PNNL-22342-11

Pacific Northwest
NATIONAL LABORATORY

Department of Energy – Office of Science
Pacific Northwest National Laboratory

PNNL-Sequim Campus Radionuclide Air Emissions Report for Calendar Year 2022

SF Snyder
SW Thompson
JM Barnett

May 2023

U.S. DEPARTMENT OF ENERGY

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under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

The U.S. Department of Energy Office of Science Pacific Northwest Site Office has oversight and stewardship duties associated with the Pacific Northwest National Laboratory (PNNL) Sequim Campus.[1] Facility operations include radiological operations with the potential to emit low levels of radioactive materials.

This report is prepared to document compliance with the Code of Federal Regulations, Title 40, Protection of the Environment, Part 61, *National Emission Standards for Hazardous Air Pollutants*, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities" and Washington Administrative Code Chapter 246-247, *Radiation Protection–Air Emissions*. Compliance is determined by comparing the estimated effective dose equivalent (EDE) to the maximally exposed individual (MEI) with the 10 millirem per year (mrem/yr) U.S. Environmental Protection Agency (EPA) standard. The PNNL-Sequim Campus has only fugitive emissions sources. Despite the fact that the regulations are intended for application to point source emissions, fugitive emissions are included with regard to complying with the EPA standard.

The EDE to the PNNL-Sequim Campus MEI due to routine operations in 2022 was 7.5E-07 mrem (7.5E-09 mSv). No nonroutine emissions occurred in 2022. The PNNL-Sequim Campus is in compliance with the federal and state 10 mrem/yr standard.

For further information concerning this report, you may contact Thomas M. McDermott, U.S. Department of Energy, Pacific Northwest Site Office, by telephone at (509) 372 4675 or by email at tom.mcdermott@science.doe.gov.

[1] Cover photo: Eelgrass Tanks at Puget Sound. Researchers are growing eelgrass, Zostera marina, for restoration of critical habitat around Puget Sound. 2018. Andrea Starr | Pacific Northwest National Laboratory.

CERTIFICATION OF PNNL-22342-11

DOE-SC
Pacific Northwest National Laboratory
Sequim Campus
Radionuclide Air Emissions Report
Calendar Year 2022

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein and, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. See, 18 U.S.C. 1001. [verbatim from 40 CFR 61, Subpart H, 61.94(b)(9)]

JULIE TURNER Digitally signed by JULIE TURNER
Date: 2023.05.17 17:55:40 -07'00'

Julie K. Turner, Acting Manager
U.S. Department of Energy
Pacific Northwest Site Office

Date

Acronyms and Abbreviations

BMI	Battelle Memorial Institute
CFR	Code of Federal Regulations
Ci	curie
CY	Calendar Year
DOE	U.S. Department of Energy
DOE-SC	U.S. Department of Energy, Office of Science
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
Major	a radioactive point source having a radiological dose potential of greater than 0.1 mrem/yr EDE, based on emissions that would result if all pollution-control equipment did not exist, but facility operations were otherwise normal
MEI	Maximally Exposed Individual
Minor	a radioactive point source having a radiological dose potential of less than or equal to 0.1 mrem/yr EDE, based on emissions that would result if all pollution-control equipment did not exist, but facility operations were otherwise normal
mrem	millirem [i.e., 1×10^{-3} rem]
MSL	Marine Sciences Laboratory
mSv	millisievert
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOC	Notice of Construction
PNNL	Pacific Northwest National Laboratory
PTE	Potential-to-Emit
RAEL	Radioactive Air Emissions License
rem	roentgen equivalent man
UDF	Unit-release Dose Factor
WAC	Washington Administrative Code
WDOH	Washington State Department of Health

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1.0 Introduction

The Pacific Northwest National Laboratory Sequim Campus (PNNL-Sequim Campus) is located on the coast of Washington State's Olympic Peninsula (Figure 1.1). The Pacific Northwest Site Office of the U.S. Department of Energy (DOE) Office of Science oversees PNNL-Sequim Campus activities through an exclusive use contract with Battelle Memorial Institute (BMI). The PNNL-Sequim Campus is DOE's only marine research laboratory.

This radiological air emissions report meets the Washington Department of Health (WDOH) requirements for radiological National Emission Standards for Hazardous Air Pollutants (NESHAP) compliance reporting for the activities at the Campus for calendar year (CY) 2022. Site air effluent emissions are governed under WDOH Radioactive Air Emissions License (RAEL)-014, Renewal 1. Compared to the prior year, radiological laboratory activities have not substantially changed. Campus on-site activities were reduced in March 2020 through 2021, due to the COVID-19 pandemic. On-site radiological operations are generally considered at their new normal levels around mid-2022. This pandemic response did not impact the considerations or calculations for this compliance report, largely as a consequence of the low level of radiological operations at the site. PNNL staff conducted a campaign to minimize unneeded radioactive materials at the PNNL-Sequim Campus during 2021, which reduced the 2022 inventory and dose estimates, compared to prior years.

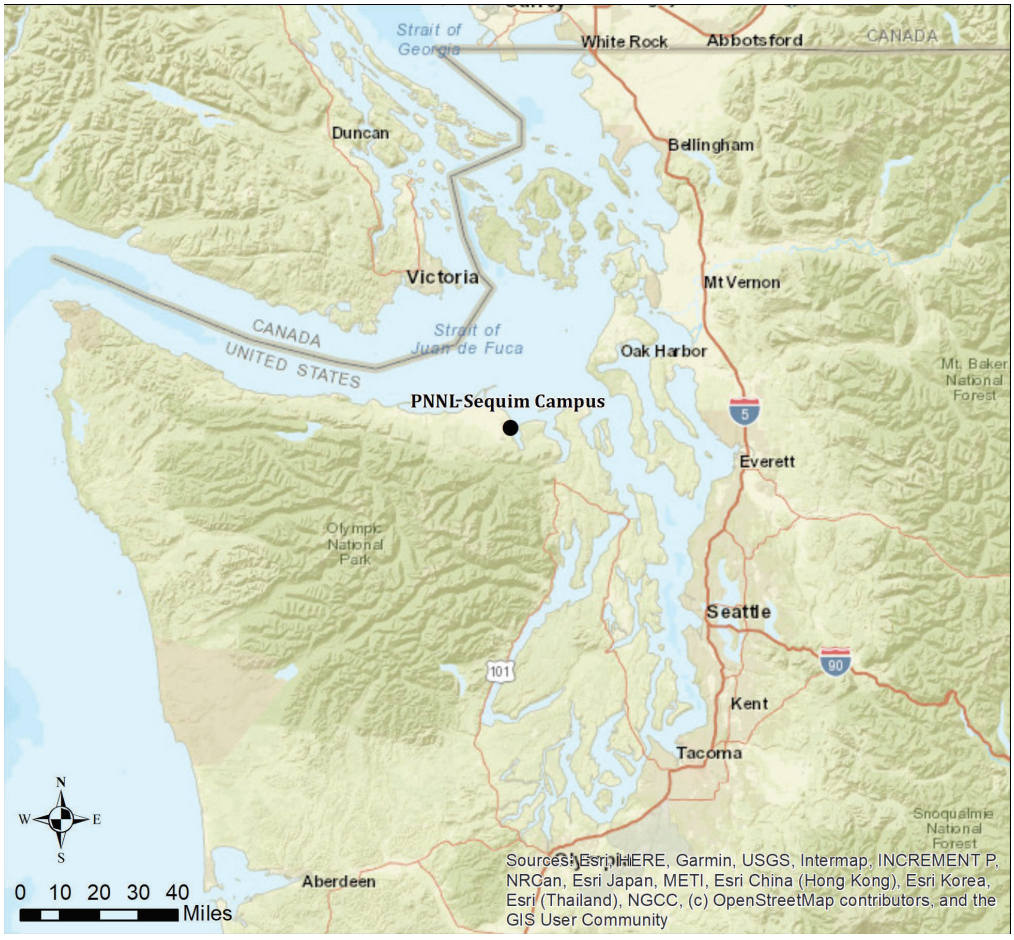

Figure 1.1. PNNL-Sequim Campus in Northwestern Washington State

1.1 PNNL-Sequim Campus Description

Research operations at the PNNL-Sequim Campus include forested, coastal, tidal, and developed lands with analytical and general-purpose laboratories. In addition, the PNNL-Sequim Campus research uses a state-of-the-art waste seawater treatment system, a dock facility for a 28-foot research vessel, and a specialized scientific diving boat.

The PNNL-Sequim Campus is shown in Figure 1.2. The boundary is consistent with the Master Plan for DOE operations at the PNNL-Sequim Campus (PNSO 2020). The entire PNNL-Sequim Campus as presented in this report encompasses 117 acres of dry lands (65 ac) and tidelands (52 ac), of which about 7.5 acres has been developed for research operations.

Figure 1.2. PNNL-Sequim Campus including Tidelands

Nearby Washington State cities are Sequim (population 8,020), Port Angeles (population 19,960), and Port Townsend (population 10,140) (WOFM 2022). The population within 50 miles of the PNNL-Sequim Campus is 2,936,686 (Rose et al. 2023), based on the 2020 U.S. Census. The 50-mile population increased 25% since the 2010 Census. Seattle is approximately 50 miles from the PNNL-Sequim Campus. The nearest sea border with Canada is about 17 miles from the PNNL-Sequim Campus in the Salish Sea; the nearest Canadian land border is about 25 miles NW from the Campus.

The PNNL-Sequim Campus lies on the shores of the Strait of Juan de Fuca and is in the rain shadow of the Olympic Mountains in Clallam County, at approximate coordinates 48°04’40” N, 123°02’55” W. Despite its coastal location, it receives less than 15 inches of rainfall on average annually. Meteorology at the PNNL-Sequim Campus in 2022 is summarized in Table 1.1. Average monthly 2022 temperatures ranged from 37°F–64°F (2.7°C–18°C). Winds in 2022 were below average, with average temperatures and total precipitation typical of historical norms for the year.

Table 1.1. 2022 and 5-year Average Meteorological Summary for Sequim, Washington

Parameter	2022	5-yr Average (2016-17,2019-21)
Average Temperature	49.2°F (9.56°C)	50.1°F (10.1°C)
Average Wind Speed [(a)]	2.6 mph (1.2 m/s)	3.1 mph (1.4 m/s)
Predominant Wind Direction (from)[(b)]	W/WNW	n/a
Total Precipitation	13.9 in. (35.3 cm)	16.5 in. (41.9 cm)

Data courtesy of WSU AgWeatherNet (acquired February 2023 http://weather.wsu.edu / Smith Farm Station).
(a) As-recorded, results. After removing wind speed records in hourly results that were below the detection threshold of the sensor [1 mph (0.45 m/s)], the re-calculated average wind speed in 2022 was 3.67 mph (1.6 m/s), with calms (i.e., <1 mph results) considered evenly distributed across all 16 wind directions.
(b) See Appendix B, Table B.3.

The PNNL-Sequim Campus research may emit low levels of radioactive material. Radiological emissions predominantly occur from laboratories in two buildings: MSL-1 and MSL-5 (Figure 1.2, Figure 1.3, and Figure 1.4). Radiological laboratories activities include:

- conducting biological, chemical, and physical studies in which marine or aquatic environmental conditions need to be maintained;
- maintenance of a "cleanroom" for ultra-low-level trace measurements in environmental media;
- storage of radioactive and mixed waste; and
- laboratory space that could be set up for radiological work.

Figure 1.3. MSL-1 Building

Figure 1.4. MSL-5 Building

2.0 Radionuclide Air Emissions

This section describes the registered PNNL-Sequim Campus emission unit operations during CY 2022. Information regarding the radionuclides of concern, emission rates, and emission unit physical characteristics are described. All emissions are assumed to be released from a single, Central Campus location (Figure 2.1).

Figure 2.1. PNNL-Sequim Campus with Central Campus and 2022 MEI Location Identified

2.1 Major, Minor, and Fugitive Emissions Points

A single minor, fugitive, nonpoint source emission unit, J-MSL, is registered with the state of Washington under the RAEL-014, Renewal-1 (WDOH 2018). J-MSL is a sitewide emission unit. Essentially, any structure or abatement controls from which an emission traverses are disregarded when

compliance determinations are estimated. The PNNL-Sequim Campus had no major emission units in 2022.

The RAEL-014, Renewal 1 is effective through calendar year 2022. The Renewal 2 application was submitted and approved in 2022 with an effective date of January 1, 2023. Permit conditions between Renewal 1 and Renewal 2 are unchanged.

Radioactive air emissions continue to be well below the criteria for classification as a minor emission unit (i.e., potential to emit [PTE] contribution is < 0.1 millirem per year [mrem/yr] effective dose equivalent [EDE] to the maximally exposed individual [MEI]). J-MSL is also classified as a Potential Impact Category-4 (licensed PTE of ≤ 0.001 mrem/yr) emission unit (Barnett 2018).

Campus radiological operations emit very low levels of radioactive materials. Appendix A contains the full list of radionuclides that may be handled at the PNNL-Sequim Campus. The 2022 radioactive material emissions to the air are given in Table 2.1. The 40 CFR 61, Appendix D method of determining unabated emissions was used. No radioactive gases were emitted from J-MSL in 2022.

Table 2.1. 2022 PNNL-Sequim Campus J-MSL Emissions

Nuclide / Type		2022 – J-MSL[a,b] (Ci)
K-40	Beta	7.65E-12
Fe-55	Beta	3.46E-14
Co-57	Beta	9.47E-15
Co-60	Beta	9.39E-12
Sr-90	Beta	8.38E-12
Tc-99	Beta	3.40E-10
Ru-106	Beta	7.83E-13
Sb-125	Beta	1.05E-12
Cs-134	Beta	6.28E-12
Cs-137	Beta	2.23E-10
Ba-133	Beta	8.80E-13
I-125	Beta	4.71E-11
I-129	Beta	2.30E-17
Eu-152	Beta	6.20E-14
Eu-154	Beta	1.69E-14
Eu-155	Beta	1.78E-14
Pb-210	Beta	1.28E-13
Ra-226	Alpha	4.33E-13
Ra-228	Beta	4.97E-14
Th-228	Alpha	2.60E-13
Th-230	Alpha	1.53E-13
Th-232	Alpha	3.95E-13
U-234	Alpha	1.88E-10
U-235	Alpha	8.67E-12
U-238	Alpha	1.92E-10
Pu-238	Alpha	8.18E-14
Pu-239	Alpha	3.76E-13
Pu-240	Alpha	3.76E-13
Am-241	Alpha	4.35E-13
	Total Alpha Ci	3.91E-10
	Total Beta Ci	6.45E-10
	TOTAL (Ci)	1.04E-09

(a) "Beta" (gray-shaded) includes beta- and gamma-emitters.
(b) Emissions based on 40 CFR 61, Appendix D methods.

3.0 Dose Assessment

This section describes the potential impact of PNNL-Sequim Campus radiological air emissions. Radiological operations at the Campus have not changed substantially from the prior year.

3.1 Dose Model and Potential Receptors

The COMPLY Code version 1.7 (Level 4) (EPA 1989) was used for estimating dose for comparison to the U.S. Environmental Protection Agency (EPA) standard of 10 mrem/yr EDE to any member of the public (40 CFR 61, Subpart H, and WAC 246-247). This code is approved for use for compliance determination (40 CFR 61, Subpart H).

COMPLY input for the 2022 dose assessment are provided in this section and Appendix B. The distance from source-to-receptor reflects the use of a "Central Campus" emission location assumption (N 48° 4' 42.45", W 123° 2' 48.51"; Google Earth, image date July 29, 2021) (see Figure 2.1, yellow marker). This Central Campus location was selected because it is considered central to all operations areas. Further details regarding dose assessment assumptions can be found in Snyder et al. (2019) and Snyder (2021).

Potential MEI locations for each of the 16 compass directions are provided in Table 3.1. Distances from the assumed Central Campus upland release location to the lowland boundary locations are determined by the straight-line path to account for the additional plume transport distance resulting from the vertical difference of the upland (~30 m above the shore) and shore boundaries (i.e., rather than only using the horizontal (map) distance). The nearest location where a member of the public would actually reside or abide (e.g., dwelling, business, school, office) relative to the Central Campus emission location was determined to be 230 m WNW. Food for the MEI was assumed to be grown at the MEI location.

Potential maximum annual air locations are boundary locations in each of the 16 compass directions provided in Table 3.1. The boundary locations do not take credit for the farther tideland boundary of Figure 1.2. The maximum annual air location (WAC 2007) dose was determined by COMPLY modeling. No members of the public routinely inhabit these boundary locations; food modeling in COMPLY for this maximum annual air location assumed food to be grown at a distance resulting from averaging all terrestrial boundary distances, 145 m (476 ft) from Central Campus, as an overestimating assumption.

Dispersion modeling for 2022 emissions used a 5-year average meteorological file because detailed hourly data for 2022 were not available (see Table 1.1 and Appendix B). The meteorological file used the average 2016–17 and 2019–21 hourly results from a meteorological station 1290 m (0.80 mi) NW of the Central Campus location. The 2018 data were not used because hourly results were not available for significant portions of the year.

Table 3.1. Potential PNNL-Sequim Campus MEI Locations and Distances to Boundary

Direction from Central Campus	Smallest Distance to a Potential MEI Location	Smallest Distance to the Campus Boundary Potential Maximum Air Location
N	1,834 m, res	319 m
NNE	30,670 m, busi	211 m
NE	10,000 m, busi	147 m
ENE	1,877 m, res	129 m
E	1,979 m, res	131 m
ESE	2,678 m, res	154 m
SE	3,693 m, res	176 m
SSE	1,532 m, busi	474 m
S	720 m, res	291 m
SSW	723 m, res	230 m
SW	340 m, res	95 m
WSW	276 m, res	81 m
W	234 m, res	80 m
WNW	230 m, res	81 m
NW	1,261 m, busi	96 m
NNW	840 m, res	220 m

Central Campus point and PNNL-Sequim Campus boundary (see Figure 2.1).
Blue cell highlight = a conservative shore location where no member of the public could occupy 24/7 and not the farther out tideland boundary location.
res = residential structure.
busi = business (NNE and NE are parks on small-island parks; SSE is a marina park; NW is a sewage treatment plant).

3.2 Compliance Assessment

The dose standard in 40 CFR 61, Subpart H, applies to radionuclide air emissions, other than radon, from DOE facilities. The emissions from Table 2.1 resulted in the MEI doses reported in Table 3.2. The 230 m WNW receptor location was determined to be the MEI location (40 CFR Part 61, Subpart H, and WAC 2019) based on the COMPLY Level 4 evaluation of all potential receptors and use of Sequim multiyear average meteorology (see Appendix B). This MEI location is indicated in Figure 2.1.

Doses were estimated using a unit-release dose factor (UDF_r) times the release rate (A_r) for radionuclide "r" [i.e., UDF_r (mrem/yr per 1 $Ci_{released}$/yr) × A_r ($Ci_{releasead}$) = D_r (mrem/yr)]. COMPLY v1.7.1, Level 4-determined UDFs, the multiyear average wind rose, and other input used in the 2022 dose assessment are indicated in Appendix B.

As a conservative (overestimating) assumption, all alpha activity releases were assumed to be Am-241. All beta activity releases were assumed to be Cs-137. For radionuclides, where using the generic nuclide does not produce a conservative result (i.e., I-125, I-129, Pb-210, Ra-228, and Th-232), external calculations verified that a nuclide-specific dose calculation would not change the last significant digit of the final reported alpha or beta dose, even though the nuclide-specific dose factor was greater than the generic beta or alpha dose factor used.

The dose assigned to the 2022 PNNL-Sequim Campus MEI overestimates any actual off-site dose that receptor might receive. The MEI dose is 230 m (755 ft) WNW of the Central Campus location. Table 3.2 summarizes emissions and MEI dose results.

Table 3.2. PNNL-Sequim Campus 2022 MEI Dose Summary

Data	Alpha	Beta	Total
J-MSL Releases (Ci)	3.91E-10	6.45E-10	**1.04E-09 Ci**
Annual MEI Dose (mrem) [a,b]	7.0E-07	4.3E-08	**7.5E-07 mrem**
Dose Contributions	**94%**	**6%**	**100%**

(a) Unit dose factor for Am-241 applied to estimate dose.
(b) Unit dose factor for Cs-137 applied to estimate dose.

The EDE to the 2022 PNNL-Sequim Campus MEI from routine J-MSL emissions was 7.5E-07 mrem (7.5E-09 mSv) for 40 CFR Part 61, Subpart H, and WAC 246-247 compliance reporting. Last year, the 2021 MEI dose estimate was 5.4E-05 mrem (5.4E-07 mSv) EDE (Snyder et al. 2022).

Comparing the PNNL-Sequim Campus 2022 MEI dose to average U.S. background radiation (NCRP 2009):

- Annual natural background radiation 310.0 mrem/yr
- Daily natural background radiation 0.85 mrem/d
- Hourly natural background radiation 0.035 mrem/hr
- Per minute natural background radiation 0.00059 mrem/min
- Per second natural background radiation 0.0000098 mrem/sec
- **PNNL-Sequim Campus - 2022 MEI dose 0.00000075 mrem/yr**

The EDE to the maximally impacted boundary location was modeled, indicating the at-boundary location where maximum air concentrations of radioactive materials are modeled. This location is on a shore 131 m (420 ft) E of the Central Campus location. The wind rose option, using multiyear average meteorology and all potential boundary locations (Table 3.1), was input for this receptor evaluation. Food (vegetables, milk, meat) was assumed to be grown 145 m (476 ft) from the release location. The estimated dose to this boundary location individual, assumed to be at this shore location 24/7, is 9.3E-06 mrem (9.3E-08 mSv), which is well below the 10 mrem/yr dose standard for WAC 173-480 (2007) reporting.

4.0 Supplemental Information

This section provides supplemental information related to PNNL-Sequim Campus radionuclide air emissions in 2021. Supplemental information is provided as part of a Memorandum of Understanding between DOE and EPA (DOE 1995). Collective dose information is reported under DOE O 458.1 requirements (DOE 2020).

4.1 Collective Dose Estimate

In prior years, regional populations were determined using data based on 2010 U.S. and 2011 Canada Census data in Zuljevic et al. (2016). More recent 2020 U.S. and 2021 Canada Census became available in 2022 for determining current 50-mile regional populations. The population assessment in Rose et al. (2023) was used to determine collective dose for this report. For the 50-mile region, the total population increased 25% between the two Census periods (2.35 million to 2.94 million); and more than 50% for the City of Sequim.

An estimated 2.94 million people live within 50 miles (80 km) of the PNNL-Sequim Campus, with about 456,415 of those residing in Canada (Rose et al. 2023). The populations and major U.S. cities at various distances from the Campus are given in Table 4.1. Victoria, British Columbia (20-40 mi to the NW and NNW) is the only major Canadian city within 50 miles of the PNNL-Sequim Campus.

Table 4.1. Populations and Significant U.S. Cities within 50 Miles of the PNNL-Sequim Campus

Distance (miles)	2010 Population at Indicated Distance[(a)]	2020 Population at Indicated Distance[(b)]	U.S. Cities at Indicated Distances
0–10	29,097	68,549	City of Sequim
10–20	55,533	70,914	Port Angeles, Port Townsend
20–30	240,311	295,481	Oak Harbor, Poulsbo
30–40	701,151	869,187	Anacortes, Bremerton (portion), Edmonds, Everett (portion), Friday Harbor, Lynnwood, Marysville (portion), Mukilteo, Shoreline, Stanwood
40–50	1,322,999	1,632,049	Arlington, Bothell, Bremerton (portion), Burlington, Everett (portion), Kirkland, Marysville (portion), Mount Vernon, Seattle (large portion)

(a) Zuljevic et al. 2016
(b) Rose et al. 2023

The 2022 collective dose was estimated assuming that the total curies released (Table 3.2) were dispersed in a single direction. The maximum collective dose was determined to result from dispersion to the west, which only contains U.S. populations. The MEI dose (7.5E-7 mrem) was multiplied by a population-weighted air concentration in the direction of maximum collective impact for a collective dose of 2.1E-6 person-rem. If the release were dispersed only to the maximum Canadian sector (NNW), the maximum estimated Canadian collective dose would be 3.9E-7 person-rem. Dispersal toward the large, but distant, Seattle population sector (southeast) would have resulted in a collective dose about 50% less than the collective U.S. dose indicated.

Due to the delay in the availability of the 2020 U.S. Census data, for 2020 and 2021 collective dose estimation, the Zuljevic et al. (2016) data had been used for collective dose assessment. To provide a more precise estimate of collective dose, the values for emissions during 2020 and 2021 were updated using the more recent Census data (Table 4.2). The 2022 results are also indicated for trending purposes.

Table 4.2. Collective Doses 2020–2021 (Revised) and 2022

	Year of Emissions		
	2020 Collective Dose (person-rem)	2021 Collective Dose (person-rem)	2022 Collective Dose (person-rem)
US Collective Dose			
2010-Census-based[(a)]	3.9E-5	6.0E-5	n/a
2020-Census-based[(b)]	**9.7E-5**	**1.5E-4**	**2.1E-6**
Canada Collective Dose			
2011-Census-based[(a)]	1.6E-5	2.4E-5	n/a
2021-Census-based[(b)]	**1.8E-5**	**2.8E-5**	**3.9E-7**

(a) Zuljevic et al. 2016 for 2010/2011 Census 50-mi (80 km) populations.
(b) Rose et al. 2023 for 2020/2021 Census 50-mi (80 km) populations

4.2 Compliance Status with Subparts Q and T of 40 CFR 61

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

4.3 Other Supplemental Information

- Periodic confirmatory measurement information is not required by the PNNL-Sequim Campus Notice of Construction (NOC).
- The PNNL Radioactive Material Tracking system is used to manage potential emissions below permit thresholds, resulting in overall confirmation of inventory limits and emissions estimates to respective NOCs.
- Quality assurance program status of compliance with 40 CFR 61, Appendix B, Method 114 does not apply because no air sampling is conducted at the PNNL-Sequim Campus.
- There were no radon emissions in 2022.
- There were no unplanned emissions in 2022.
- A review of radiological assessment needs under the license renewal was completed in 2019 (Snyder et al. 2019), as an update to the Data Quality Objects report (Barnett et al. 2012). Final recommendations were that no emission unit sampling or ambient air emissions surveillance is recommended. However, the authors recommended ambient air baseline particulate background (e.g., gross alpha/beta and gamma scan) measurements and baseline external dose measurements

because this regional information is currently lacking. Due to the continued COVID-19 workplace safety measures implemented at PNNL, no action was taken on this recommendation through CY 2022.

However, in late 2022, it was decided that the previous location recommended for siting the ambient background air surveillance station may need to be revisited due to potential land transfer decisions between BMI and DOE. If the transfer of land to DOE occurs, the proposed station location will be reevaluated, as necessary.

In addition, PNNL staff will explore the establishment of an on-site meteorological station in 2023. While site fugitive emissions of radioactive air effluent are low, the dearth of off-site resources for meteorological information for the Sequim region limits options when equipment or data failures impact the current resource. The addition of such on-site equipment will strengthen both the PNNL Environmental Radiation Task operations as well as Health and Safety Programs at the PNNL-Sequim Campus.

5.0 References

40 CFR 61, as amended. *National Emission Standards for Hazardous Air Pollutants* (NESHAP), Appendix B, "Test Methods."

40 CFR 61, as amended. *National Emission Standards for Hazardous Air Pollutants* (NESHAP), Appendix D, "Methods for Estimating Radionuclide Emissions."

40 CFR 61, as amended. *National Emission Standards for Hazardous Air Pollutants* (NESHAP), Appendix E, "Compliance Procedures Methods for Determining Compliance with Subpart I."

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40 CFR 61, as amended. *National Emission Standards for Hazardous Air Pollutants* (NESHAP), Subpart Q, "National Emission Standards for Radon Emissions from Department of Energy Facilities."

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Appendix A

List of Radioactive Materials Handled or Potentially Handled, or Authorized for Use at the PNNL-Sequim Campus in 2022

Appendix A: List of Radioactive Materials Handled or Potentially Handled, or Authorized for Use at the PNNL-Sequim Campus in 2022

Table A.1. List of Radioactive Materials Handled or Potentially Handled, or Authorized for Use at the PNNL-Sequim Campus in 2022

Ac-225	Au-195	C-11	Co-58m	F-18	Ho-166	K-42	Nb-91	Pa-234m
Ac-226	Au-195m	C-14	Co-60	Fe-55	Ho-166m	Kr-81	Nb-91m	Pb-203
Ac-227	Au-196	C-15	Co-60m	Fe-59	I-122	Kr-81m	Nb-92	Pb-204m
Ac-228	Au-196m	Ca-41	Cr-49	Fr-221	I-123	Kr-83m	Nb-92m	Pb-205
Ag-105	Au-198	Ca-45	Cr-51	Fr-222	I-124	Kr-85	Nb-93m	Pb-209
Ag-106m	Au-198m	Ca-47	Cr-55	Fr-223	I-125	Kr-85m	Nb-94	Pb-210
Ag-108	Au-199	Cd-107	Cs-131	Ga-67	I-126	Kr-87	Nb-94m	Pb-211
Ag-108m	Ba-131	Cd-109	Cs-132	Ga-68	I-128	Kr-88	Nb-95	Pb-212
Ag-109m	Ba-131m	Cd-111m	Cs-134	Ga-70	I-129	Kr-89	Nb-95m	Pb-214
Ag-110	Ba-133	Cd-113	Cs-134m	Ga-72	I-130	Kr-90	Nb-96	Pd-103
Ag-110m	Ba-133m	Cd-113m	Cs-135	Gd-148	I-130m	La-137	Nb-97	Pd-107
Ag-111	Ba-135m	Cd-115	Cs-135m	Gd-149	I-131	La-138	Nb-97m	Pd-109
Ag-111m	Ba-137m	Cd-115m	Cs-136	Gd-150	I-132	La-140	Nb-98	Pd-109m
Ag-112	Ba-139	Cd-117	Cs-137	Gd-151	I-132m	La-141	Nd-144	Pd-111
Al-26	Ba-140	Cd-117m	Cs-138	Gd-152	I-133	La-142	Nd-147	Pd-112
Al-28	Ba-141	Ce-139	Cs-138m	Gd-153	I-133m	La-144	Ni-56	Pm-143
Am-240	Ba-142	Ce-141	Cs-139	Gd-159	I-134	Lu-177	Ni-57	Pm-144
Am-241	Ba-143	Ce-142	Cs-140	Ge-68	I-134m	Lu-177m	Ni-59	Pm-145
Am-242	Be-10	Ce-143	Cs-141	Ge-69	I-135	Mg-27	Ni-63	Pm-146
Am-242m	Be-7	Ce-144	Cu-64	Ge-71	In-106	Mg-28	Ni-65	Pm-147
Am-243	Bi-207	Cf-249	Cu-66	Ge-71m	In-111	Mn-52	Np-235	Pm-148
Am-244	Bi-208	Cf-250	Cu-67	Ge-75	In-111m	Mn-52m	Np-236	Pm-148m
Am-244m	Bi-210	Cf-251	Dy-159	Ge-77	In-112	Mn-53	Np-236m	Pm-149
Am-245	Bi-210m	Cf-252	Dy-165	Ge-77m	In-112m	Mn-54	Np-237	Pm-150
Am-246	Bi-211	Cl-36	Dy-169	H-3	In-113m	Mn-56	Np-238	Pm-151
Ar-37	Bi-212	Cm-241	Er-169	Hf-175	In-114	Mo-93	Np-239	Po-208
Ar-39	Bi-213	Cm-242	Er-171	Hf-177m	In-114m	Mo-93m	Np-240	Po-209
Ar-41	Bi-214	Cm-243	Es-254	Hf-178m	In-115	Mo-99	Np-240m	Po-210
Ar-42	Bk-247	Cm-244	Eu-150	Hf-179m	In-115m	Mo-103	O-15	Po-211
As-73	Bk-248m	Cm-245	Eu-150m	Hf-180m	In-116	Mo-104	O-19	Po-212
As-74	Bk-249	Cm-246	Eu-152	Hf-181	In-116m	Mo-105	Os-185	Po-212m
As-76	Bk-250	Cm-247	Eu-152m	Hf-182	In-117	N-13	Os-191	Po-213
As-77	Br-82	Cm-248	Eu-152n	Hg-203	In-117m	Na-22	P-32	Po-214
At-217	Br-82m	Cm-249	Eu-154	Hg-205	Ir-189	Na-24	P-33	Po-215
At-218	Br-83	Cm-250	Eu-154m	Hg-206	Ir-190	Na-24m	Pa-231	Po-216
Au-193	Br-84	Co-56	Eu-155	Ho-163	Ir-192	Nb-100	Pa-232	Po-218
Au-193m	Br-84m	Co-57	Eu-156	Ho-164	Ir-194	Nb-101	Pa-233	Pr-142

Table A.1 (cont'd)

Pr-143	Ra-226	Rh-104m	Sc-44m	Sn-125	Tc-98	Th-233	U-240	Y-91m
Pr-144	Ra-227	Rh-105	Sc-46	Sn-125m	Tc-99	Th-234	V-48	Y-92
Pr-144m	Ra-228	Rh-105m	Sc-47	Sn-126	Tc-99m	Ti-44	V-49	Y-93
Pt-191	Rb-81	Rh-106	Sc-48	Sr-82	Tc-101	Ti-45	W-181	Yb-164
Pt-193	Rb-81m	Rn-218	Se-75	Sr-83	Tc-103	Ti-51	W-185	Yb-165
Pt-193m	Rb-82	Rn-219	Se-77m	Sr-85	Tc-106	Tl-200	W-185m	Yb-166
Pt-195m	Rb-82m	Rn-220	Se-79	Sr-85m	Te-121	Tl-201	W-187	Yb-167
Pt-197	Rb-83	Rn-222	Se-79m	Sr-87m	Te-121m	Tl-202	W-188	Yb-169
Pt-197m	Rb-84	Rn-224	Si-31	Sr-89	Te-123	Tl-204	Xe-122	Yb-175
Pt-198m	Rb-84m	Ru-103	Si-32	Sr-90	Te-123m	Tl-206	Xe-123	Yb-177
Pt-199	Rb-86	Ru-105	Sm-145	Sr-91	Te-125m	Tl-206m	Xe-125	Zn-65
Pt-199m	Rb-86m	Ru-106	Sm-146	Sr-92	Te-127	Tl-207	Xe-127	Zn-69
Pu-234	Rb-87	Ru-97	Sm-147	Ta-179	Te-127m	Tl-208	Xe-127m	Zn-69m
Pu-235	Rb-88	S-35	Sm-148	Ta-180	Te-129	Tl-209	Xe-129m	Zr-88
Pu-236	Rb-89	Sb-122	Sm-151	Ta-182	Te-129m	Tl-210	Xe-131m	Zr-89
Pu-237	Rb-90	Sb-122m	Sm-153	Ta-182m	Te-131	Tm-168	Xe-133	Zr-89m
Pu-238	Rb-90m	Sb-124	Sm-155	Ta-183	Te-131m	Tm-170	Xe-133m	Zr-93
Pu-239	Re-186	Sb-124m	Sm-156	Tb-157	Te-132	Tm-171	Xe-135	Zr-95
Pu-240	Re-186m	Sb-124n	Sm-157	Tb-158	Te-133	U-232	Xe-135m	Zr-97
Pu-241	Re-187	Sb-125	Sn-113	Tb-160	Te-133m	U-233	Xe-137	Zr-98
Pu-242	Re-188	Sb-126	Sn-113m	Tb-161	Te-134	U-234	Xe-138	Zr-99
Pu-243	Rh-101	Sb-126m	Sn-117m	Tc-95	Th-227	U-235	Xe-139	Zr-100
Pu-244	Rh-101m	Sb-127	Sn-119m	Tc-95m	Th-228	U-235m	Y-88	-
Pu-246	Rh-102	Sb-128	Sn-121	Tc-96	Th-229	U-236	Y-89m	-
Ra-223	Rh-102m	Sb-128m	Sn-121m	Tc-96m	Th-230	U-237	Y-90	-
Ra-224	Rh-103m	Sb-129	Sn-123	Tc-97	Th-231	U-238	Y-90m	-
Ra-225	Rh-104	Sc-44	Sn-123m	Tc-97m	Th-232	U-239	Y-91	-

Appendix B

COMPLY Unit Dose Factors

Appendix B: PNNL-Sequim Campus 2022 COMPLY Unit Dose Factors and 2022 Meteorological Data

COMPLY v1.7.1 (EPA 1989), Level 4, was used to determine unit-release dose factors, which represent impacts to a hypothetical receptor. Two sets of unit-release dose factors were calculated, one set with no wind rose (NWR) and another set with the multiyear average (2016-17, 2019-2021) wind rose (i.e., meteorological data) entered. The 2018 hourly data did not meet recoverability criteria, so 2018 results were not included in the 5-year average data set. COMPLY input for each set is provided in Table B.1 with results indicated in Table B.2.

For the NWR set, the 230 m receptor from the *Central Campus* point of assumed releases was used with other assumptions listed in Table B.1. When no wind rose is supplied, the model uses the default assumption that the wind blows toward the receptor 25% of the time with the user-supplied annual average wind speed information.

The second set of COMPLY input parameters listed in Table B.1 uses multiyear average meteorology (Table B.3) and the direction-specific potential receptor distances (Table 3.1) to determine more precise unit-release dose factors. Using these inputs, COMPLY indicated the 230 m WNW receptor was the maximally exposed individual (MEI). This was the same as the all-directions closest-receptor-distance that was user-entered in the first set of dose factors.

For unit dose factor determinations (Table B.2), the appropriate solubility class (DOE 2010) was applied, replacing the DOE 2010 solubility classifications (F, M, S) with the analogous solubility classifications available in COMPLY (D, W, Y, respectively). The COMPLY default inhalation solubility class, in the following table, are used as simplifying, overestimating assumptions for dose determination (see solubility class preferences in Table 3.1 of Snyder and Rokkan 2016).

The multiyear average PNNL-Sequim Campus meteorological data details are provided in Table B.3. Tabulated data indicate that winds are most common from the W and WNW directions, which are seaward from the Campus. Fractional direction frequencies can be compared to the NWR, Level 4, assumption applied in the NWR unit dose factor calculations.

Table B.1. COMPLY Input Parameters

Parameter	J-MSL Value (Level 4, NWR)[(a)]	J-MSL Value (Level 4 with multiyear average wind rose)
Nuclide names	<varies by year>	<varies by year>
Concentrations (Ci/m^3)	NA	NA
Annual possession amount (Ci)	NA	NA
Release rates (Ci/yr *or* Ci/s)	<varies Ci/year>	<varies Ci/year>
Release height (m)	5 m	5 m
Building height (m)	5 m	5 m
Stack or vent diameter (m)	NA	NA
Volumetric flow rate (m^3/s)	NA	NA
Distance from source-to-receptor (m)	230 m[(a)]	NA
Source and receptor on same building?	N	N
Input wind rose?	NA	Y
Building width (m)	5 m	5 m
Building length (m)	NA(NWR)[(b)]	5 m
Stack distances from file?	NA	Y <enter and save to file>
Wind speed (m/s) – multiyear average	1.6 m/s	NA
Distances to sources of food production (m)	230 m[(b)]	NA
Stack temperature (°F)	NA	NA
Ambient air temperature (°F)	NA	NA
Wind rose	NA(NWR)[(c)]	<enter and save to file>

NA = not applicable.
(a) The No Wind Rose (NWR) option was not used for CY 2022 compliance determinations.
(b) Smallest potential MEI distance.
(c) NA(NWR) = not applicable because NWR data is used.

Table B.2. PNNL-Sequim Campus MEI Unit Dose Factors

Nuclide	Footnote	COMPLY Solubility Class	CY 2022 Unit Dose Factor (230 m receptor and NWR) (mrem/yr EDE per Ci/yr released)	CY 2022 Unit Dose Factor [(a)] (multiyear average wind rose and 2022 receptor distances) (mrem/yr EDE per Ci/yr released)
Am-241		W	13,100	1790.0
Cs-137		D	525	71.4
Cm-244		W	7300	998.0
I-125		D	94.9	12.8
I-129		D	1410	190.0
Np-237		W	17,300	2350.0
Pb-210	(b)	D	1230	162.0
Ra-228		W	663	88.7
Th-232	(c)	W	49,200	6730.0

Bold font = alpha-emitting nuclides. All others are beta/gamma emitters.
EDE = effective dose equivalent.
(a) Using meteorological data, the receptor identified for all dose factors COMPLY cases was 230 m WNW of the Central Campus release location, which happens to be the same as the closest potential MEI location.
(b) The solubility class listed is the only available option in COMPLY v1.7.1.
(c) Solubility class S is preferred, but the default class W was used as an overestimating assumption.

Table B.3. PNNL-Sequim Campus Multiyear (2016-17, 2019-2021) Meteorological Data

Wind Direction From	Wind Blows Toward	Fraction of Multiyear Average	Multiyear Average Wind Speed ≥1 mph (mph)
N	S	0.062	3.25
NNE	SSW	0.024	3.19
NE	SW	0.021	2.70
ENE	WSW	0.021	2.50
E	W	0.029	2.93
ESE	WNW	0.033	3.42
SE	NW	0.061	5.26
SSE	NNW	0.053	3.64
S	N	0.064	3.27
SSW	NNE	0.046	2.12
SW	NE	0.057	2.11
WSW	ENE	0.083	2.49
W	E	0.161	3.70
WNW	ESE	0.164	4.59
NW	SE	0.078	4.36
NNW	SSE	0.043	3.75

Data courtesy of WSU AgWeatherNet (based on Smith Farm Station hourly results) http://weather.wsu.edu / Smith Farm Station.

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