Pacific Northwest
NATIONAL LABORATORY

PNNL-22342-13

PNNL-Sequim Campus Radionuclide Air Emissions Report for Calendar Year 2024

Department of Energy – Office of Science
Pacific Northwest National Laboratory

April 2025

TR Hay
SF Snyder
JM Barnett

U.S. DEPARTMENT OF ENERGY

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

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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

The U.S. Department of Energy Office of Science's 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. Although 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 2024 was 7.2E-13 mrem (7.2E-15 mSv). No unplanned releases occurred in 2024. 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: Marine and Coastal Research Laboratory, PNNL-Sequim campus. Pacific Northwest National Laboratory.

CERTIFICATION OF PNNL-22342-13

DOE-SC
Pacific Northwest National Laboratory
Sequim Campus
Radionuclide Air Emissions Report
Calendar Year 2024

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.

Julie K. Turner Digitally signed by Julie K. Turner
Date: 2025.05.23 13:59:15 -07'00'

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

Acronyms and Abbreviations

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
MSL	Marine Sciences Laboratory
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
Sv	sievert
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. The PNNL-Sequim campus is DOE's only marine research laboratory.

This radiological air emissions report meets the Washington State 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) 2024. Site air effluent emissions are governed under WDOH Radioactive Air Emissions License (RAEL)-014, Renewal 2. Compared to the prior year, radiological laboratory activities have not substantially changed.

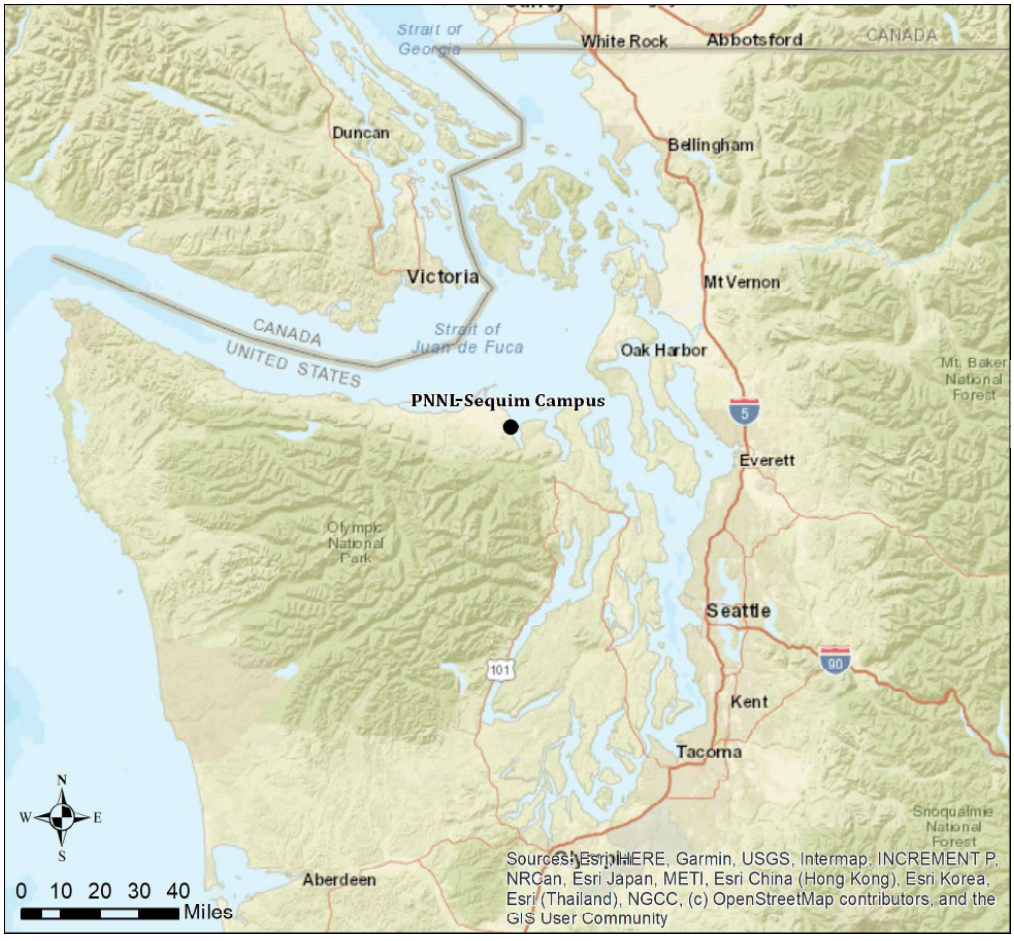

Figure 1.1. PNNL-Sequim Campus in Northwestern Washington State

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

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. 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. Seattle is approximately 50 miles from the 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.

Despite its coastal location, the campus receives less than 15 inches (38.1 cm) of rainfall on average annually. Meteorology at the PNNL-Sequim campus is summarized in Table 1.1. Note: The Smith farm weather station was out of commission during the months of November and December 2024 and the average is not reported in Table 1.1. Due to this outage, the 5-yr average weather data was used in dose calculations instead of the 2024 yearly average.

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

Parameter	5-yr Average (2016-2021)
Average Temperature	50.1°F (10.1°C)
Average Wind Speed [(a)]	3.1 mph (1.4 m/s)
Predominant Wind Direction (from)[(b)]	n/a
Total Precipitation	16.5 in. (41.9 cm)

Data (2016-17 and 2019-2021) courtesy of WSU AgWeatherNet (acquired from 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 from 2016-2021 was 3.1 mph (1.4 m/s), with calms (i.e., <1 mph results) considered evenly distributed across all 16 wind directions.
(b) See Appendix B, Table B.3.

PNNL-Sequim campus research may result in the release of low levels of radioactive material to ambient air. 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 laboratory activities may 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 2024. Information regarding the radionuclides of concern, emission rates, and emission unit physical characteristics is provided. All emissions are assumed to be released from a single, Central Campus location.

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-2 (WDOH 2022). 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 2024. The RAEL-014, Renewal 2 was in effect starting CY 2023 through January 1, 2028.

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 2024 radioactive material emissions to the air are given in Table 2.1. The list of radionuclide emissions is shorter this year due to excessing of materials and reduced levels of radiological research in 2024. The 40 CFR 61, Appendix D method of determining unabated emissions was used. No radioactive gases were emitted from J-MSL in 2024.

Because J-MSL is registered as a sitewide emission unit, all radioactive material air emissions were assumed to be released from a “Central Campus” emission location (N 48° 4’ 42.45”, W 123° 2’ 48.51”; Google Earth, image date July 13, 2023) (see Figure 2.1, yellow marker). This location was selected because it is considered central to all operations areas.

Table 2.1. 2024 PNNL-Sequim Campus J-MSL Emissions

Nuclide / Type		2024 – J-MSL[a, b] (Ci)
Co-60	Beta	9.4E-18
Sr-90	Beta	8.4E-18
Cs-137	Beta	2.2E-16
U-234	Alpha	1.9E-16
U-235	Alpha	8.7E-18
U-238	Alpha	1.9E-16
	Total Alpha Ci	3.9E-16
	Total Beta Ci	2.4E-16
	TOTAL (Ci)	**6.29E-16**

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

Figure 2.1. PNNL-Sequim Campus with Central Campus and 2024 MEI Location Identified

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 2024 dose assessment is provided in this section and Appendix B. The distance from source-to-receptor reflects the use of the Central Campus emission location assumption (Figure 2.1). Further details regarding dose assessment assumptions can be found in Snyder et al. (2019) and Snyder and Cooley (2024).

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 (approximately 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 234 m (768 ft) W. 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; modeling in COMPLY for this maximum annual air location assumed food is 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 emissions used 5 year average (2016-2021) meteorological data (see Table 1.1 and Appendix B). The meteorological file data is from a station 1290 m (0.80 mi) NW of the Central Campus location.

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 shading = 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 2024 MEI location (40 CFR Part 61, Subpart H, and WAC 246-247) was determined based on the COMPLY Level 4 evaluation of all potential receptors and use of the 5 year average Sequim (2016-2021) meteorology, and other input 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. The dose assigned to the 2024 PNNL-Sequim campus MEI overestimates any actual off-site dose that receptor might receive. The COMPLY model indicates that the 2024 MEI is 234 m (767 ft) W of the Central Campus location (Figure 2.1). Table 3.2 summarizes emissions and MEI dose results.

Table 3.2. PNNL-Sequim Campus 2024 MEI Dose Summary

Data	Alpha	Beta	Total
J-MSL Releases (Ci)	3.9E-16	2.4E-16	**6.3E-16 Ci**
Annual MEI Dose (mrem) [a, b]	7.0E-13	1.7E-14	**7.2E-13 mrem**
Dose Contributions	**97.6%**	**2.4%**	**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 2024 PNNL-Sequim campus MEI from routine J-MSL emissions was 7.2E-13 mrem (7.2E-15 mSv) for 40 CFR Part 61, Subpart H, and WAC 246-247 compliance reporting. The 2023 MEI dose estimate was 5.8E-08 mrem (5.8E-10 mSv) EDE (Snyder et al. 2024).

The RAEL-014 limit for J-MSL is 9.23E-04 mrem/yr. The 2024 MEI dose estimate is well below this limit.

Comparing the PNNL-Sequim campus 2024 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 – 2024 MEI dose 0.00000000000072 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 forest on Battelle-owned land 80 m (262 ft) W of the Central Campus location. The wind rose option, using 2016-2021 five-year 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 location 24/7, is 2.7E-12 mrem (2.7E-14 mSv), which is well below the 10 mrem/yr dose standard for WAC 173-480 reporting.

4.0 Supplemental Information

This section provides supplemental information related to PNNL-Sequim campus radionuclide air emissions in 2024. 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 2020a).

4.1 Collective Dose Estimate

Regional populations from the 2020 U.S. and 2021 Canada censuses were used for assessing collective dose to the 50-mile regional populations (Rose et al. 2023). 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. 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)	2020 Population at Indicated Distance[(a)]	U.S. Cities at Indicated Distances
0–10	68,549	City of Sequim
10–20	70,914	Port Angeles, Port Townsend
20–30	295,481	Oak Harbor, Poulsbo
30–40	869,187	Anacortes, Bremerton (portion), Edmonds, Everett (portion), Friday Harbor, Lynnwood, Marysville (portion), Mukilteo, Shoreline, Stanwood
40–50	1,632,049	Arlington, Bothell, Bremerton (portion), Burlington, Everett (portion), Kirkland, Marysville (portion), Mount Vernon, Seattle (large portion)

(a) Rose et al. 2023

The 2024 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 (7.2E-13 mrem) was multiplied by a population-weighted air concentration in the direction of maximum collective impact for a collective dose of 2.0E-12 person-rem (2.0E-14 person-Sv). If the release were dispersed only to the maximum Canadian sector (NNW), the maximum estimated Canadian collective dose would be 3.7E-13 person-rem (3.7E-15 person-Sv). Dispersal toward the large, but distant, Seattle population sector (SE) would have resulted in a collective dose about 50% less than the collective U.S. dose indicated.

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 RAEL-014.
- During 2024, no applications to construct or modify emission units were submitted for the PNNL-Sequim campus pursuant to WAC 246-247 and 40 CFR Subpart H.
- 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.
- EM-QA-01 (Barnett 2024) is the internal PNNL quality assurance program implementation document. PNNL has adopted ASME NQA-1 (ASME 2001) as its single consensus standard and EM-QA-01 is written in the format of DOE Order 414.1D (DOE 2020b).
- There were no radon emissions in 2024.
- There were no unplanned releases in 2024.
- Until DOE land transfer decisions are finalized, several environmental surveillance programmatic decisions at PNNL-Sequim remain pending.

5.0 References

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Appendix A – List of Radioactive Materials Handled or Potentially Handled, or Authorized for Use at the PNNL-Sequim Campus in 2024

Table A.1. List of Radioactive Materials Handled or Potentially Handled, or Authorized for Use at the PNNL-Sequim Campus in 2024

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

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 2016-2021 average wind rose (i.e., meteorological data) entered. COMPLY input for each set is provided in Table B.1 with results given in Table B.2.

Applying the 2016-2021 average wind rose indicated that the maximally exposed individual (MEI) was 234 m W of the assumed release location. For the NWR set, the nearest receptor, 230 m 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 default 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 234 m W receptor was the MEI. This differs slightly from the all-directions closest-receptor-distance (230 m) that was user-entered in the NWR set of dose factors.

For unit dose factor determinations (Table B.2), the appropriate solubility class (Snyder and Rokkan 2016) was applied, replacing the modern solubility classifications (F, M, S) with the analogous older solubility classifications available in COMPLY (D, W, Y, respectively). The COMPLY default inhalation solubility classes, in Table B.2, 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 2016-2021 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) – default value	2.0 m/s[b]	NA
Distances to sources of food production (m)	230 m[c]	NA
Stack temperature (°F)	NA	NA
Ambient air temperature (°F)	NA	NA
Wind rose	NA(NWR)[d]	<enter and save to file>

NA = not applicable. To convert to feet, multiply meters by 3.28.
(a) The no wind rose (NWR) option was not used for calendar year 2024 compliance determinations.
(b) Conservative value relative to the average wind speed for closest receptors.
(c) Smallest potential MEI distance.
(d) NA(NWR) = not applicable because NWR data is used.

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

Nuclide	COMPLY Solubility Class	CY 2024 Unit Dose Factor (NWR and 230 m receptor) (mrem/yr EDE per Ci/yr released)	CY 2024 Unit Dose Factor[a] (2016-2021 wind rose and 2024 receptor distances) (mrem/yr EDE per Ci/yr released)
Am-241	W	10,500	1790.0
Cs-137	D	420.0	71.4

Bold font = alpha-emitting nuclide. Cs-137 is a beta/gamma emitter.
EDE = effective dose equivalent.
(a) Using meteorological data, the receptor identified for all dose factors COMPLY cases was 234 m W of the Central Campus release location, which happens to be the same as the closest potential MEI location.

Table B.3. PNNL-Sequim Campus 2016-2021 average Meteorological Data

Wind Direction From	Wind Blows Toward	Fraction of Multiyear Average	Multiyear Average Wind Speed ≥1 mph (mph)
N	S	0.0620	3.25E+00
NNE	SSW	0.0244	3.19E+00
NE	SW	0.0212	2.70E+00
ENE	WSW	0.0211	2.50E+00
E	W	0.0288	2.93E+00
ESE	WNW	0.0329	3.42E+00
SE	NW	0.0610	5.26E+00
SSE	NNW	0.0530	3.64E+00
S	N	0.0635	3.27E+00
SSW	NNE	0.0458	2.12E+00
SW	NE	0.0566	2.11E+00
WSW	ENE	0.0833	2.49E+00
W	E	0.1610	3.70E+00
WNW	ESE	0.1640	4.59E+00
NW	SE	0.0781	4.36E+00
NNW	SSE	0.0435	3.75E+00

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

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