fiddleneck			
<i>Amsinckia tessellata</i>	tessellate fiddleneck			
<i>Aphyllon corymbosum</i>	flat-topped broomrape			
<i>Artemisia campestris</i>	Pacific sagewort			
<i>Artemisia dracunculus</i>	tarragon			
<i>Artemisia ludoviciana</i>	prairie sage			
<i>Artemisia tridentata</i>	big sagebrush			
<i>Asclepias speciosa</i>	showy milkweed			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class [2021] ^(b)
<i>Asparagus officinalis</i>	garden asparagus			
<i>Astragalus caricinus</i>	buckwheat milkvetch			
<i>Avena sativa</i>	cultivated oats			
<i>Balsamorhiza careyana</i>	Carey's balsamroot			
<i>Bassia scoparia</i>	burning-bush			B
<i>Bromus tectorum</i>	cheatgrass			
<i>Calochortus macrocarpus</i>	sagebrush mariposa lily			
<i>Camissonia parvula</i>	small desertprimrose			
<i>Capsella bursa-pastoris</i>	shepherd's purse			
<i>Carex douglasii</i>	Douglas's sedge			
<i>Cenchrus longispinus</i>	bur-grass			C
<i>Centaurea diffusa</i>	diffuse knapweed			B
<i>Centaurea solstitialis</i>	yellow starthistle			B
<i>Cerastium fontanum</i>	common mouse-ear			
<i>Chaenactis douglasii</i>	hoary false yarrow			
<i>Chamaesyce serpyllifolia</i>	thymeleaf sandmat			
<i>Chenopodium album</i>	white goosefoot			
<i>Chenopodium leptophyllum</i>	slimleaf goosefoot			
<i>Chondrilla juncea</i>	skeletonweed			B
<i>Chorisporea tenella</i>	chorisporea			
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush			
<i>Cichorium intybus</i>	chicory			
<i>Cirsium arvense</i>	Canada thistle			C
<i>Clematis ligusticifolia</i>	western clematis			
<i>Comandra umbellata</i>	bastard toadflax			
<i>Convolvulus arvensis</i>	bindweed			C
<i>Conyza canadensis</i>	Canadian horseweed			
<i>Coreopsis tinctoria</i>	Columbia coreopsis			
<i>Crepis atriobarba</i>	slender hawksbeard			
<i>Cryptantha flaccida</i>	weak-stemmed cryptantha			
<i>Cryptantha fendleri</i>	Fendler's cryptantha			
<i>Cryptantha pterocarya</i>	winged cryptantha			
<i>Cymopterus terebinthinus</i>	turpentine spring parsley			
<i>Cynodon dactylon</i>	cynodon			
<i>Dalea ornata</i>	western prairie-clover			
<i>Delphinium nuttallianum</i>	upland larkspur			
<i>Descurainia pinnata</i>	western tansymustard			
<i>Descurainia sophia</i>	flixweed			
<i>Dieteria canescens</i>	hoary-aster			
<i>Draba nemorosa</i>	woodland draba			
<i>Draba verna</i>	spring Whitlow-grass			
<i>Elaeagnus angustifolia</i>	Russian olive			C

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class [2021] ^(b)
<i>Eleocharis</i> sp.	spike-rush			
<i>Elymus elymoides</i>	bottlebrush squirreltail			
<i>Elymus lanceolatus</i>	thickspike wheatgrass			
<i>Elymus violaceus</i>	Alaska wheatgrass			
<i>Epilobium brachycarpum</i>	tall annual willow-herb			
<i>Equisetum</i> sp.	horsetail			
<i>Ericameria nauseosa</i>	common rabbitbrush			
<i>Erigeron filifolius</i>	thread-leaf fleabane			
<i>Eriogonum niveum</i>	snow buckwheat			
<i>Eriogonum vimineum</i>	broom buckwheat			
<i>Erodium cicutarium</i>	redstem stork's bill			
<i>Erysimum asperum</i>	wallflower			
<i>Euphorbia glyptosperma</i>	ribseed sandmat			
<i>Euphorbia serpillifolia</i>	thymeleaf spurge			
<i>Fallopia convolvulus</i>	climbing bindweed			
<i>Fritillaria pudica</i>	yellow bell			
<i>Galium aparine</i>	cleavers			
<i>Gaillardia aristata</i>	blanket-flower			
<i>Gilia minutiflora</i>	small-flowered gilia			
<i>Gilia sinuata</i>	rosy gilia			
<i>Gratiola neglecta</i>	common American hedge-hyssop			
<i>Grayia spinosa</i>	hopsage			
<i>Greeneocharis circumscissa</i>	matted cryptantha			
<i>Grindelia hirsutula</i>	hairy gumweed			
<i>Gypsophila paniculata</i>	baby's-breath			C
<i>Hesperostipa comata</i>	needle-and-thread			
<i>Holosteum umbellatum</i>	jagged chickweed			
<i>Hordeum jubatum</i>	foxtail barley			
<i>Hymenopappus filifolius</i>	hymenopappus			
<i>Hypericum perforatum</i>	common St. John's-wort			C
<i>Iris missouriensis</i>	Rocky Mountain			
<i>Juniperus scopulorum</i>	Rocky Mountain juniper			
<i>Koeleria macrantha</i>	junegrass			
<i>Lactuca serriola</i>	prickly lettuce			
<i>Ladeania lanceolata</i>	lance-leaf scurf-pea			
<i>Lagophylla rammosissima</i>	hareleaf			
<i>Lamium amplexicaule</i>	common dead-nettle			
<i>Layia glandulosa</i>	tidytips			
<i>Lepidium draba</i>	heart-podded hoarycress			C
<i>Lepidium densiflorum</i>	common pepperweed			
<i>Lepidium latifolium</i>	broadleaf pepperweed			B
<i>Lepidium perfoliatum</i>	clasping pepperweed			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class [2021] ^(b)
<i>Leymus cinereus</i>	Great Basin wildrye			
<i>Linanthus pungens</i>	granite prickly-phlox			
<i>Logfia gallica</i>	daggerleaf cottonrose			
<i>Lomatium macrocarpum</i>	bigseed biscuitroot			
<i>Malus pumila</i>	cultivated apple			
<i>Malva neglecta</i>	common mallow			
<i>Marrubium vulgare</i>	horehound			
<i>Medicago lupulina</i>	black medick			
<i>Medicago sativa</i>	alfalfa			
<i>Melilotus officinalis</i>	common yellow sweet-clover			
<i>Mentha arvensis</i>	mint			
<i>Mentzelia albicaulis</i>	small-flowered mentzelia			
<i>Microsteris gracilis</i>	microsteris			
<i>Morus alba</i>	white mulberry			
<i>Narcissus pseudonarcissus</i>	common daffodil			
<i>Oenothera pallida</i>	pale evening primrose			
<i>Onopordum acanthium</i>	cotton thistle			B
<i>Opuntia polyacantha</i>	starvation pricklypear			
<i>Parthenocissus vitacea</i>	Virginia creeper			
<i>Phacelia hastata</i>	silverleaf phacelia			
<i>Phacelia linearis</i>	thread-leaf phacelia			
<i>Phlox longifolia</i>	longleaf phlox			
<i>Plantago lanceolata</i>	English plantain			
<i>Plantago patagonica</i>	Indian-wheat			
<i>Plectritis macrocera</i>	longhorn plectritis			
<i>Poa bulbosa</i>	bulbous bluegrass			
<i>Poa pratensis</i>	Kentucky bluegrass			
<i>Poa secunda</i>	Sandberg's bluegrass			
<i>Polemonium micranthum</i>	annual Jacob's ladder			
<i>Polygonum aviculare</i>	doorweed			
<i>Prunus virginiana</i>	chokecherry			
<i>Pseudognaphalium stramineum</i>	cottonbatting plant			
<i>Pseudoroegneria spicata</i>	bluebunch wheatgrass			
<i>Purshia tridentata</i>	bitterbrush			
<i>Rhaponticum repens</i>	hardheads (Russian knapweed)			B
<i>Ribes aureum</i>	golden currant			
<i>Robinia pseudoacacia</i>	black locust			
<i>Rosa woodsii</i>	rose			
<i>Rubus bifrons</i>	Himalayan blackberry			C
<i>Rumex salicifolius</i>	willow dock			
<i>Rumex venosus</i>	veiny dock			
<i>Salix exigua</i>	coyote willow			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class [2021] ^(b)
<i>Salsola tragus</i>	Russian thistle			
<i>Senecio vulgaris</i>	common groundsel			C
<i>Setaria pumila</i>	foxtail			
<i>Sisymbrium altissimum</i>	tall tumbled mustard			
<i>Sisymbrium loeselii</i>	Loesel tumbled mustard			
<i>Solidago lepida</i>	western Canada goldenrod			
<i>Solanum dulcamara</i>	climbing nightshade			
<i>Solanum triflorum</i>	cut-leaved nightshade			
<i>Sonchus arvensis</i>	sow-thistle			
<i>Sphaeralcea munroana</i>	Munro's globemallow			
<i>Sporobolus cryptandrus</i>	sand dropseed			
<i>Stephanomeria paniculata</i>	stiff-branched wirelettuce			
<i>Taraxacum officinale</i>	common dandelion			
<i>Toxicoscordion venenosum</i>	meadow death-camas			
<i>Thinopyrum intermedium</i>	intermediate wheatgrass			
<i>Tragopogon dubius</i>	yellow salsify			
<i>Tribulus terrestris</i>	puncturevine			B
<i>Trifolium repens</i>	white clover			
<i>Triteleia grandiflora</i>	large-flowered triteleia			
<i>Ulmus pumila</i>	Siberian elm			
<i>Ulmus americana</i>	American elm			
<i>Verbascum thapsus</i>	common mullein			
<i>Verbena bracteata</i>	bracted verbena			
<i>Veronica arvensis</i>	common speedwell			
<i>Veronica peregrina</i>	purslane speedwell			
<i>Vulpia microstachys</i>	small fescue			
<i>Vulpia octoflora</i>	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, WA. 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, 2009–2021

Species Name	Common Name	State Status[2021]	Federal Status
<i>Agelaius phoeniceus</i>	red-winged blackbird		
<i>Artemisiospiza nevadensis</i>	sagebrush sparrow	Candidate	
<i>Anas platyrhynchos</i>	mallard		
<i>Asio flammeus</i>	short-eared owl		
<i>Branta canadensis</i>	Canada goose		
<i>Buteo jamaicensis</i>	red-tailed hawk		
<i>Buteo swainsoni</i>	Swainson's hawk		
<i>Callipepla californica</i>	California quail		
<i>Carpodacus mexicanus</i>	house finch		
<i>Carduelis tristis</i>	American goldfinch		
<i>Charadrius vociferus</i>	killdeer		
<i>Chordeiles minor</i>	common nighthawk		
<i>Chondestes grammacus</i>	lark sparrow		
<i>Circus cyaneus</i>	northern harrier		
<i>Colaptes auratus</i>	northern flicker		
<i>Columbus livia</i>	rock pigeon		
<i>Corvus brachyrhynchos</i>	American crow		
<i>Corvus corax</i>	common raven		
<i>Eremophila alpestris</i>	horned lark		
<i>Euphagus cyanocephalus</i>	Brewer's blackbird		
<i>Haliaeetus leucocephalus</i>	bald eagle		
<i>Hirundo pyrrhonota</i>	cliff swallow		
<i>Hirundo rustica</i>	barn swallow		
<i>Icterus bullockii</i>	Bullock's oriole		
<i>Lanius ludovicianus</i>	loggerhead shrike	Candidate	
<i>Numenius americanus</i>	long-billed curlew		
<i>Pandion haliaetus</i>	osprey		
<i>Passer domesticus</i>	house sparrow		
<i>Phasianus colchicus</i>	ring-necked pheasant		
<i>Pica pica</i>	black-billed magpie		
<i>Riparia riparia</i>	bank swallow		
<i>Sayornis saya</i>	Say's phoebe		
<i>Sturnella neglecta</i>	western meadowlark		
<i>Sturnus vulgaris</i>	European starling		
<i>Tachycineta thalassina</i>	violet-green swallow		
<i>Turdus migratorius</i>	American robin		
<i>Tyrannus tyrannus</i>	eastern kingbird		
<i>Tyrannus verticalis</i>	western kingbird		
<i>Zenaidura macroura</i>	mourning dove		
<i>Zonotrichia leucophrys</i>	white-crowned sparrow		

Table A.3. Mammal Species Observed on the Undeveloped Upland Portions of the PNNL Richland Campus, 2009–2021

Species Name	Common Name	State Status (2021)	Federal Status
<i>Canis latrans</i>	coyote		
<i>Castor canadensis</i>	beaver		
<i>Cervus elaphus</i>	elk		
<i>Erithizon dorsatum</i>	porcupine		
<i>Lepus californicus</i>	black-tailed jackrabbit	Candidate	
<i>Odocoileus hemionus</i>	mule deer		
<i>Perognathus parvus</i>	Great Basin pocket mouse		
<i>Sylvilagus nutalli</i>	mountain cottontail		
<i>Taxidea taxus</i>	badger		
<i>Thomomys talpoides</i>	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 [2021] ^(b)
<i>Achillea millefolium</i>	common yarrow			
<i>Achnatherum hymenoides</i>	Indian ricegrass			
<i>Agropyron cristatum</i>	crested wheatgrass			
<i>Ailanthus altissima</i>	tree-of-heaven			C
<i>Allium schoenoprasum</i>	chives			
<i>Ambrosia acanthicarpa</i>	bur ragweed			
<i>Amsinckia lycopsoides</i>	tarweed fiddleneck			
<i>Apocynum cannabinum</i>	clasping-leaved dogbane			
<i>Artemisia campestris</i>	Pacific sagewort			
<i>Artemisia dracunculus</i>	tarragon			
<i>Artemisia ludoviciana</i>	prairie sage			
<i>Artemisia tridentata</i>	big sagebrush			
<i>Asclepias speciosa</i>	showy milkweed			
<i>Asparagus officinalis</i>	garden asparagus			
<i>Bromus tectorum</i>	cheatgrass			
<i>Centaurea diffusa</i>	diffuse knapweed			B
<i>Chondrilla juncea</i>	skeletonweed			B
<i>Chrysothamnus viscidiflorus</i>	green rabbitbrush			
<i>Cirsium arvense</i>	creeping thistle			C
<i>Clematis ligusticifolia</i>	western clematis			
<i>Convolvulus arvensis</i>	bind weed			C
<i>Conyza canadensis</i>	Canadian horseweed			
<i>Coreopsis tinctoria</i>	Columbia coreopsis			
<i>Descurainia pinnata</i>	western tansymustard			
<i>Descurainia sophia</i>	flixweed			
<i>Dieteria canescens</i>	hoary-aster			
<i>Eleocharis palustris</i>	common spike-rush			
<i>Elymus lanceolatus</i>	thickspike wheatgrass			
<i>Equisetum sp.</i>	horsetail			
<i>Ericameria nauseosa</i>	rubber rabbitbrush			
<i>Eriogonum niveum</i>	snow buckwheat			
<i>Eriogonum sp.</i>	buckwheat			
<i>Euphorbia glyptosperma</i>	ribseed sandmat			
<i>Euphorbia serpyllifolia</i>	thymeleaf sandmat			
<i>Gaillardia aristata</i>	blanket-flower			
<i>Galium sp.</i>	bedstraw			
<i>Hesperostipa comata</i>	needle-and-thread			
<i>Holosteum umbellatum</i>	jagged chickweed			
<i>Hypericum perforatum</i>	common St. John's-wort			C
<i>Iris missouriensis</i>	Rocky Mountain iris			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class [2021] ^(b)
<i>Lactuca serriola</i>	prickly lettuce			
<i>Ladeania lanceolata</i>	lance-leaf scurf-pea			
<i>Lepidium densiflorum</i>	common pepperweed			
<i>Lepidium draba</i>	heart-podded hoarycress			C
<i>Lepidium perfoliatum</i>	clasping pepperweed			
<i>Leymus cinereus</i>	Great Basin wildrye			
<i>Logfia gallica</i>	daggerleaf cottonrose			
<i>Acemispia americana</i>	Spanish-clover			
<i>Lupinus sericeus</i>	silky lupine			
<i>Medicago sativa</i>	alfalfa			
<i>Melilotus officinalis</i>	common yellow sweet-clover			
<i>Mentha piperita</i>	mint			
<i>Morus alba</i>	white mulberry			
<i>Oenothera pallida</i>	pale evening primrose			
<i>Parthenocissus vitacea</i>	Virginia creeper			
<i>Phalaris arundinacea</i>	reed canarygrass			C
<i>Plantago lanceolata</i>	English plantain			
<i>Plantago patagonica</i>	Indian-wheat			
<i>Poa bulbosa</i>	bulbous bluegrass			
<i>Poa compressa</i>	Canada bluegrass			
<i>Poa secunda</i>	Sandberg's bluegrass			
<i>Prunus virginiana</i>	chokecherry			
<i>Purshia tridentata</i>	Antelope-brush			
<i>Rhaponticum repens</i>	hardheads (Russian knapweed)			B
<i>Rhus glabra</i>	smooth sumac			
<i>Ribes aureum</i>	golden currant			
<i>Robinia pseudoacacia</i>	black locust			
<i>Rosa woodsii</i>	rose			
<i>Rubus bifrons</i>	Himalayan blackberry			C
<i>Rumex crispus</i>	curly dock			
<i>Rumex patientia</i>	patience dock			
<i>Rumex salicifolius</i>	willow dock			
<i>Rumex venosus</i>	veiny dock			
<i>Salix exigua</i>	coyote willow			
<i>Salsola tragus</i>	Russian thistle			
<i>Sisymbrium altissimum</i>	tall tumbled mustard			
<i>Solidago lepida</i>	western Canada goldenrod			
<i>Solanum dulcamara</i>	climbing nightshade			
<i>Sphaeralcea munroana</i>	Munro's globemallow			
<i>Sporobolus cryptandrus</i>	sand dropseed			
<i>Stephanomeria paniculata</i>	stiff-branched wirelettuce			
<i>Taraxacum officinale</i>	common dandelion			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class [2021] ^(b)
<i>Tragopogon dubius</i>	yellow salsify			
<i>Ulmus americana</i>	American elm			
<i>Verbascum thapsus</i>	common mullein			
<i>Vicia cracca</i>	bird vetch			
<i>Xanthium strumarium</i>	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, WA. 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.

Field surveys in the riparian zone have not been conducted since 2018.

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
<i>Actitis macularius</i>	spotted sandpiper		
<i>Agelaius phoeniceus</i>	red-winged blackbird		
<i>Anas platyrhynchos</i>	mallard		
<i>Ardea herodias</i>	great blue heron		
<i>Branta canadensis</i>	Canada goose		
<i>Bubo virginianus</i>	great-horned owl		
<i>Calidris bairdii</i>	Baird's sandpiper		
<i>Calidris mauri</i>	western sandpiper		
<i>Callipepla californica</i>	California quail		
<i>Ardea alba</i>	great egret		
<i>Columba livia</i>	rock pigeon		
<i>Corvus corax</i>	common raven		
<i>Icterus bullockii</i>	Bullock's oriole		
<i>Larus californicus</i>	California gull		
<i>Megaceryle alcyon</i>	belted kingfisher		
<i>Melospiza lincolni</i>	Lincoln's sparrow		
<i>Melospiza melodia</i>	song sparrow		
<i>Mergus merganser</i>	common merganser		
<i>Nycticorax nycticorax</i>	black-crowned night heron		
<i>Pandion halaetus</i>	osprey		
<i>Pelecanus erythrorhynchos</i>	American white pelican	Threatened	
<i>Phalacrocorax auritus</i>	double-crested cormorant		
<i>Pica pica</i>	black-billed magpie		
<i>Riparia riparia</i>	bank swallow		
<i>Sturnus vulgaris</i>	European starling		
<i>Tyrannus tyrannus</i>	eastern kingbird		
<i>Tyrannus verticalis</i>	western kingbird		
<i>Turdus migratorius</i>	American robin		
<i>Zenaida macroura</i>	mourning dove		
Field surveys in the riparian zone have not been conducted since 2018.			

Table A.6. Mammal Species Observed in the Riparian Area of the PNNL Richland Campus in 2015 and 2017–2018

Species Name	Common Name	State Status	Federal Status
<i>Canis latrans</i>	coyote		
<i>Castor canadensis</i>	American beaver		
<i>Erithizon dorsatum</i>	porcupine		
<i>Odocoileus hemionus</i>	mule deer		
<i>Sciurus niger</i>	eastern fox squirrel		
Field surveys in the riparian zone have not been conducted since 2018.			

Appendix B

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



Only birds were surveyed in CY 2021 at 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)
<i>Abies grandis</i>	grand fir			
<i>Abronia latifolia</i>	yellow sand verbena			
<i>Acer circinatum</i>	vine maple			
<i>Acer glabrum</i>	Rocky Mountain maple			
<i>Acer macrophyllum</i>	bigleaf maple			
<i>Achillea millefolium</i>	common yarrow			
<i>Agropyron repens</i>	quackgrass			
<i>Alnus rubra</i>	red alder			
<i>Ambrosia chamissonis</i>	silver bursage			
<i>Amelanchier alnifolia</i>	Saskatoon serviceberry			
<i>Anaphalis margaritacea</i>	pearly-everlasting			
<i>Arbutus menziesii</i>	madrone			
<i>Arctostaphylos uva-ursi</i>	kinnikinnick			
<i>Artemisia suksdorfii</i>	Suksdorf's sagebrush			
<i>Atriplex patula</i>	spear orache			
<i>Avena</i> sp.	oat			
<i>Bellis perennis</i>	daisy			
<i>Berberis aquifolium</i>	shining Oregon-grape			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class ^(b)
<i>Berberis nervosa</i>	dull Oregon-grape			
<i>Brassica rapa</i>	field mustard			
<i>Cakile edentula</i>	American searocket			
<i>Calystegia soldanella</i>	beach morning-glory			
<i>Capsella bursa-pastoris</i>	shepherd's-purse			
<i>Carex</i> sp.	sedge			
<i>Castilleja hispida</i>	harsh Indian-paintbrush			
<i>Cerastium arvense</i>	field chickweed			
<i>Chamaenerion angustifolium</i>	fireweed			
<i>Chenopodium album</i>	white goosefoot			
<i>Cirsium arvense</i>	creeping thistle			C
<i>Cirsium remotifolium</i>	Pacific fringed thistle			
<i>Cirsium vulgare</i>	bull thistle			
<i>Claytonia perfoliata</i>	miner's lettuce			
<i>Collinsia parviflora</i>	small-flowered blue-eyed Mary			
<i>Conium maculatum</i>	poison-hemlock			B
<i>Convolvulus arvensis</i>	small bindweed			
<i>Cornus stolonifera</i>	red-osier dogwood			
<i>Corylus cornuta</i> var. <i>californica</i>	beaked hazelnut			
<i>Crataegus douglasii</i>	Douglas's hawthorne			
<i>Crataegus monogyna</i>	1-seed hawthorn			C
<i>Crepis capillaris</i>	smooth hawksbeard			
<i>Cuscuta pacifica</i>	Pacific salt marsh dodder			
<i>Cytisus scoparius</i>	Scot's broom			B
<i>Dactylis glomerata</i>	orchard-grass			
<i>Danthonia intermedia</i>	timber oatgrass			
<i>Delphinium</i> sp.	larkspur			
<i>Deschampsia caespitosa</i>	tufted hairgrass			
<i>Dipsacus sylvestris</i>	teasel			C
<i>Distichlis spicata</i>	saltgrass			
<i>Draba verna</i>	Whitlow-grass			
<i>Elymus glaucus</i>	blue wildrye			
<i>Elymus mollis</i>	American dunegrass			
<i>Epilobium ciliatum</i>	common willow-herb			
<i>Epilobium minutum</i>	small-flowered willow-herb			
<i>Equisetum arvense</i>	common horsetail			
<i>Equisetum hyemale</i>	common scouring-rush			
<i>Erodium cicutarium</i>	redstem stork's bill			
<i>Eschscholzia californica</i>	poppy			
<i>Fragaria virginiana</i>	mountain strawberry			
<i>Fritillaria affinis</i>	checker lily			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class ^(b)
<i>Galium aparine</i>	stickywilly			
<i>Galium triflorum</i>	sweetscented bedstraw			
<i>Gaultheria shallon</i>	salal			
<i>Geranium molle</i>	dovefoot geranium			
<i>Glehnia leiocarpa</i>	glehnia			
<i>Grindelia integrifolia</i>	Puget Sound gumweed			
<i>Hedera helix</i>	English ivy			
<i>Heracleum maximum</i>	common cow-parsnip			
<i>Hieraceum</i> sp.	hawkweed			
<i>Holodiscus discolor</i>	oceanspray			
<i>Hordeum brachyanterum</i>	meadow barley			
<i>Hypericum scouleri</i>	western St. John's-wort			
<i>Hypochaeris radicata</i>	hairy cat's ear			C
<i>Ilex aquifolium</i>	holly			M
<i>Juncus</i> sp.	rush			
<i>Lathyrus japonicus</i>	sea peavine			
<i>Lathyrus polyphyllus</i>	leafy peavine			
<i>Lepidium densiflorum</i>	common pepperweed			
<i>Leucanthemum vulgare</i>	oxeye-daisy			C
<i>Linnaea borealis</i>	twinline			
<i>Lomatium nudicaule</i>	bare-stemmed biscuitroot			
<i>Lonicera ciliosa</i>	orange honeysuckle			
<i>Lonicera hispidula</i>	California honeysuckle			
<i>Lupinus</i> sp.	lupine			
<i>Lysichiton americanus</i>	skunk cabbage			
<i>Lysimachia latifolia</i>	western starflower			
<i>Maianthemum dilatatum</i>	false lily-of-the-valley			
<i>Maianthemum racemosum</i> ssp. <i>amplexicaule</i>	large false Solomon's seal			
<i>Malus fusca</i>	Oregon crabapple			
<i>Matricaria discoidea</i>	pineapple weed			
<i>Medicago lupulina</i>	black medick			
<i>Mycelis muralis</i>	mycelis			
<i>Myosotis laxa</i>	small-flowered forget-me-not			
<i>Oemleria cerasiformis</i>	Indian plum			
<i>Osmorhiza berteroi</i>	sweet-cicely			
<i>Petasites frigidus</i>	sweet coltsfoot			
<i>Physocarpus capitatus</i>	Pacific ninebark			
<i>Plantago lanceolata</i>	English plantain			
<i>Plantago major</i>	common plantain			
<i>Plantago maritima</i>	sea tongue			
<i>Plectritis congesta</i>	sea blush			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class ^(b)
<i>Polygonum paronychia</i>	black knotweed			
<i>Polystichum munitum</i>	western swordfern			
<i>Populus trichocarpa</i>	black cottonwood			
<i>Potentilla anserina</i>	cinquefoil			
<i>Prunella vulgaris</i>	self-heal			
<i>Prunus emarginata</i>	bitter cherry			
<i>Prunus laurocerasus</i>	cherry laurel			
<i>Pseudotsuga menziesii</i>	Douglas fir			
<i>Pteridium aquilinum</i>	bracken fern			
<i>Ranunculus repens</i>	creeping buttercup			
<i>Ranunculus uncinatus</i>	little buttercup			
<i>Ribes divaricatum</i>	straggly gooseberry			
<i>Ribes sanguineum</i>	redflower currant			
<i>Rosa gymnocarpa</i>	little wild rose			
<i>Rosa nutkana</i>	Nootka rose			
<i>Rubus bifrons</i>	Himalayan blackberry			C
<i>Rubus leucodermis</i>	blackcap			
<i>Rubus nutkanus</i>	thimbleberry			
<i>Rubus ursinus</i>	Pacific blackberry			
<i>Rumex acetosella</i>	sheep sorrel			
<i>Rumex crispus</i>	curly dock			
<i>Rumex occidentalis</i>	western dock			
<i>Salicornia depressa</i>	low glasswort			
<i>Salix sitchensis</i>	Sitka willow			
<i>Sambucus racemosa</i>	red elderberry			
<i>Senecio vulgaris</i>	old-man-in-the-spring			
<i>Senecio sylvaticus</i>	wood groundsel			
<i>Sonchus asper</i>	prickly sow-thistle			
<i>Spiraea douglasii</i>	spirea			
<i>Stellaria media</i>	common chickweed			
<i>Struthiopteris spicant</i>	hard fern			
<i>Symphoricarpos albus</i>	common snowberry			
<i>Taraxacum officinale</i>	common dandelion			
<i>Tellima grandiflora</i>	fringecup			
<i>Thuja plicata</i>	western red cedar			
<i>Tolmiea menziesii</i>	youth-on-age			
<i>Tragopogon dubius</i>	yellow salsify			
<i>Trifolium dubium</i>	suckling clover			
<i>Trifolium pratense</i>	red clover			
<i>Trifolium repens</i>	white clover			
<i>Triglochin maritima</i>	seaside arrow-grass			
<i>Triphysaria pusilla</i>	dwarf owl-clover			
<i>Tsuga heterophylla</i>	western hemlock			

Species Name ^(a)	Common Name ^(a)	State Status	Federal Status	Noxious Weed Class ^(b)
<i>Urtica dioica</i>	stinging nettle			
<i>Vicia americana</i>	American vetch			
<i>Vicia cracca</i>	bird vetch			
<i>Vicia nigricans</i>	giant vetch			
<i>Vicia sativa</i>	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, WA. 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, 2010–2021

Species Name	Common Name	State Status	Federal Status
<i>Accipiter cooperii</i>	Cooper's hawk		
<i>Agelaius phoeniceus</i>	red-winged blackbird		
<i>Accipiter striatus</i>	sharp-shinned hawk		
<i>Aechmophorus occidentalis</i>	western grebe	Candidate	
<i>Agelaius phoeniceus</i>	red-winged blackbird		
<i>Anas platyrhynchos</i>	mallard		
<i>Anthus rubescens</i>	American pipit		
<i>Ardea herodias</i>	great blue heron		
<i>Aythya marila</i>	greater scaup		
<i>Branta bernicla</i>	brandt		
<i>Branta canadensis</i>	Canada goose		
<i>Bubo virginianus</i>	great-horned owl		
<i>Bucephala albeola</i>	bufflehead		
<i>Bucephala clangula</i>	common goldeneye		
<i>Buteo jamaicensis</i>	red-tailed hawk		
<i>Calidris alpina</i>	dunlin		
<i>Callipepla californica</i>	California quail		
<i>Calypte anna</i>	Anna's hummingbird		
<i>Cardellina pusilla</i>	Wilson's warbler		
<i>Cathartes aura</i>	turkey vulture		
<i>Catharus ustulatus</i>	Swainson's thrush		
<i>Catharus guttatus</i>	hermit thrush		
<i>Cephus columba</i>	pigeon guillemot		
<i>Cerorhinca monocerata</i>	rhinoceros auklet		
<i>Certhia americana</i>	brown creeper		
<i>Charadrius vociferus</i>	killdeer		
<i>Circus hudsonius</i>	northern harrier		
<i>Cistothorus palustris</i>	marsh wren		
<i>Coccothraustes vespertinus</i>	evening grosbeak		
<i>Clangula hyemalis</i>	long-tailed duck		
<i>Colaptes auratus</i>	northern flicker		
<i>Columba livia</i>	rock dove (pigeon)		
<i>Contopus cooperi</i>	olive-sided flycatcher		
<i>Corvus brachyrhynchos</i>	American crow		
<i>Corvus corax</i>	common raven		
<i>Cyanocitta stelleri</i>	Steller's jay		
<i>Dryobates pubescens</i>	downy woodpecker		
<i>Dryobates villosus</i>	hairy woodpecker		
<i>Empidonax difficilis</i>	Pacific-slope flycatcher		
<i>Empidonax hammondi</i>	Hammond's flycatcher		
<i>Euphagus cyanocephalus</i>	Brewer's blackbird		
<i>Falco peregrinus</i>	peregrine falcon		
<i>Haematopus bachmani</i>	black oystercatcher		

Species Name	Common Name	State Status	Federal Status
<i>Haemorhous mexicanus</i>	house finch		
<i>Haliaeetus leucocephalus</i>	bald eagle		
<i>Hirundo rustica</i>	barn swallow		
<i>Histrionicus histrionicus</i>	harlequin duck		
<i>Hydroprogne caspia</i>	Caspian tern		
<i>Ixoreus naevius</i>	varied thrush		
<i>Junco hyemalis</i>	dark-eyed junco		
<i>Larus glaucescens</i>	glaucus-winged gull		
<i>Larus glaucescens</i> x <i>L. occidentalis</i>	Olympic gull		
<i>Larus occidentalis</i>	western gull		
<i>Leiothlypis celata</i>	orange-crowned warbler		
<i>Lophodytes cucullatus</i>	hooded merganser		
<i>Megaceryle alcyon</i>	belted kingfisher		
<i>Melanitta deglandi</i>	white-winged scoter		
<i>Melospiza lincolnii</i>	Lincoln's sparrow		
<i>Melospiza melodia</i>	song sparrow		
<i>Mergus merganser</i>	common merganser		
<i>Mergus serrator</i>	red-breasted merganser		
<i>Molothrus ater</i>	brown-headed cowbird		
<i>Passerculus sandwichensis</i>	savannah sparrow		
<i>Passerella iliaca</i>	fox sparrow		
<i>Patagioenas fasciata</i>	band-tailed pigeon		
<i>Petrochelidon pyrrhonota</i>	cliff swallow		
<i>Phalacrocorax auritus</i>	double-crested cormorant		
<i>Phalacrocorax pelagicus</i>	pelagic cormorant		
<i>Phalacrocorax penicillatus</i>	Brant's cormorant		
<i>Pheucticus melanocephalus</i>	black-headed grosbeak		
<i>Pipilo maculatus</i>	spotted towhee		
<i>Piranga ludoviciana</i>	western tanager		
<i>Podiceps nigricollis</i>	eared grebe		
<i>Podilymbus podiceps</i>	pied-billed grebe		
<i>Poecile atricapillus</i>	black-capped chickadee		
<i>Poecile rufescens</i>	chestnut-backed chickadee		
<i>Progne subis</i>	purple martin		
<i>Psaltirparus minimus</i>	bushtit		
<i>Regulus calendula</i>	ruby-crowned kinglet		
<i>Regulus satrapa</i>	golden-crowned kinglet		
<i>Selasphorus rufus</i>	rufous hummingbird		
<i>Setophaga coronata</i>	yellow-rumped warbler		
<i>Setophaga petechia</i>	yellow warbler		
<i>Setophaga townsendi</i>	Townsend's warbler		
<i>Sitta canadensis</i>	red-breasted nuthatch		
<i>Sphyrapicus ruber</i>	red-breasted sapsucker		
<i>Spinus pinus</i>	pine siskin		
<i>Spinus tristis</i>	American goldfinch		
<i>Stelgidopteryx serripennis</i>	northern rough-winged swallow		

Species Name	Common Name	State Status	Federal Status
<i>Sterna caspia</i>	Caspian tern		
<i>Strix varia</i>	barred owl		
<i>Sturnus vulgaris</i>	European starling		
<i>Tachycineta bicolor</i>	tree swallow		
<i>Tachycineta thalassina</i>	violet-green swallow		
<i>Thryomanes bewickii</i>	Bewick's wren		
<i>Troglodytes pacificus</i>	Pacific wren		
<i>Turdus migratorius</i>	American robin		
<i>Zenaida macroura</i>	mourning dove		
<i>Zonotrichia leucophrys</i>	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
<i>Anaxyrus boreas</i>	western toad		
<i>Canis latrans</i>	coyote		
<i>Odocoileus hemionus</i>	black-tailed deer		
<i>Rana aurora</i>	northern red-legged frog		
<i>Sorex</i> sp.	shrew		
<i>Tamiasciurus douglasii</i>	Douglas squirrel		
<i>Taricha granulosa</i>	rough-skinned newt		

Appendix C

Ambient External Dose Surveillance Results CY 2021



Ambient levels of external dose from beta, gamma, and X-ray sources are monitored on a quarterly basis at the five particulate air monitoring stations associated with the PNNL Richland Campus. No ambient external dose surveillance is yet conducted at the PNNL Sequim Campus. The program establishes baseline ambient external dose levels at four PNNL Richland stations and at the background (PNL-5) station. Definitions for the ambient air external dose sampling are in Table C.1; dose surveillance results are in Table C.2; and normalized quarterly external dose results are in Table C.3.

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-YY HH:MM [24 hr])	Date and time when dosimeter sampling started (time field is truncated in Table C.2).
Sample Date Time	date (DD-MMM-YY 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 2021 PNNL Richland Campus

Sample Site Name	Vendor Location ID	Sample Method	Sample Date Time On	Sample Date Time	Quarter	Value Reported (mrem)
PNL-1	00119	OSLD	30 Dec 2020	24 Mar 2021	Q1	25
PNL-2	00120	OSLD	30 Dec 2020	24 Mar 2021	Q1	28
PNL-3	00121	OSLD	30 Dec 2020	24 Mar 2021	Q1	24
PNL-4	00122	OSLD	30 Dec 2020	24 Mar 2021	Q1	26
PNL-5	00123	OSLD	30 Dec 2020	24 Mar 2021	Q1	30
PNL-T	00124	OSLD	30 Dec 2020	24 Mar 2021	Q1	22
Transit Control	00125	OSLD	30 Dec 2020	24 Mar 2021	Q1	22
PNL-1	00126	OSLD	24 Mar 2021	30 Jun 2021	Q2	30
PNL-2	00127	OSLD	24 Mar 2021	30 Jun 2021	Q2	31
PNL-3	00128	OSLD	24 Mar 2021	30 Jun 2021	Q2	28
PNL-4	00129	OSLD	24 Mar 2021	30 Jun 2021	Q2	27
PNL-5	00130	OSLD	24 Mar 2021	30 Jun 2021	Q2	31
PNL-T	00131	OSLD	24 Mar 2021	30 Jun 2021	Q2	21
Transit Control	00132	OSLD	24 Mar 2021	30 Jun 2021	Q2	23
PNL-1	00133	OSLD	30 Jun 2021	22 Sep 2021	Q3	24
PNL-2	00134	OSLD	30 Jun 2021	22 Sep 2021	Q3	24
PNL-3	00135	OSLD	30 Jun 2021	22 Sep 2021	Q3	26
PNL-4	00136	OSLD	30 Jun 2021	22 Sep 2021	Q3	22
PNL-5	00137	OSLD	30 Jun 2021	22 Sep 2021	Q3	30
PNL-T	00138	OSLD	30 Jun 2021	22 Sep 2021	Q3	16
Transit Control	00139	OSLD	30 Jun 2021	22 Sep 2021	Q3	18
PNL-1	00140	OSLD	22 Sep 2021	29 Dec 2021	Q4	27
PNL-2	00141	OSLD	22 Sep 2021	29 Dec 2021	Q4	28
PNL-3	00142	OSLD	22 Sep 2021	29 Dec 2021	Q4	27
PNL-4	00143	OSLD	22 Sep 2021	29 Dec 2021	Q4	28
PNL-5	00144	OSLD	22 Sep 2021	29 Dec 2021	Q4	28
PNL-T	00145	OSLD	22 Sep 2021	29 Dec 2021	Q4	19
Transit Control	00146	OSLD	22 Sep 2021	29 Dec 2021	Q4	19

OSLD = optically stimulated luminescence dosimeter.

Table C.3. 2021 PNNL Richland Campus Ambient External Dose Calculated for ANSI/HPS N13.37-2014 (HPS 2019) 91-d Normalized Quarters

2021 91-d Normalized Quarter Dose	PNL-1	PNL-2	PNL-3	PNL-4	PNL-5 ^(a)
Normalized Q1 (mrem/Q)	3.25	6.50	2.17	4.33	8.67
Normalized Q2 (mrem/Q)	6.51	7.44	4.65	3.72	7.44
Normalized Q3 (mrem/Q)	6.49	6.49	8.65	4.32	12.97
Normalized Q4 (mrem/Q)	7.43	8.35	7.43	8.35	8.35
Total (mrem/yr)	23.7	28.8	22.9	20.7	37.4
(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



The information in this appendix 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 are provided 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) ($1 \times 10^4 \text{ m}^2$)
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) ($1 \times 10^{-2} \text{ m}$)	Mass	
ft	foot (feet)	g	gram(s)
in.	inch(es)	kg	kilogram(s) ($1 \times 10^3 \text{ g}$)
km	kilometer(s) ($1 \times 10^3 \text{ m}$)	mg	milligram(s) ($1 \times 10^{-3} \text{ g}$)
m	meter(s)	μg	microgram(s) ($1 \times 10^{-6} \text{ g}$)
mi	mile(s)	lb	pound(s)
mm	millimeter(s) ($1 \times 10^{-3} \text{ m}$)	Time	
μm	micrometer(s) ($1 \times 10^{-6} \text{ m}$)	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)
$\mu\text{rem/hr}$	microrem per hour	L	liter(s)
Temperature		m^3	cubic meter(s)
$^{\circ}\text{C}$	degrees Celsius	mL	milliliter(s) ($1 \times 10^{-3} \text{ L}$)
$^{\circ}\text{F}$	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	$(^{\circ}\text{C} \times 9/5) + 32$	°F	°F	$(^{\circ}\text{F} - 32) \div 9/5$	°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)		

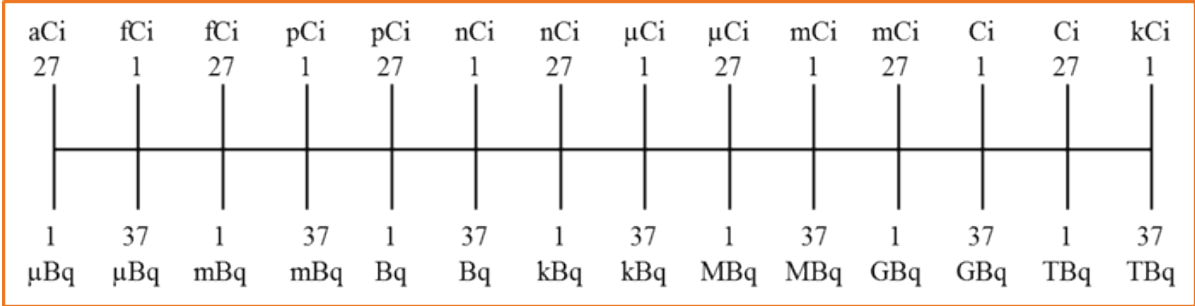


Figure D.1. Radioactivity Units, Curies to Becquerels

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 1 mrem (0.01 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, substituting Gy for Sv and substituting rad for rem in the figure.

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

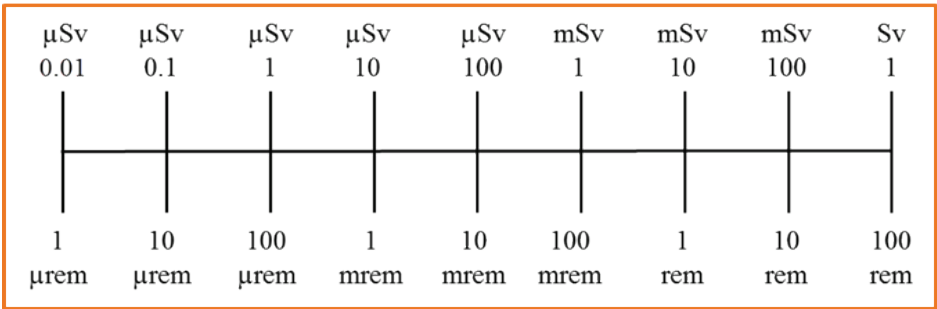


Figure D.2. Radiological Dose Units, Sieverts to Rem

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)

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

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
²⁶ Al	aluminum-26	7.17×10^5 yr	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	312.2 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	271.7 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	243.9 d	²³² Th	thorium-232	1.40×10^{10} yr
⁸² Br	bromine-82	35.282 h	U or uranium	natural uranium	$\sim 4.5 \times 10^9$ ^(b) yr
^{83m} Kr	krypton-83m	1.83 h	²³² U	uranium-232	68.9 yr
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	106.63 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

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
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



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* (3 mSv) 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 whole body 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.

essential fish habitat – Waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.

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 4, 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-rem = 0.01 person-Sv.

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 4, 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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