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Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2016

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
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ABSTRACT

This report documents radionuclide air emissions in 2016 from the U.S. Department of Energy (DOE) Hanford Site and the resulting highest effective dose equivalent (EDE) to a member of the public, referred to as the maximally exposed individual (MEI). The report has been prepared in compliance with the Code of Federal Regulations (CFR), 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 (WAC) Chapter 246-247, "Radiation Protection–Air Emissions," as well as in accordance with the quality principles of 10 CFR 830, "Nuclear Safety Management;" DOE Order 414.1D, *Quality Assurance*; and ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications*.

Under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) codified regulations as 40 CFR 61, Subpart H, by which to govern radionuclide emissions from DOE facilities. Those regulations impose a radiological dose standard of 10 mrem/yr EDE to the MEI, which is not to be exceeded. The regulations apply prescriptively to point-source radioactive material emissions yet are inclusive of fugitive emissions for compliance with the standard. Besides the Hanford Site complying with detailed point-source requirements in Subpart H, methods were developed for evaluating fugitive emissions. The methodology for this work was formalized in a Memorandum of Understanding ("Memorandum of Understanding Between the U.S. Environmental Protection Agency and the U.S. Department of Energy Concerning the Clean Air Act Emission Standards for Radionuclides 40 CFR Part 61 Including Subparts H, I, Q & T" [DOE 1995]) between DOE and EPA. Since then, dose estimates from fugitive emissions have been evaluated and reported annually as part of determining the compliance status of the Hanford Site to the dose standard. By reference, WAC 246-247 adopted this dose standard as well as requiring the reporting of radon emissions from Hanford Site sources and the resulting dose.

The EDE to the Hanford Site MEI due to routine and nonroutine emissions in 2016 from Hanford Site stacks is 0.038 mrem (0.00038 millisievert [mSv]). The MEI EDE from fugitive emissions at the Hanford Site in 2016 was 0.0060 mrem (0.000060 mSv) and from radon emissions, 0.026 mrem (0.00026 mSv). The total radiological dose for 2016 to the MEI from all Hanford Site radionuclide emissions was 0.070 mrem (0.00070 mSv), or less than 1 percent of the federal and state standard of 10 mrem/yr, with which the Hanford Site is in compliance.

Section 2.0 lists portions of the Hanford Site MEI dose attributable to individual point-sources (i.e., stacks). These doses by stack are appropriate for demonstrating the compliance status of abated stack emissions with applicable terms of the *Hanford Site Air Operating Permit* (AOP), which includes the *Hanford Site Radioactive Air Emissions License #FF-01* (FF-01).

For further information on this report, you may contact Eric Faust, U.S. Department of Energy, Richland Operations Office, by telephone at (509) 376-9607 or e-mail at Eric.Faust@rl.doe.gov.

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CERTIFICATION STATEMENT

DOE/RL-2017-17, REV. 0,
RADIONUCLIDE AIR EMISSIONS REPORT FOR THE HANFORD SITE, CALENDAR YEAR 2016

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.

Doug Shoop
Manager
U.S. Department of Energy
Richland Operations Office

6/29/17
Date

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TERMS

≤0	Analytical result that is equal to or less than the level of laboratory ambient background, is less than the analytical error, or no peak was detected, (i.e., radioactivity was not detected in the sample)
AOP	Air Operating Permit
BNI	Bechtel National, Inc.
Bq	becquerel [equals one nuclear disintegration per second]
CAP88-PC	Clean Air Act Assessment Package 1988-Personal Computer
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	Code of Federal Regulations
CHPRC	CH2M HILL Plateau Remediation Company
Ci	curie [equals 3.7×10^{10} Bq]
CSB	Canister Storage Building
CVDF	Cold Vacuum Drying Facility
CWC	Central Waste Complex
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DOE-ORP	U.S. Department of Energy, Office of River Protection
DOE-PNSO	U.S. Department of Energy, Pacific Northwest Site Office
DST	double-shell tank
EDE	effective dose equivalent
EDP	electronic data processing
Energy NW	Energy Northwest (and its Columbia Generating Station)
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ETF	200 Area Effluent Treatment Facility
FF-01	*Hanford Site Radioactive Air Emissions License #FF-01*
FFCA	Federal Facility Compliance Agreement
FFM	Far-Field Monitoring
FFTF	Fast Flux Test Facility
FUA	Facility Use Agreement
HEPA	high-efficiency particulate air (filter)
HT	elemental tritium
HTO	tritiated water
ISA	interim storage area
ISS	interim safe storage
LLBG	Low-Level Burial Ground
LIGO	Laser Interferometer Gravitational Wave Observatory
LSW	Laboratory Supply Warehouse

major	a radionuclide-emitting stack having a radiological dose potential of greater than 0.1 mrem/yr effective dose equivalent after all pollution-control equipment has been removed but operations are otherwise routine (a major stack can also be classified by way of a "potential impact category" [PIC] of PIC 1 or PIC 2), as defined in ANSI/HPS N13.1-1999, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*; this standard was reaffirmed in 2011
MASF	Maintenance and Storage Facility
MEI	maximally exposed individual
minor	a radionuclide-emitting stack having a radiological dose potential of less than or equal to 0.1 mrem/yr effective dose equivalent after all pollution-control equipment has been removed but operations otherwise are routine (a minor stack can also be classified by way of a "potential impact category" [PIC] of PIC 3 or PIC 4, as defined in ANSI/HPS N13.1-1999, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*; this standard was reaffirmed in 2011
MOU	Memorandum of Understanding
mrem	millirem [i.e., 1×10^{-3} rem]
MSA	Mission Support Alliance, LLC
mSv	millisievert [sievert = 100 rem]
NA	not applicable
ND	not detected
NEPA	*National Environmental Policy Act*
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFM	Near-Field Monitoring
NOC	Notice of Construction
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
PSF	Physical Sciences Facility
PUREX	Plutonium-Uranium Extraction (Plant)
QA	quality assurance
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	Reduction-Oxidation (S Plant)
rem	roentgen equivalent man
RPL	Radiochemistry Processing Laboratory
SNM	special nuclear material
SST	single-shell tank
TEDF	Treated Effluent Disposal Facility
WAC	*Washington Administrative Code*
WCH	Washington Closure Hanford, LLC
WDOH	Washington State Department of Health
WESF	Waste Encapsulation and Storage Facility
WRAP	Waste Receiving and Processing Facility
WRPS	Washington River Protection Solutions, LLC
WSCF	Waste Sampling and Characterization Facility
WSU	Washington State University
WTP	Waste Treatment and Immobilization Plant

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1.0 INTRODUCTION

This report documents radionuclide air emissions from the U.S. Department of Energy (DOE) Hanford Site in 2016, and the resulting effective dose equivalent (EDE) to the maximally exposed individual (MEI) member of the public. The report complies with reporting requirements in the Code of Federal Regulations (CFR), 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 in the Washington Administrative Code (WAC) Chapter 246-247, "Radiation Protection — Air Emissions." The report also is in accord with the quality principles of 10 CFR 830, "Nuclear Safety Management"; DOE Order 414.1D, *Quality Assurance*; and ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications*.

1.1 HANFORD SITE DESCRIPTION

The Hanford Site (Figure 1-1) is located in a rural region of southeastern Washington State, occupying an area of about 580 mi^2 (1,502 km^2). It lies about 200 mi (320 km) northeast of Portland, Oregon; 170 mi (270 km) southeast of Seattle, Washington; and 124 mi (200 km) southwest of Spokane, Washington. More in-depth discussions on the characteristics and activities at the Hanford Site are available in PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*, and DOE/RL-2017-24, *Hanford Site Environmental Report for Calendar Year 2016* [in press; scheduled availability is by the end of September 2017].

1.1.1 Historical Background

In 1943, the federal government acquired the land that became the Hanford Site, where facilities were constructed and operated as part of the atomic weapons program, which began during World War II. For more than 40 years, most facilities at the Hanford Site were dedicated to operations that produced plutonium for national defense and to managing the radioactive and chemical wastes generated from those production processes. In more recent years, defense programs have ceased while new programs have emerged. New programs include major efforts to clean up contamination in the environment and facilities resulting from past operational practices and the research and development of new and improved waste disposal technologies. Currently, two DOE Offices manage the programs at the Hanford Site. They are the U.S. Department of Energy, Richland Operations Office (DOE-RL) and the U.S. Department of Energy, Office of River Protection (DOE-ORP). The U.S. Department of Energy, Pacific Northwest Site Office (DOE-PNSO), manages the Pacific Northwest National Laboratory (PNNL), which has historic ties to the Hanford Site. PNNL staff currently occupy facilities within and adjacent to the Hanford Site.

1.1.2 Main Areas, Facilities and Activities

Five main operational areas at the Hanford Site actually or potentially generated radionuclide air emissions in 2016: the 100, 200, 300, 400, and 600 Areas (Figure 1-1). The 100 Areas have the deactivated 105-KW Spent Fuel Storage Basin and nine deactivated production reactors with support facilities, all located near the Columbia River. The 200 Areas are located on a plateau approximately 21.5 mi (34.7 km) northwest of the City of Richland, Washington, and 7 mi (11.3 km) from the Columbia River. Facilities in or adjacent to the 200 East Area include the Single-Shell Tank (SST) and Double-Shell Tank (DST) Farms, Canister Storage Building (CSB), Waste Encapsulation and Storage Facility (WESF), Plutonium Uranium-Extraction (PUREX) Plant, B Plant Complex, Waste Treatment and Immobilization Plant (WTP), 242-A Evaporator, 200 Area Effluent Treatment Facility (ETF), Treated Effluent Disposal Facility (TEDF), Low-Level Burial Grounds (LLBG), and the non-DOE U.S. Ecology Low-Level Burial Site. In

the 200 West Area are the Plutonium Finishing Plant (PFP), SST and DST Tank Farms, T Plant Complex, U Plant, Reduction-Oxidation (REDOX) Plant, 222-S Laboratory, Central Waste Complex (CWC), Waste Receiving and Processing Facility (WRAP), and the LLBG. The 300 Area, just north of the City of Richland, has research and development laboratories. The 400 Area has the deactivated Fast Flux Test Facility (FFTF), 8 mi (12.9 km) north of the City of Richland. The 600 Area has the Environmental Restoration Disposal Facility (ERDF), which is immediately east of the 200 West Area.

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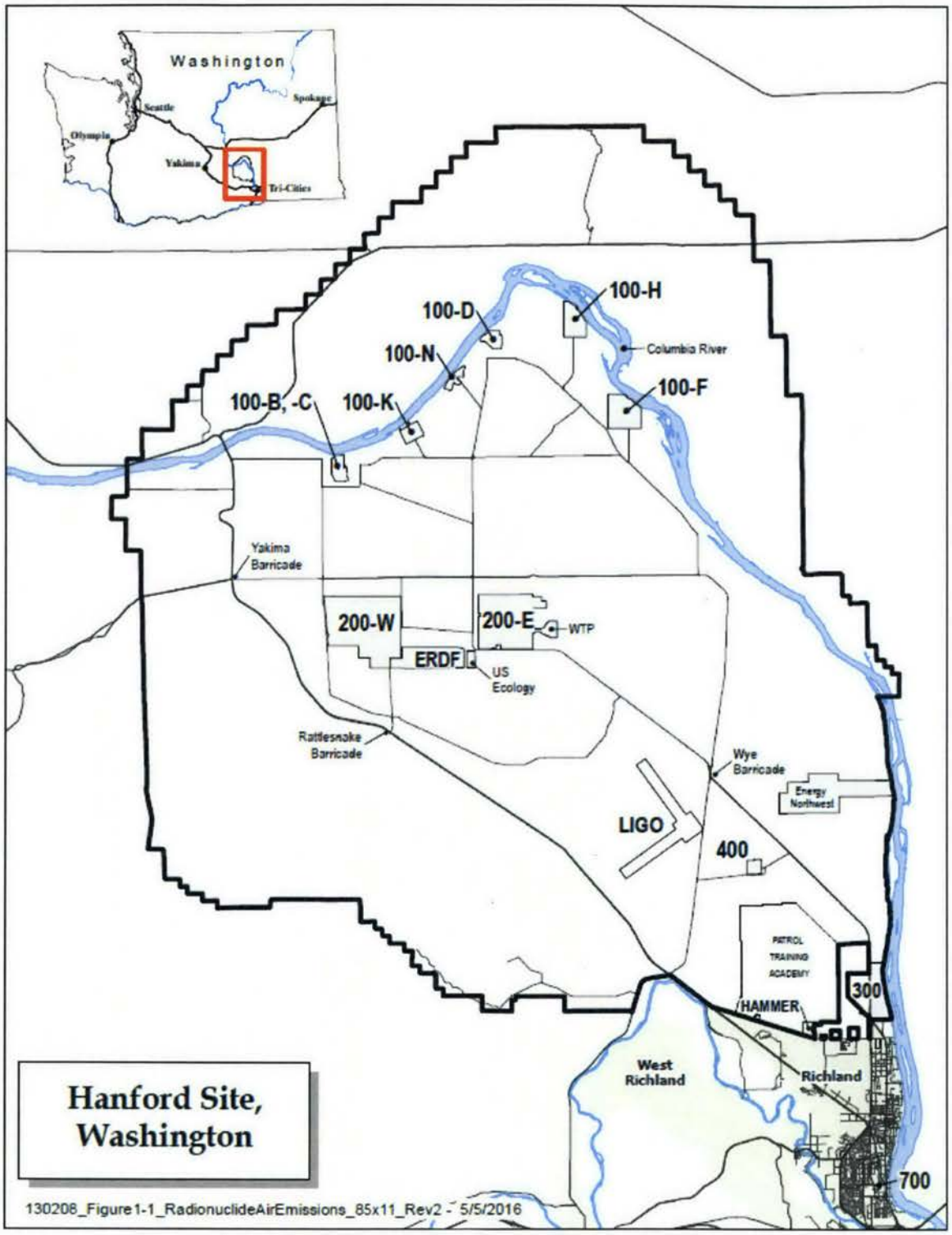
Figure 1-1. Hanford Site Map



Notable events in calendar year 2016 relevant to radioactive airborne emissions monitoring and reporting are summarized as follows:

- Environmental restoration activities continued along the river in the 100, 300, and 600 Areas of the Hanford Site. Contaminated soil and debris from inactive waste sites were excavated, transported, and disposed of at ERDF as well as at other appropriate locations. Activities were conducted in the 100 Areas designed to place the retired nuclear reactors in interim safe storage (ISS) pending their final disposition. Those activities include decontamination and decommissioning (D&D) of the reactors and of ancillary facilities, with notable work occurring at the N Reactor. Several facilities in the 300 and 400 Areas were decontaminated, decommissioned, and demolished.

- Waste from SSTs in the 200 Area Tank Farms was transferred to DSTs.

- Bechtel National, Inc. (BNI) continued construction of WTP. Four major facilities are being constructed: the Pretreatment Facility, the High-Level Waste Vitrification Facility, the Low-Activity Waste Vitrification Facility, and the Analytical Laboratory. Through 2016, WTP has received no radioactive material; thus, no radioactive airborne emissions were released as a result of construction in 2016.

- The 200 Area Interim Storage Area (ISA) continued storing spent fuel from non-defense production reactors in a dry-cask storage system.

- The WESF K3 Ventilation exhaust system was upgraded in support of Project W-130. The new K3N replacement-in-kind system is a skid-mounted, above ground system that exhausts through the existing 296-B-10 stack. The new system allowed for the commencement of stabilization of contamination in the old K3 duct, high-efficiency particulate air (HEPA) filter housing, filter pit, Hot Cells A through F and associated pipe trenches.

- The T Plant waste management activities supported the preparation for future receipt of KW Basin sludge for interim storage.

- At PFP facilities, deactivation and demolition work continued under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

- The 200 Area ETF received and processed radioactive hazardous aqueous waste.

- The 222-S Laboratory continued characterizing tank waste and supporting Hanford operational and remediation projects.

1.1.3 Prime Contractors

The DOE-RL prime contractors, along with their management responsibilities, are briefly described in this section.

- **CH2M HILL Plateau Remediation Company**. CH2M HILL Plateau Remediation Company (CHPRC) manages the Plateau Remediation Contract at the Hanford Site. Summarized here are the principal contractual goals CHPRC is committed to advancing:

Environmental remediation, decontamination, and decommissioning of facilities on the Central Plateau in the 200 Areas, where five chemical separations plants and other facilities separated and recovered plutonium and other materials used for national defense, including specifically decontamination and demolition of facilities at PFP; groundwater characterization, monitoring, and remediation; site-wide drilling management; characterizing of facilities and waste sites; disposal activities of non-tank farm waste; environmental surveillance and maintenance; managing operations at the Cold Vacuum Drying Facility (CVDF), CSB, ISA, WRAP, FFTF, CWC, LLBG, WESF, and the T Plant Complex, and as applicable the decontamination and demolition of facilities such as the 105-KW Spent Fuel Storage Basin and PFP; monitoring liquid effluents and air emissions; the surveillance and maintenance of inactive facilities on the Central Plateau, such as the PUREX Facility, B Plant Complex, and REDOX Complex; and developing regulatory documents for activities related to groundwater, soil, and facilities. In February of 2016 CHPRC received the following work scope at the closure of the Washington Closure Hanford (WCH) contract: management of the 324 Building; the completion of the remediation of the 618-10 Burial Ground; and management of ERDF.

- **Mission Support Alliance, LLC**. Mission Support Alliance, LLC (MSA) is the Hanford Site "integrating contractor," responsible for fulfilling the Mission Support Contract goals, which include managing these five primary functions at the Hanford Site: safety, security, and the environment; site infrastructure and utilities; site business management; information resources and content management; and portfolio management.

- **Washington Closure Hanford, LLC**. Washington Closure Hanford, LLC (WCH) managed the River Corridor Closure Project for DOE-RL until the end of their contract in February 2016. That scope of work included surveillance and maintenance of inactive past-practice waste sites and of inactive facilities; remediation of past-practice waste sites pursuant to CERCLA; closure of *Resource Conservation and Recovery Act of 1976* (RCRA) land-based treatment, storage, and disposal units; and the deactivation, decontamination, decommissioning, and demolition of facilities pursuant to CERCLA. The remaining scope of work: management of the 324 Building; the completion of the remediation of the 618-10 Burial Ground; and management of ERDF; has been reassigned to the CHPRC.

The DOE-ORP prime contractors at the Hanford Site are identified next, along with their management responsibilities and the facilities they oversee that have or have had radionuclide air emissions.

- **Bechtel National, Inc**. The mission of Bechtel National, Inc. (BNI) is to design, build, and commission WTP to vitrify tank waste at the Hanford Site. This project includes a pretreatment facility to separate the radioactive tank waste into high-level waste and low-activity waste. The High-Level Waste Vitrification Facility and the Low-Activity Waste Vitrification Facility both will immobilize the waste in a glass form encased in canisters.

- **Washington River Protection Solutions, LLC**. Washington River Protection Solutions, LLC (WRPS) manages the tank farms for DOE-ORP. These responsibilities include storing and retrieving for treatment of approximately 56 million gallons of highly radioactive and hazardous waste stored in 177 underground tanks; characterizing the waste; and eventually delivering the waste to an under-construction vitrification facility at which the waste will be converted into a glass-like substance for permanent disposal. WRPS also operates the 222-S Radioanalytical Laboratory, to support the sampling and characterization of tank waste, and operates the ETF, Liquid Effluent Retention Facility (LERF), and TEDF. Wastren Advantage Inc., as a prime

contractor to ORP, manages the 222-S Laboratory, where sample receiving, analyzing, and storing is performed, as well as special tests related to the most radioactive and hazardous chemical wastes at the Hanford Site.

The DOE-PNSO prime contractor at the Hanford Site is identified next, along with its management responsibilities and the facilities it oversees that have or previously had radionuclide air emissions.

- **Battelle Memorial Institute**. Battelle Memorial Institute operates PNNL for DOE-PNSO. PNNL staff perform research and development in the physical, chemical, life, and environmental sciences; investigate advanced methods of nuclear waste management; and conduct applicable liquid effluent and emission monitoring at the DOE facilities it manages.

Some privately or publicly owned facilities capable of generating airborne radioactive emissions are located at or near the Hanford Site. These facilities include (1) a low-level waste burial site operated by U.S. Ecology on the 200 Area plateau; (2) Energy Northwest Columbia Generating Station (Energy NW) commercial nuclear power reactor and office buildings, near the Columbia River, north of the 300 Area and east of the 400 Area; (3) TestAmerica Richland, south of the 300 Area; (4) AREVA Federal Services LLC fuel fabrication facility, adjacent to the Hanford Site southern boundary; (5) Perma-Fix Northwest, Inc., adjacent to the east side of the AREVA Federal Services LLC; (6) Unitech Services, Inc., located 1 mi (1.6 km) south of the southern boundary of the Hanford Site; and (7) the DOE-PNSO PNNL Richland Campus, which includes the PNNL Site and Battelle's research laboratories located in north Richland, Washington. Emissions from these facilities are not included in this report because they are not regulated as part of the Hanford Site.

1.2 STACK DESCRIPTIONS

This section includes descriptions of radionuclide-emitting stacks and vents (from hereon, *stack* will also mean *vent*, or other ducted-flow equipment as well, unless "vent" is used as a proper name) that are actively exhausted when in operation, as opposed to passively ventilated. A stack is reported in this document if in 2016 it met the following four criteria: (1) required continuous monitoring or periodic confirmatory measurements (which can include, in lieu of conventional emission sampling and analysis, the calculational use of factors in 40 CFR 61, Appendix D) in accordance with 40 CFR 61, Subpart H, and with WAC 246-247; (2) was described in the *Hanford Site Radioactive Air Emissions License #FF-01* (FF-01); (3) emitted or had the potential- to-emit radionuclides; and (4) is a stack, vent, or otherwise ducted flow that was monitored via emission sampling equipment.

Air emissions from other sources of radioactive materials are reported in Sections 4.0 and 5.0. Fugitive emissions from those sources were estimated using methods described in Section 4.0.

1.2.1 General Description and Reporting Criteria

Radionuclide air emissions from stacks are generally discharged from stacks and vents. Stack sizes, shapes, and discharge paths vary because of facility requirements at the time of construction. Discharge heights range from nearly ground level to 200 ft (61 m), and flow rates range from about 30 ft^3/min (0.014 m^3/s) to 290,000 ft^3/min (137 m^3/s). Stacks vary in design from horizontal to vertical, rectangular to cylindrical, actively to passively ventilated, and permanent to portable.

A longstanding practice of Hanford Site contractors, DOE, and regulators is to refer to emission sources as "major" or "minor" with respect to the potential radiological dose that would result from unabated emissions under normal operating conditions. A key example of this practice is evidenced in the FF-01

section of the Hanford Site Air Operating Permit. Whether point (including stacks) or fugitive, every emission source identified in the FF-01 is defined as either major or minor. Numerous other predicating documents, such as letters from WDOH, EPA, DOE-RL, and Hanford Site contractors refer to stacks in this manner. A major emission source is defined thusly: When in the hypothetical absence of all pollution control equipment its potential maximum emissions can cause a dose greater than 0.1 millirem (mrem)/yr EDE to a member of the public who lives near and/or has unrestricted access to a place of employment on the Hanford Site. An emission source is designated minor when under the same hypothetical conditions it cannot cause a dose greater than 0.1 mrem/yr EDE. The level of monitoring and quality-assurance requirements imposed on the operation of a stack depends on which of the two definitions is imposed.

Even though it continues to be routine to use the terms *major* and *minor* in conversation and written communication, another set of stack definitions is valid. This set is known as the Potential Impact Category (PIC), of which four (and perhaps more contingent on licensing agreements) levels of potential dose ranges have been delineated. Table 1-1 shows these four PICs; the table is a replica of Table 2 in *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*, ANSI/HPS N13.1–1999 (reaffirmed without change in 2011). PICs apply only to stacks, not fugitive emission sources.

Table 1-1. Graded Approach to Sampling and Monitoring

Potential Impact Category (PIC)	Monitoring and Sample Analysis Procedures	Potential Fraction of Allowable Limit
1	Continuous sampling for a record of emissions and in-line, real time *[sic]* monitoring with alarm capability; consideration of separate accident monitoring system	>0.5
2	Continuous sampling for record of emissions, with retrospective, off-line periodic analysis	>0.01 and ≤0.5
3	Periodic confirmatory sampling and off-line analysis	>0.0001 and ≤0.01
4	Annual administrative review of facility uses to confirm absence of radioactive materials in forms and quantities not conforming to prescribed specifications and limits	≤0.0001

PICs have not been applied to a number of stacks because they are grandfathered under an older standard, *American National Standard Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities,* ANSI N13.1-1969 (N13.1-1969), published years before PICs were developed for inclusion in N13.1-1999, which was adopted for use in 2002. Also, stacks whose operations are governed by CERCLA regulations are not subject to PICs. Where applicable in the stack descriptions that follow, the associated PIC will be listed. However, in Tables 2-1 and 2-2, the terms *major* and *minor* will be retained as the primary stack categories. In subsequent reports, those tables may display the stack PIC if the use of PICs becomes more commonplace, or clearly preferred over major and minor.

The following principal emission abatement devices were used singly or in combination to remove radioactive constituents from most stack emissions during 2016: (1) HEPA filters, (2) sand filters, (3) deep-bed fiberglass filters, (4) fiberglass prefilters, and (5) charcoal adsorbers. Generally, one to three stages of HEPA filtration were used as the final particulate-removal method before an air emission

stream was exhausted to the atmosphere. Other emission abatement technology employed at stacks includes: demisters, deentrainers, moisture separators, water chillers, condensers, evaporative towers, isolation and backdraft dampers, and so on (see Tables 2-3 and 2-4 for a listing of emission abatement technology employed at each stack).

1.2.2 100 Area Facilities

The 100 Areas contain nine inactive production reactors and their associated support facilities. Many of the reactors have been placed in ISS and many associated support facilities demolished. The only active radionuclide-emitting stacks are at facilities in the 100-K Area. Those stacks are briefly described below and their locations illustrated in Figure 1-2.

1.2.2.1 100-K Areas

Located in this area is CVDF, along with various ancillary structures. Currently under CERCLA management are two retired reactors awaiting decommissioning; one remaining storage basin, originally of two, which previously stored irradiated nuclear fuel under water; and various supporting structures.

105-KW Unfiltered air from the spent-fuel storage basin in the 105-KW Building exhausts via two CERCLA minor vents on the building roof. In 2016, both vents were operational and particulate emissions were sampled.

105-KW Air Sparging Vent Air associated with the work area of the 105-KW Integrated Water Treatment System passively moves back and forth through this vent equipped with a single HEPA filter; the vent is treated as a CERCLA major emission point source. In 2016, this vent was operational and particulate emissions were sampled.

Note: Analysis results are shown in Table 5-2, not Table 2-1 for stack data, because the vent does not have concentration and release values based on flow rates, which cannot be measured at the vent due to the bi-directional nature of the continual passive air exchange.

296-K-142 This CERCLA minor stack at the CVDF did not operate in 2016; however, emissions are reported herein in accordance with an agreement CHPRC has with WDOH. Because the stack did not operate, its calculated release is treated as a fugitive emission, and any impact from actual emissions accounted for in the sitewide fugitive-dose calculation.

1.2.3 200 East Area Facilities

The 200 East Area contains facilities formerly operated for chemical separations and reprocessing. Some facilities are currently supporting waste handling and disposal while others are being managed under surveillance and maintenance status. Locations of radionuclide air emission discharge points in the 200 East Area are illustrated in Figure 1-3. The monitored radionuclides emitted from the 200 Areas are in particulate form, apart from the volatile long-lived radionuclide ^{129}I sampled at the PUREX Plant.

1.2.3.1 Plutonium-Uranium Extraction Facility

The PUREX Facility was used to separate plutonium from spent nuclear fuel. The facility was deactivated in June 1997 and is currently managed under a surveillance and maintenance status.

291-A-1 This N13.1-1969 major stack exhausts filtered air from the canyon. In 2016, this stack was operational and emissions were sampled for particulate radionuclides and for ^{129}I, a volatile radionuclide.

1.2.3.2 B Plant Complex

The B Plant Complex separated plutonium from spent nuclear fuel, but its operations were later reconfigured to remove ^{90}Sr and ^{137}Cs from highly radioactive liquid waste. The main canyon building, 221-B, contains radioactive contamination from various production campaigns, primarily contained in concrete walls. The B Plant Complex, excluding WESF, was deactivated in 1998 and is currently managed under surveillance and maintenance status.

296-B-1 This N13.1-1969 major stack exhausts filtered air from the main canyon and process cells in the 221-B Building, the process cell in the 212-B Building, and the 224-B Building via a vessel vent. In 2016, this stack operated and particulate emissions were sampled.

1.2.3.3 Waste Encapsulation and Storage Facility

At WESF, ^{90}Sr and ^{137}Cs from waste separations material were converted to solid strontium fluoride and cesium chloride, respectively. Those cesium and strontium compounds were separately double-encapsulated and placed in water-filled storage basins at WESF. The current mission for WESF is to continue storing these radioactive capsules and maintaining the process portion of the facility.

296-B-10 This PIC 1 major stack exhausts filtered air from the 225-B Building. In 2016, this stack operated and particulate emissions were sampled.

1.2.3.4 200 East Area Tank Farms

Radioactive waste stored in Tank Farms consists of sludge and saltcake in SSTs, and liquids and slurry in DSTs.

296-A-18 This minor stack exhausts filtered air from the 241-AY-101 Tank annulus. In 2016, this stack operated and particulate emissions were sampled.

296-A-19 This N13.1-1969 major stack exhausted filtered air from the 241-AY-102 Tank annulus. Particulate emissions were sampled prior to permanently shutting down April 13, 2016.

296-A-20 This minor stack exhausts filtered air from the 241-AZ-101 and -102 Tank annuli. In 2016, this stack operated and particulate emissions were sampled.

296-A-28 This minor stack exhausts filtered air from the tank annuli in the 241-AW Tank Farm. In 2016, this stack operated and particulate emissions were sampled.

296-A-30 This minor stack exhausts filtered air from the tank annuli in the 241-AN Tank Farm. In 2016, this stack operated and particulate emissions were sampled.

296-A-40 This N13.1-1969 minor stack exhausted filtered air from the 241-AP tanks. In 2016, this stack operated and particulate emissions were sampled prior to permanently ceasing operations September 8, 2016.

296-A-41 This minor stack exhausts filtered air from the tank annuli in the 241-AP Tank Farm. In 2016, this stack operated and particulate emissions were sampled.

296-A-42 This N13.1-1969 major stack exhausts filtered air from the tanks in the 241-AY and 241-AZ Tank Farms. In 2016, this stack operated and particulate emissions were sampled.

296-A-43 This N13.1-1969 minor stack exhausts filtered building ventilation air from the 702-AZ Building. In 2016, this stack operated and particulate emissions were sampled.

296-A-44 This PIC 1 major stack exhausts filtered air from the 241-AN tanks and operates in conjunction with the 296-A-45 stack. In 2016, this stack operated and particulate emissions were sampled.

Note: In Table 2-1, emission and dose data for these two stacks are combined because they exhaust the same tanks.

296-A-45 This PIC 1 major stack exhausts filtered air from the 241-AN tanks and operates in conjunction with the 296-A-44 stack. In 2016, this stack operated and particulate emissions were sampled.

Note: In Table 2-1, emission and dose data for these two stacks are combined because they exhaust the same tanks.

296-A-46 This PIC 1 major stack exhausts filtered air from the 241-AW tanks and operates in conjunction with the 296-A-47 stack. In 2016, this stack operated and particulate emissions were sampled.

Note: In Table 2-1, emission and dose data for these two stacks are combined because they exhaust the same tanks.

296-A-47 This PIC 1 major stack exhausts filtered air from the 241-AW tanks and operates in conjunction with the 296-A-46 stack. In 2016, this stack operated and particulate emissions were sampled.

Note: In Table 2-1, emission and dose data for these two stacks are combined because they exhaust the same tanks.

296-A-48 This newly operational PIC 1 major stack exhausts filtered air from the 241-AP tank and operates in conjunction with the 296-A-49 stack. This stack initiated operations September 22, 2016 and particulate emissions were sampled.

Note: In Table 2-1, emission and dose data for these two stacks are combined because they exhaust the same tanks.

296-A-49 This newly operational PIC 1 major stack exhausts filtered air from the 241-AP tanks and operates in conjunction with the 296-A-48 stack. This stack initiated operations September 22, 2016 and particulate emissions were sampled.

Note: In Table 2-1, emission and dose data for these two stacks are combined because they exhaust the same tanks.

296-P-47 This PIC 1 major stack, a portable exhauster, was used in support of waste retrieval from tank C-111. In 2016, this stack operated and particulate emissions were sampled prior to permanently ceasing operations June 30, 2016.

296-P-48 This PIC 1 major stack, a portable exhauster, did not operate in 2016.

296-P-107 This PIC 1 major stack, a portable exhauster, is used to support waste retrieval in tanks C-101, C-102, and C-105. In 2016, this stack operated and particulate emissions were sampled.

1.2.3.5 242-A Evaporator

The 242-A Evaporator is used to remove liquid from DST liquid mixed waste to produce a more concentrated waste stream, which gets transferred back to the Tank Farms. Two waste processing campaigns were conducted in 2016.

296-A-21A This PIC 3 minor stack exhausts filtered air from the 242-A Building. In 2016, this stack operated and particulate emissions were sampled.

296-A-22 This N13.1-1969 minor stack exhausts filtered air from the 242-A Evaporator vessel ventilation system. During 242-A Evaporator campaigns, continuous sampling is required as well as measurement of radionuclides that could contribute greater than 10 percent of the potential total EDE defined in the applicable Notice of Construction (NOC). During non-campaign periods, the requirement is that only one sample a quarter be collected and analyzed for gross alpha and gross beta. In 2016, this stack operated and particulate emissions were sampled.

1.2.3.6 200 Area Effluent Treatment Facility

ETF treats mixed aqueous waste streams prior to their disposal at the State-Approved Land Disposal Site, also designated as the 616-A Crib.

296-E-1 This N13.1-1969 minor stack exhausts filtered air from the 2025-E Building and ETF processing vents. In 2016, this stack operated and particulate emissions were sampled.

1.2.3.7 Canister Storage Building

This facility stores irradiated fuel primarily from the 100-K Spent Fuel Storage Basins. The fuel is contained in specially engineered canisters housed in storage tubes within the facility. Before the 100-K fuel was received at CSB, it passed through the CVDF, where it was dried and packaged in canisters for shipment.

296-H-212 This PIC 1 major stack exhausts filtered air from the 212-H Building. In 2016, this stack operated and particulate emissions were sampled.

1.2.4 200 West Area Facilities

The 200 West Area contains facilities for laboratory analysis, for waste handling and disposal, and formerly for chemical separations and processing. Locations of radionuclide air emission discharge points in the 200 West Area are illustrated in Figure 1-4.

1.2.4.1 Reduction-Oxidation Plant

The Reduction-Oxidation Plant, or REDOX, for short, commonly referred to as the 202-S Building and/or as S Plant, operated as a fuel reprocessing facility until it was shut down in 1967. It is currently in a surveillance and maintenance status.

291-S-1 This N13.1-1969 minor stack exhausts filtered air from the REDOX canyon. In 2016, this stack operated and particulate emissions were sampled.

1.2.4.2 T Plant Complex

The T Plant Complex consists of two main structures: the 221-T Building and the 2706-T Building. The 221-T Building is one of the original fuel-processing facilities. The last fuel processed at the 221-T Building was in 1956. Both the 221-T Building and the 2706-T Building are now used for the treatment, storage, repackaging, sampling, and verification of waste containers. Liquid waste was treated and stored in tank systems and radioactively contaminated equipment decontaminated in both structures.

291-T-1 This PIC 1 major stack exhausts filtered air from the 221-T Canyon and process ventilation system. Previously, the 224-T Process Cell emissions were exhausted from the 291-T-1 stack. The 224-T Process Cell emissions are now captured in the diffuse and fugitive license collected by the Near Facility Air Monitoring network of samplers. In 2016, this stack operated and particulate emissions were sampled.

296-T-7 This N13.1-1969 minor stack exhausts HEPA-filtered air from the 2706-T and 2706-TA Buildings when activities with the potential to increase airborne contamination (decontamination, treatment, storage, sampling, etc.,) are underway. Unless remediation activities are being performed, this stack does not operate. In 2016, this stack operated and particulate emissions were sampled.

1.2.4.3 Plutonium Finishing Plant

The original mission of the PFP was to produce plutonium metal from plutonium nitrate received from other onsite facilities such as T Plant, B Plant, REDOX, and PUREX. Subsequent missions, including the recovering of plutonium (in the form of plutonium nitrate), from plutonium scrap, the safe and secure storage of special nuclear material (SNM), and most recently, a significant cleanup effort to

decontaminate the facility, have ended. The current and final mission, designated as the PFP Closure Project, is underway and includes activities for the safe and compliant demolition, down to the facility's foundation, thus eliminating major hazards onsite and reducing the costs of safe and secure surveillance.

291-Z-1 This CERCLA major stack exhausts filtered air from the 234-5Z, 236-Z, and 242-Z Buildings. In 2016, this stack operated and particulate emissions were sampled.

1.2.4.4 200 West Area Tank Farms

Tank farms located in the 200 West Area hold high-level radioactive waste consisting of sludge/saltcake in SSTs and liquids/slurry in DSTs.

296-P-22 This minor stack exhausts filtered air from annuli in the 241-SY-101, -102, and -103 Tanks. In 2016, this stack operated and particulate emissions were sampled.

296-P-23 This minor stack exhausted filtered air from tanks 241-SY-101, -102, and -103. Operation of this stack (designated as "B" train), alternates in conjunction with the 296-S-25 stack (designated as "A" train). In 2016, this stack operated and particulate emissions were sampled.

Note: In Table 2-2, emission and dose data for these two stacks are combined in Table 2-2 because they exhaust the same tanks.

296-P-43 This N13.1-1969 major stack, a portable exhauster, did not operate in 2016.

296-P-44 This N13.1-1969 major stack, a portable exhauster, did not operate in 2016.

296-P-45 This PIC 1 major portable exhauster emitted filtered air from tanks in the 241-T-111 tank farm in 2016. In 2016, this stack operated and particulate emissions were sampled.

296-S-25 This minor stack exhausted filtered air from tanks 241-SY-101, -102, and -103. Operation of this stack (designated as "A" train) alternated with 296-P-23 (designated as "B" train). In 2016, this stack operated and particulate emissions were sampled.

Note: Emission and dose data for these two stacks are combined in Table 2-2 because they exhaust the same tanks.

1.2.4.5 200 West Area Evaporators

Two evaporators are in the 200 West Area: the 242-S Evaporator-Crystallizer Building and the 242-T Evaporator-Crystallizer Building. Both of these evaporators were shut down in the early 1980s. The evaporators were designed to remove most of the water from radioactive liquid waste, with the resulting slurry then rerouted to the Tank Farms for interim storage.

296-S-18 This minor stack did not operate in 2016. When it did operate, it exhausted filtered air from the 242-S Evaporator-Crystallizer Building and particulate emissions were sampled.

1.2.4.6 222-S Laboratory

The 222-S Laboratory provides chemical and radiochemical analytical support for Tank Farm waste characterization, research and development, environmental sample analysis, and Hanford operation and remediation projects.

296-S-16 This minor stack exhausted filtered air from the 219-S Waste Handling Facility waste tanks. In 2016, this stack operated and particulate emissions were sampled.

296-S-21 This PIC 2 major stack exhausted filtered air from 222-S Laboratory hoods, gloveboxes, hot-cells, and room ventilation system. In 2016, this stack operated and particulate emissions were sampled.

296-S-23 This minor stack exhausted filtered air from the 219-S Waste Handling Facility Sample Gallery Hood. To verify low emissions from this stack, nondestructive analysis of the primary HEPA filter is performed every odd-numbered calendar year.

Note: Analysis results are presented in Table 5-1, not Table 2-2 where other minor stack data are reported. However, being this report documents emissions for an even-numbered year, no analytical results are included.

1.2.4.7 Waste Receiving and Processing Facility

WRAP is used for examining, assaying, characterizing, and repackaging waste, principally transuranic waste.

296-W-4 This PIC 1 major stack exhausted filtered air from WRAP. In 2016, this stack operated and particulate emissions were sampled.

1.2.5 300 Area Facilities

The 300 Area consists primarily of laboratories, research facilities, and inactive facilities associated with prior Hanford Site missions. Many of these facilities have been demolished as part of CERLCA cleanup activities conducted in the 300 Area. Locations of emission points in the 300 Area are illustrated in Figure 1-5.

1.2.5.1 324 Waste Technology Engineering Laboratory

The building contains laboratories that were used for chemical and process development activities, and is now undergoing clean-out and deactivation under CERCLA.

EP-324-01-S This CERCLA major stack exhausted filtered building air. In 2016, this stack operated and particulate emissions were sampled.

1.2.5.2 325 Radiochemical Processing Laboratory

The Radiochemical Processing Laboratory (RPL) manages radioactive inventory to the room, area, and building. The RPL has the capacity for handling Type I and Type II sealed radioactive materials sources, sealed sources, unsealed radioactive sources in the form of fissionable materials, SNM, and high-toxicity radioactive materials. Inventory of these materials shall not exceed the allowable limits of a Facility Use Agreement (FUA). The building is operated as a major emission unit and ventilated through a series of HEPA filters. Its emissions were sampled by silica gel and record samples.

EP-325-01-S This PIC 1 major stack exhausted filtered building air. In 2016, emissions were sampled using a record particulate sampler and a tritium sampler.

1.2.5.3 331 Life Sciences Laboratory I

The Life Sciences Laboratory I has the capacity for handling Type I and Type II sealed-source radioactive materials and unsealed radioactive sources such as fissionable materials and SNM. Inventory of these materials shall not exceed the allowable limits of an FUA.

EP-331-01-V This PIC 1 major vent exhausted filtered building ventilation air through single-stage HEPA filters. In 2016, particulate emissions were sampled by use of record samples.

EP-331-09-S Emissions reported as emanating from this PIC 4 minor stack were determined using calculations based on Appendix D of 40 CFR 61.

1.2.6 400 Area Facilities

The 400 Area consists of the deactivated FFTF, the Maintenance and Storage Facility (MASF), and the Fuels Materials Examination Facility. Locations of 400 Area emission points are illustrated in Figure 1-6.

1.2.6.1 Fast Flux Test Facility

Deactivation of FFTF was completed in June 2009. Located in the 400 Area, it formally operated as a 400–megawatt thermal, sodium-cooled, low-pressure, high-temperature reactor plant, which had been constructed for irradiation testing of breeder reactor fuels and materials.

FFTF-CB-EX This N13.1-1969 minor stack, also referred to as the Combined Exhaust, is the subject of a continuing agreement with the Washington State Department of Health (WDOH). The agreement allows the discontinuance of emission sampling and in its place the use of calculated emissions based on residual contamination within the FFTF primary piping systems to estimate radioactive material emitted annually.

1.2.6.2 Maintenance and Storage Facility

MASF, or the 437 Building, is a multipurpose service center supporting the specialized maintenance and storage requirements of FFTF. MASF provides the capability for decontamination, repair, and storage of non-fueled components and hardware for FFTF, as well as housing mockups and related training for such actions as 100-K basin sludge retrieval.

437-MN&ST This N13.1-1969 minor stack exhausted filtered air from MASF. In 2016, this stack operated and particulate emissions were sampled.

437-1-61 This N13.1-1969 minor stack exhausted filtered air from MASF. In 2016, this stack operated and particulate emissions were sampled.

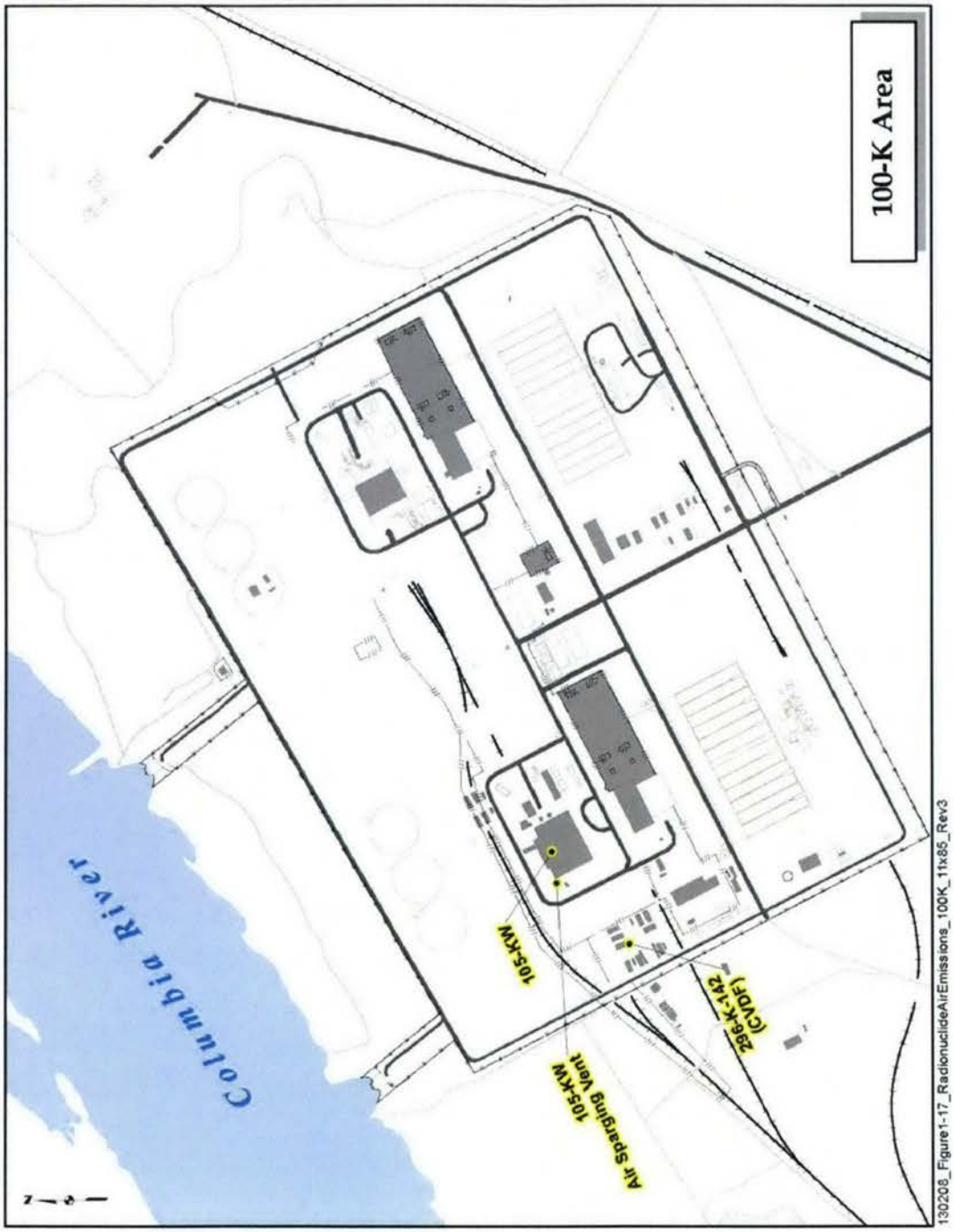


Figure 1-2. 100-K Area Radionuclide-Emitting Stacks

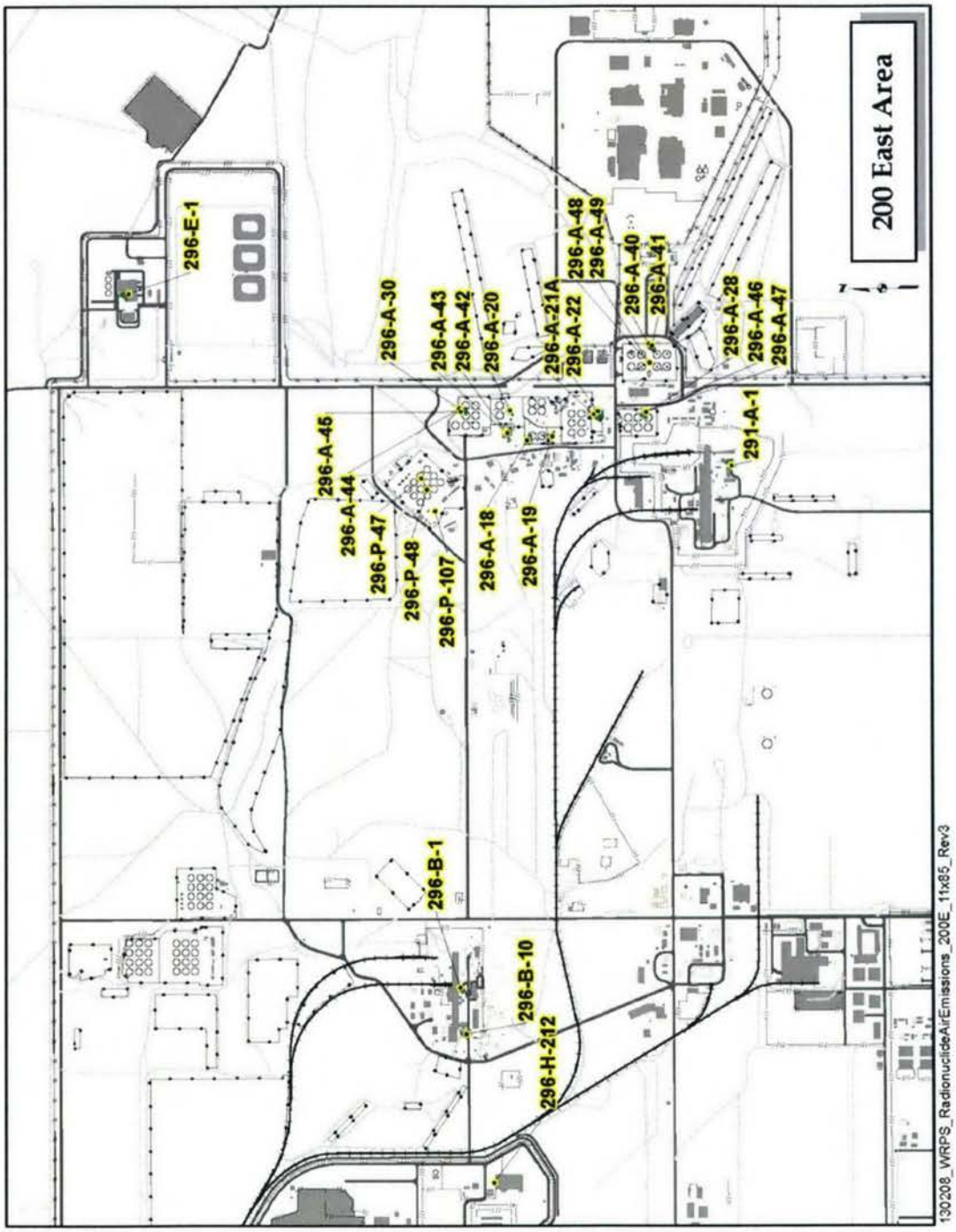


Figure 1-3. 200 East Area Radionuclide-Emitting Stacks

Figure 1-4. 200 West Area Radionuclide-Emitting Stacks

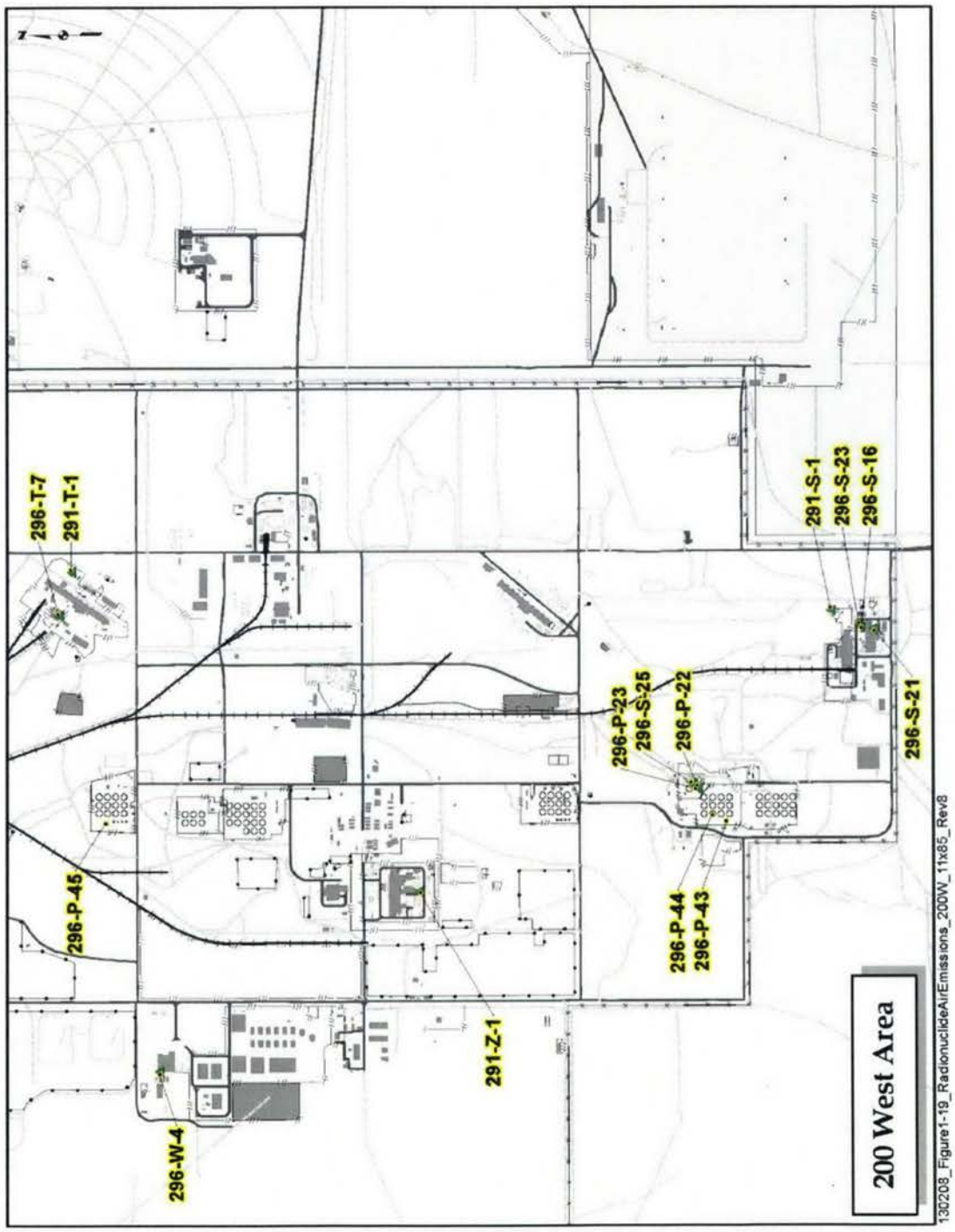


Figure 1-5. 300 Area Radionuclide-Emitting Stacks

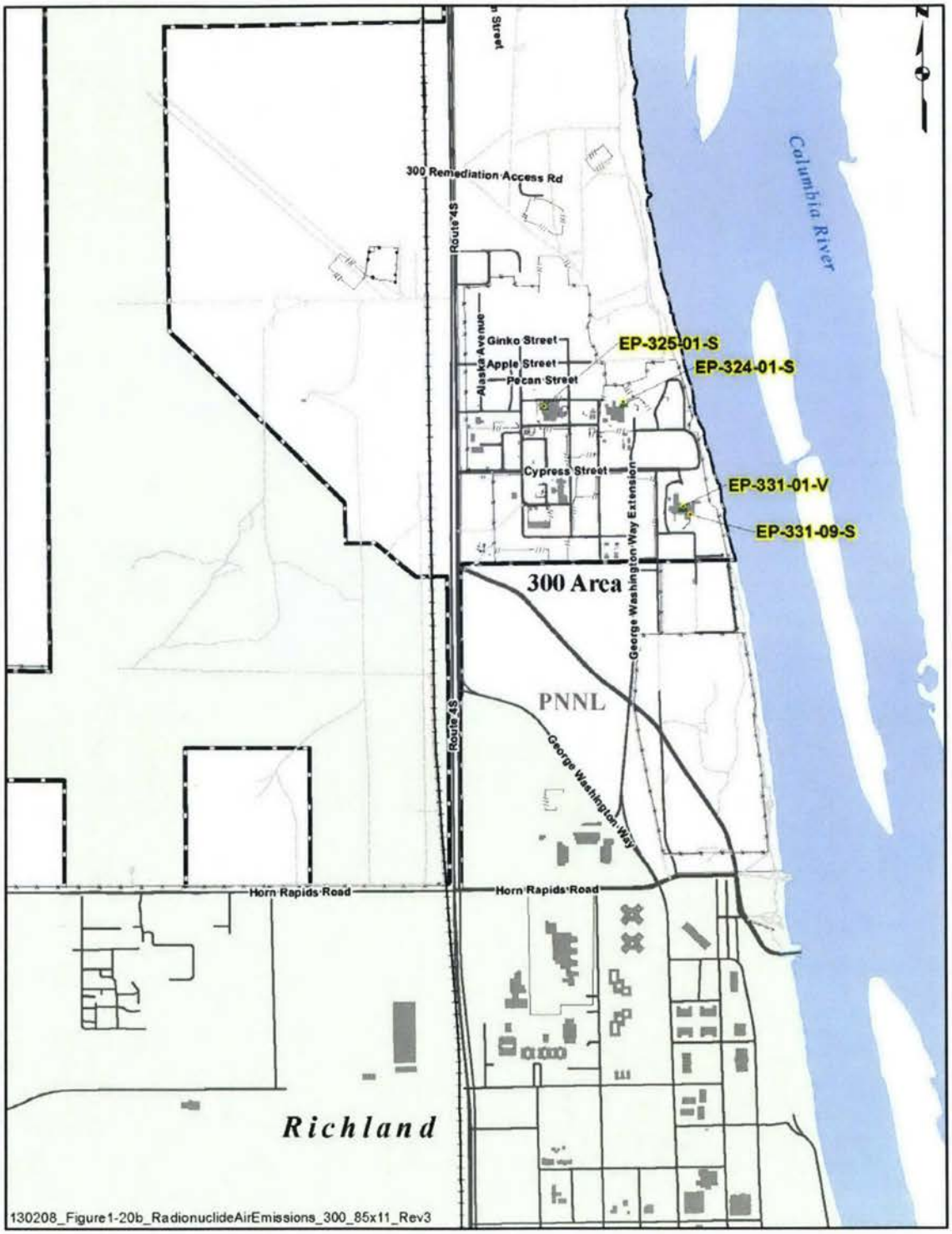
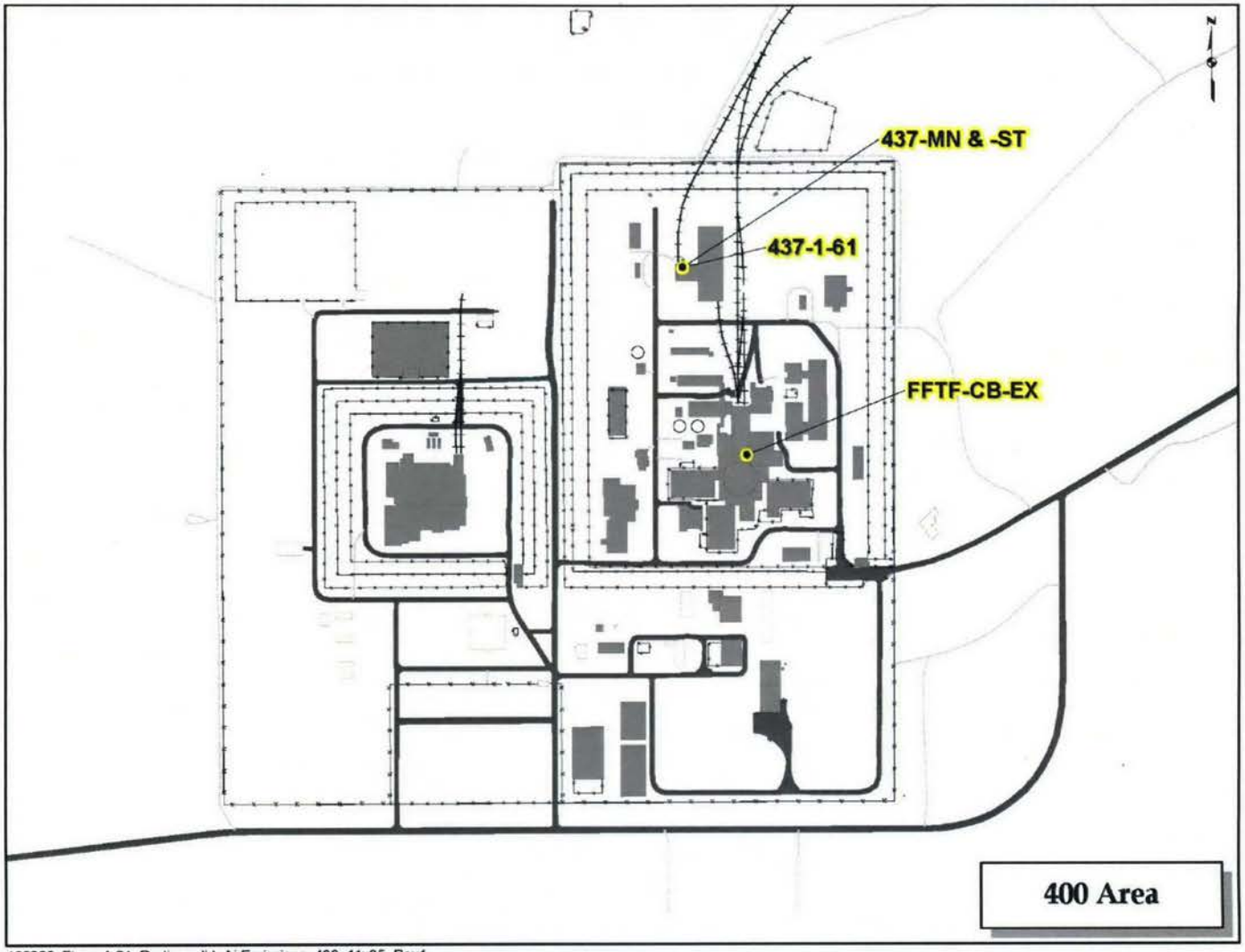


Figure 1-6. 400 Area Radionuclide-Emitting Stacks



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2.0 STACK RADIONUCLIDE AIR EMISSION DATA

This section presents information on radionuclide-emitting stacks at the Hanford Site. The stacks listed are actively ventilated, using electrically powered exhausters from which emissions are discharged under controlled conditions. The criteria for reporting stack emissions in this report are in Section 1.2. Data on radionuclides emitted from stacks in 2016 are shown in Tables 2-1 and 2-2.

Tables 2-1 and 2-2 display emission data of 22 major and 23 minor stacks, respectively, which operated during 2016. Several stacks listed did not operate in 2016. The data include total releases in 2016 of radionuclides or types of radioactivity from each stack and the consequent radiological doses from those releases. Tables 2-3 and 2-4 present information on stack heights and in-place abatement technology.

Each stack is assigned to the major operational area in which it is located (i.e., 100, 200 East, 200 West, 300, or 400 Areas). For each of the operational areas, a nearest location (e.g., dwelling, business [which can be on an unrestricted area of the Hanford Site], school, or office) relative to that area is determined for a real or hypothetical public receptor who has the potential of receiving the maximum exposure to emissions from that area. A common distance to that nearest public receptor is applied to each of the emission points within an operational area; for dose modeling, the two stacks in the 600 Area are treated as though located in the 200 West Area. Thus, each of the five operational areas has assigned to it a respective location of a nearest public receptor. Radioactive doses calculated for these receptors are used to determine the regulatory category of each stack (i.e., whether it is major or minor) as well as requisite monitoring requirements. Information on these nearest receptors is in Table 2-5, including distances to the nearest farms that produce milk, meat, and vegetables.

In contrast to the five nearest public receptors is the Hanford Site MEI, a member of the public who hypothetically receives the highest calculated radiological dose attributable to exposure to all combined emissions from the Hanford Site in one calendar year. Selection of the annual MEI is contingent on the MEI's place of residence or employment. (**Note:** A place of business may be at a location on the Hanford Site to which access is unrestricted, such as the Laser Interferometer Gravitational Wave Observatory [LIGO]). Emission data used in the calculations represent those from all point and fugitive sources in the five operational areas and in the 600 Area.

The MEI for 2016 was located at the PNNL Laboratory Supply Warehouse (LSW), an offsite business located at 3475 George Washington Way in north Richland, Benton County, Washington, directly south of the Hanford Site 300 Area. The warehouse is on the DOE-PNSO PNNL Richland Campus, separate from, though adjacent to, the Hanford Site[1]. The 2015 MEI was also at LSW. From 2012 through 2014, the MEI was at the PNNL Site Physical Sciences Facility (PSF), an offsite business located just south of LSW. From 2005 through 2011, the MEI had been a resident on a farm near Sagemoor Road, Franklin County, directly across the Columbia River from the Hanford Site 300 Area, as was also the case from 1993 through 1999. For 2004, the MEI location was Ringold, also the site of the MEI from 1990 through 1992. In 2000 and 2001, the location of the MEI shifted to two different locations within the 300 Area where non-DOE-related employment existed; those businesses ended by early 2002.

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[1] Selection of LSW as the location of the Hanford Site MEI for 2016 was a conservative choice based on the meteorology and stack emissions and characteristics ascribing the highest dose estimate to LSW among other locations considered.

The radiological dose to the MEI was calculated using the dose-modeling program Clean Air Act Assessment Package 1988-Personal Computer (CAP88-PC) Version 4 (EPA 2015, *CAP88-PC Version 4.0 User Guide*), approved by the EPA. This dose value is used in determining the status of Hanford Site compliance with the dose standard in Subpart H of 40 CFR 61 of 10 mrem/yr EDE to any member of the public, as well as to the dose standard in WAC 246-267, which is also 10 mrem/yr EDE to any member of the public.

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Table 2-1. Hanford Site Radionuclide Air Emissions from Major Stacks in Calendar Year 2016
(Radiological Dose Potential of >0.1 mrem/yr EDE to Nearest Public Receptor)[a] (7 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
			200 East Area			
291-A-1[j]	28,654	1.5E+10	^{129}I	2.0E-12	9.8E-04	1.9E-04
(PUREX Plant;	(13.52)	(4.3E+08)	^{238}Pu	≤0	0	0
CHPRC; A006)			$^{239/240}Pu$	3.7E-17	3.2E-08	1.6E-08
			^{241}Am	1.4E-16	1.2E-07	5.0E-08
			gross α	1.4E-15	1.3E-06	6.6E-07
			gross β	6.7E-15	5.9E-06	3.0E-07
					291-A-1 Total Dose:	**1.9E-04**
296-A-19	707	1.1E+08	^{90}Sr	≤0	0	0
(TF; WRPS; E061)	(0.33)	(3.0E+06)	^{137}Cs	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	1.3E-15	5.2E-09	2.7E-10
					296-A-19 Total Dose:	**2.7E-10**
296-A-42	811	4.3E+08	^{90}Sr	≤0	0	0
(TF; WRPS; E147)	(0.38)	(1.2E+07)	^{137}Cs	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	1.8E-16	3.0E-09	1.5E-10
					296-A-42 Total Dose:	**1.5E-10**
296-A-44	1,810	9.5E+08	^{90}Sr	≤0	0	0
and	(0.85)	(2.7E+07)	^{90}Y	≤0	0	0
296-A-45			^{134}Cs	≤0	0	0
(TF; WRPS; E920			^{137}Cs	≤0	0	0
& E922; [These			^{231}Pa	≤0	0	0
two stacks			^{238}Pu	≤0	0	0
exhaust the			$^{239/240}Pu$	≤0	0	0
same source])			^{241}Pu	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	3.9E-16	1.5E-08	7.6E-10
					296-A-44 and 296-A-45 Total Dose:	**7.6E-10**

Table 2-1. Hanford Site Radionuclide Air Emissions from Major Stacks in Calendar Year 2016
(Radiological Dose Potential of >0.1 mrem/yr EDE to Nearest Public Receptor)[a] (7 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
296-A-46	1,018	5.4E+08	^{90}Sr	≤0	0	0
and	(0.48)	(1.5E+07)	^{90}Y	≤0	0	0
296-A-47			^{134}Cs	≤0	0	0
(TF; WRPS; E924			^{137}Cs	≤0	0	0
& E926; [These			^{231}Pa	≤0	0	0
two stacks			^{238}Pu	≤0	0	0
exhaust the			$^{239/240}Pu$	≤0	0	0
same source])			^{241}Pu	≤0	0	0
			^{241}Am	1.4E-17	2.8E-10	1.2E-10
			gross α	≤0	0	0
			gross β	7.3E-16	1.6E-08	8.2E-10
				296-A-46 and 296-A-47 Total Dose:		**9.4E-10**
296-A-48	1,552	2.2E+08	^{90}Sr	≤0	0	0
&	(0.73)	(6.4E+06)	^{137}Cs	≤0	0	0
296-A-49			^{241}Am	≤0	0	0
(TF; WRPS; E986			gross α	≤0	0	0
& E988; [These			gross β	2.0E-16	1.8E-09	9.2E-11
two stacks						
exhaust the						
same source])						
				296-A-48 and 296-A-49 Total Dose:		**9.2E-11**
296-B-1	15,121	8.0E+09	^{90}Sr	≤0	0	0
(B Plant; CHPRC;	(7.14)	(2.3E+08)	^{137}Cs	≤0	0	0
B001)			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	2.4E-17	6.7E-09	3.4E-10
					296-B-1 Total Dose:	**3.4E-10**
296-B-10	24,449	1.1E+10	^{90}Sr	4.5E-14	2.2E-05	9.0E-07
(WESF; CHPRC;	(11.54)	(3.1E+08)	^{106}Ru	≤0	0	0
B748)			^{137}Cs	1.5E-14	7.6E-06	3.9E-07
			^{241}Am	≤0	0	0
			gross α	2.3E-17	1.1E-08	5.6E-09
			gross β	1.0E-13	5.1E-05	2.6E-06
					296-B-10 Total Dose:	**3.9E-06**

Table 2-1. Hanford Site Radionuclide Air Emissions from Major Stacks in Calendar Year 2016
(Radiological Dose Potential of >0.1 mrem/yr EDE to Nearest Public Receptor)[a] (7 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
296-H-212	9,000	4.7E+09	^{90}Sr	≤0	0	0
(CSB; CHPRC;	(4.25)	(1.3E+08)	^{137}Cs	≤0	0	0
C601)			^{238}Pu	≤0	0	0
			$^{239/240}Pu$	≤0	0	0
			^{241}Pu	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	≤0	0	0
					296-H-212 Total Dose:	**0**
296-P-47	311	7.8E+07	^{90}Sr	8.5E-16	2.6E-09	1.1E-10
(TF; WRPS; E096)	(0.15)	(2.2E+06)	^{137}Cs	4.8E-15	1.5E-08	7.6E-10
			$^{239/240}Pu$	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	2.9E-15	8.4E-09	4.3E-10
					296-P-47 Total Dose:	**1.3E-09**
296-P-48 (TF; WRPS; E098)			Did Not Operate			
296-P-107	1,352	4.3E+08	^{90}Sr	≤0	0	0
(TF; WRPS; E104)	(0.64)	(1.2E+07)	^{137}Cs	≤0	0	0
			$^{239/240}Pu$	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	4.3E-17	6.9E-10	3.5E-10
			gross β	7.8E-16	1.2E-08	6.1E-10
					296-P-107 Total Dose:	**9.6E-10**
			200 West Area			
291-T-1	40,000	2.1E+10	^{90}Sr	5.5E-16	4.2E-07	1.8E-08
(221-T; CHPRC;	(18.88)	(6.0E+08)	^{137}Cs	≤0	0	0
T785)			^{238}Pu	3.3E-17	2.5E-08	1.3E-08
			$^{239/240}Pu$	1.6E-15	1.2E-06	6.6E-07
			^{241}Am	1.3E-16	1.0E-07	4.6E-08
			gross α	2.4E-15	1.8E-06	9.9E-07
			gross β	3.5E-15	2.6E-06	1.4E-07
					291-T-1 Total Dose:	**1.9E-06**

Table 2-1. Hanford Site Radionuclide Air Emissions from Major Stacks in Calendar Year 2016
(Radiological Dose Potential of >0.1 mrem/yr EDE to Nearest Public Receptor)[a] (7 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
291-Z-1	290,000	1.5E+11	^{238}Pu	2.3E-17	1.2E-07	6.1E-08
(PFP; CHPRC; Z810	(136.86)	(4.3E+09)	$^{239/240}Pu$	1.5E-15	7.7E-06	4.2E-06
[under CERCLA[f]])			^{241}Pu	2.0E-17	9.9E-08	9.9E-10
			^{241}Am	4.0E-16	2.0E-06	9.2E-07
			gross α	4.9E-15	2.5E-05	1.4E-05
			gross β	1.3E-16	6.7E-07	3.7E-08
					291-Z-1 Total Dose:	**1.9E-05**
296-P-43 (TF; WRPS; E045)			Did Not Operate			
296-P-44 (TF; WRPS; E046)			Did Not Operate			
296-P-45	264	1.4E+08	^{90}Sr	≤0	0	0
(TF; WRPS; E047)	(0.12)	(3.9E+06)	^{137}Cs	≤0	0	0
			^{238}Pu	≤0	0	0
			$^{239/240}Pu$	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	≤0	0	0
					296-P-45 Total Dose:	**0**
296-S-21	74,869	3.9E+10	^{90}Sr	≤0	0	0
(222-S; WRPS;	(35.33)	(1.1E+09)	^{137}Cs	≤0	0	0
S289)			^{238}Pu	9.3E-19	1.4E-09	7.1E-10
			$^{239/240}Pu$	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	3.4E-17	5.3E-08	2.9E-08
			gross β	9.0E-17	1.4E-07	7.7E-09
					296-S-21 Total Dose:	**3.7E-08**

Table 2-1. Hanford Site Radionuclide Air Emissions from Major Stacks in Calendar Year 2016
(Radiological Dose Potential of >0.1 mrem/yr EDE to Nearest Public Receptor)[a] (7 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
296-W-4	13,925	7.3E+09	^{90}Sr	≤0	0	0
(WRAP; CHPRC;	(6.57)	(2.1E+08)	^{106}Ru	≤0	0	0
W123)			^{137}Cs	≤0	0	0
			^{238}Pu	≤0	0	0
			$^{239/240}Pu$	≤0	0	0
			^{241}Pu	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	4.1E-17	1.2E-08	6.6E-10
					296-W-4 Total Dose:	**6.6E-10**
			300 Area			
EP-324-01-S	62,152	3.3E+10	^{90}Sr	≤0	0	0
(324 Building;	(22.33)	(9.3E+08)	^{137}Cs	≤0	0	0
WCH/CHPRC; F025			^{238}Pu	≤0	0	0
[under CERCLA[f]])			$^{239/240}Pu$	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	≤0	0	0
			gross β	1.3E-16	1.5E-07	5.1E-07
					EP-324-01–S Total Dose:	**5.1E-07**

Table 2-1. Hanford Site Radionuclide Air Emissions from Major Stacks in Calendar Year 2016
(Radiological Dose Potential of >0.1 mrem/yr EDE to Nearest Public Receptor)[a] (7 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
EP-325-01-S	142,467	7.49E+10	^{3}H (HT)	1.1E-08	2.39E+01	3.1E-03
(325 Building;	(67.2)	(2.12E+09)	^{3}H (HTO)	1.1E-07	2.42E+02	3.5E-02
PNNL; NA)			^{60}Co	1.5E-17	3.1E-08	7.3E-08
			^{85}Kr	1.3E-16	2.8E-07[g]	3.4E-13
			^{90}Sr	4.0E-17	8.6E-08	2.3E-07
			^{99}Tc	1.9E-15	4.1E-06[h]	1.6E-06
			^{106}Ru	6.2E-19	1.3E-09[h]	1.7E-10
			^{137}Cs	3.2E-18	6.9E-09	2.3E-08
			^{152}Eu	9.1E-19	1.9E-09[h]	4.1E-09
			^{154}Eu	5.4E-18	1.1E-08[h]	1.9E-08
			^{153}Gd	3.8E-20	8.0E-11[h]	1.2E-12
			^{220}Rn	8.4E-08	1.8E+02[i]	[See Table 3.5]
			^{226}Ra	1.8E-19	3.7E-10[h]	4.8E-09
			^{227}Ac	1.4E-19	3.1E-10[h]	1.8E-08
			^{232}U	4.1E-18	8.6E-09[h]	1.0E-07
			^{233}U	1.2E-17	2.7E-08[h]	6.8E-08
			^{238}Pu	1.8E-19	3.9E-10	1.4E-08
			$^{239/240}Pu$	1.0E-18	2.1E-09	8.5E-08
			^{241}Pu	≤0	0	0
			^{241}Am	1.8E-19	3.9E-10	1.3E-08
			^{243}Am	4.2E-18	8.9E-09	3.0E-07
			$^{243/244}Cm$	≤0	0	0
			gross α	3.5E-17	7.3E-08	2.9E-06
			gross β	2.3E-16	4.8E-07	1.6E-06
					EP-325-01–S Total Dose:	**3.8E-02**

Table 2-1. Hanford Site Radionuclide Air Emissions from Major Stacks in Calendar Year 2016
(Radiological Dose Potential of >0.1 mrem/yr EDE to Nearest Public Receptor)[a] (7 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
EP-331-01-V	61,600	3.24E+10	^{60}Co	7.1E-17	6.5E-08	1.5E-07
(331 Building;	(29.1)	(9.17E+08)	^{90}Sr	9.0E-17	8.2E-08	2.2E-07
PNNL; NA)			^{137}Cs	5.4E-18	4.9E-09	1.7E-08
			^{237}Np	1.5E-17	1.4E-08[h]	2.7E-07
			^{238}Pu	4.0E-17	3.7E-08[h]	1.4E-06
			$^{239/240}Pu$	0	<0	0
			^{241}Am	1.0E-19	9.3E-11	3.1E-09
			^{243}Am	4.4E-17	4.0E-08[h]	1.4E-06
			gross α	3.2E-17	3.0E-08	1.2E-06
			gross β	2.3E-16	2.1E-07	7.1E-07
					EP-331-01–V Total Dose:	**5.3E-06**

General definitions: ≤0 = analytical result equal to level of laboratory ambient background radioactivity or less than that level, which in practical terms means the radionuclide or type of radioactivity was not detected in the sample of the emission collected; Ci = curie; 1 Ci = 3.7E+10 becquerels (Bq); ft3 = cubic feet; HT is tritium, or elemental tritium, in the form of an incondensable gas; HTO is tritiated water vapor, or tritium in the form of condensable water vapor; m3 = cubic meters; min = minute; mrem = millirem; 1 mrem=0.01 mSv; NA = not applicable; s = second; yr = year.

[a]Determining the potential prospective dose impact of each stack necessitated using nearest public receptors, who may differ from the annually determined Hanford Site MEI.

[b]Abbreviations and acronyms in this column are: CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980; CHPRC = CH2M HILL Plateau Remediation Company; CSB = Canister Storage Building; CVDF = Cold Vacuum Drying Facility; EDP code = electronic data processing code, used in chain-of-custody activities to identify sampling locations; PNNL = Pacific Northwest National Laboratory; PFP = Plutonium Finishing Plant; PUREX = Plutonium-Uranium Extraction; TF = Tank Farms; WCH = Washington Closure Hanford, LLC; WESF = Waste Encapsulation and Storage Facility; WRAP = Waste Receiving and Processing Facility; WRPS = Washington River Protection Solutions, LLC.

[c]Reflects stack flow rate averaged over time of stack operation or averaged over the calendar year.

[d]Reflects concentration averaged over time of stack operation.

[e]EDE for MEI = effective dose equivalent for the maximally exposed individual; for calendar year 2016, the MEI was located at LSW, 3475 George Washington Way, in north Richland, Benton County, directly south of the Hanford Site 300 Area.

[f]Emissions from this stack are associated with cleanup operations conducted under the authority of CERCLA. Reporting its emissions in Table 2-1 demonstrates compliance with the monitoring requirements of 40 CFR 61, Subpart H, a substantively equivalent law (i.e., "applicable or relevant and appropriate requirement") as defined by CERCLA.

[g]Release value based on release records from annual PNNL Radioactive Gas Inventory database.

[h]Release value was calculated using Appendix D method of 40 CFR 61 and annual PNNL material inventories.

[i]Radon release value conservatively calculated, not actually measured, and is based on release records from annual PNNL Radioactive Gas Inventory database.

[j]Heat trace arced through the sample line sometime between 2/1/16 and 3/7/16. During that period the filter collected combustion particulates and ambient air for some unknown length of time. Therefore, the samples collected during that period do not constitute a representative sample of the PUREX Stack effluent and those results were not used to calculate emissions.

Table 2-2. Hanford Site Radionuclide Air Emissions from Minor Stacks in Calendar Year 2016
(Radiological Dose Potential of <0.1 mrem/yr EDE to Nearest Public Receptor)[a] (4 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
			100 Areas			
105-KW Basin	20,700	1.1E+10	^{90}Sr	9.3E-15	3.2E-06	5.4E-08
(100-K Area; CHPRC;	(9.77)	(3.1E+08)	^{137}Cs	7.7E-15	2.6E-06	5.5E-08
Y234 & Y236;			^{238}Pu	1.5E-15	5.0E-07	9.5E-08
[Combined, these			$^{239/240}Pu$	8.6E-15	2.9E-06	5.8E-07
vents exhaust the			^{241}Pu	2.6E-14	8.8E-06	3.3E-08
same source;			^{241}Am	8.0E-15	2.7E-06	4.6E-07
Under CERCLA[f]])			gross α	3.0E-14	1.0E-05	2.0E-06
			gross β	3.9E-14	1.3E-05	2.7E-07
					105-KW Basin Total Dose:	**3.5E-06**
296-K-142	Via WDOH approval, the annual emissions associated with this non-operating stack are calculated, not measured; the static calculation yields a dose of 1.52E-06 mrem/yr EDE (see ECF-100KR2-13-0001, *Cold Vacuum Drying Facility Estimated PTE for Surveillance and Maintenance*); these calculated emissions are accounted for in the fugitive dose calculation for the Hanford Site.					
			200 East Area			
296-A-18	843	4.4E+08	gross α	≤0	0	0
(TF; WRPS; E060)	(0.40)	(1.3E+07)	gross β	1.0E-15	1.8E-08	9.2E-10
					296-A-18 Total Dose:	**9.2E-10**
296-A-20	2,022	1.1E+09	gross α	≤0	0	0
(TF; WRPS; E197)	(0.95)	(3.0E+07)	gross β	3.9E-16	1.6E-08	8.2E-10
					296–A–20 Total Dose:	**8.2E-10**
296-A-21A	15,296	8.1E+09	gross α	≤0	0	0
(TF; WRPS; E651)	(7.22)	(2.3E+08)	gross β	≤0	0	0
					296–A–21A Total Dose:	**0**
296-A-22	395	2.1E+08	^{90}Sr	≤0	0	0
(TF; WRPS; E643)	(0.19)	(5.9E+06)	^{137}Cs	≤0	0	0
			^{238}Pu	≤0	0	0
			$^{239/240}Pu$	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	3.2E-16	2.6E-09	1.3E-09
			gross β	9.0E-16	7.3E-09	3.7E-10
					296-A-22 Total Dose:	**1.7E-09**

Table 2-2. Hanford Site Radionuclide Air Emissions from Minor Stacks in Calendar Year 2016
(Radiological Dose Potential of <0.1 mrem/yr EDE to Nearest Public Receptor)[a] (4 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
296-A-28	3,585	1.9E+09	gross α	8.4E-16	6.1E-08	3.1E-08
(TF; WRPS; E272)	(1.69)	(5.4E+07)	gross β	1.3E-15	9.8E-08	5.0E-09
					296-A-28 Total Dose:	**3.6E-08**
296-A-30	1,555	8.2E+08	gross α	3.2E-16	1.4E-08	7.1E-09
(TF; WRPS; E903)	(0.73)	(2.3E+07)	gross β	1.9E-15	7.9E-08	4.0E-09
					296-A-30 Total Dose:	**1.1E-08**
296-A-40	770	2.8E+08	^{90}Sr	≤0	0	0
(TF; WRPS; E013)	(0.36)	(7.9E+06)	^{137}Cs	≤0	0	0
			$^{239/240}Pu$	≤0	0	0
			^{241}Am	≤0	0	0
			gross α	1.7E-16	1.9E-09	9.7E-10
			gross β	7.2E-16	7.8E-09	4.0E-10
					296-A-40 Total Dose:	**1.4E-09**
296-A-41	4,989	2.6E+09	gross α	≤0	0	0
(TF; WRPS; E015)	(2.35)	(7.4E+07)	gross β	6.0E-16	6.2E-08	3.2E-09
					296-A-41 Total Dose:	**3.2E-09**
296-A-43	748	3.9E+08	gross α	≤0	0	0
(TF; WRPS; E148)	(0.35)	(1.1E+07)	gross β	≤0	0	0
					296-A-43 Total Dose:	**0**
296-E-1	54,947	2.9E+10	gross α	1.8E-16	2.0E-07	1.0E-07
(ETF; WRPS; E036)	(25.93)	(8.2E+08)	gross β	2.6E-16	2.9E-07	1.5E-08
					296-E-1 Total Dose:	**1.1E-07**
			200 West Area			
291-S-1	17,829	9.4E+09	gross α	1.2E-15	4.6E-07	2.5E-07
(REDOX Plant; CHPRC; S006)	(8.41)	(2.7E+08)	gross β	5.7E-15	2.1E-06	1.2E-07
					291-S-1 Total Dose:	**3.7E-09**
296-P-22	710	3.7E+08	gross α	1.2E-16	1.7E-09	9.4E-10
(TF; WRPS; W191)	(0.34)	(1.1E+07)	gross β	4.7E-16	6.8E-09	3.7E-10
					296-P-22 Total Dose:	**1.3E-09**

Table 2-2. Hanford Site Radionuclide Air Emissions from Minor Stacks in Calendar Year 2016
(Radiological Dose Potential of <0.1 mrem/yr EDE to Nearest Public Receptor)[a] (4 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
296-P-23 and 296-S-25 (TF; WRPS; W190 & W145; These two stacks exhaust the same source])	858 (0.41)	4.5E+08 (1.3E+07)	gross α gross β	5.6E-16 1.3E-15	9.9E-09 2.2E-08	5.4E-09 1.2E-09
					296-P-23 and 296-S-25 Total Dose:	**6.6E-09**
296-S-16 (219-S; WRPS; S264)	20 (0.01)	1.1E+07 (3.0E+05)	gross α gross β	8.6E-16 3.7E-15	3.5E-10 1.5E-09	1.9E-10 8.2E-11
					296-S-16 Total Dose:	**2.7E-10**
296-S-23	This stack is sampled every odd year via nondestructive analysis of its primary HEPA filter.					
296-T-7 (2706-T; CHPRC; T154)	3.77 (0.001)	1.98E+06 (5.6E+04)	^{137}Cs gross α gross β	≤0 ≤0 2.1E-15	0 0 1.7E-09	0 0 9.2E-11
					296-T-7 Total Dose:	**9.2E-11**
			300 Area			
EP-331-09-S (331 Building; PNNL; NA)	20,700[h] (9.8)	1.09E+10 (3.09E+08)	^{14}C gross α gross β	3.7E-13 3.3E-18 1.3E-14	1.15E-04[i] 1.0E-09[i] 4.0E-06[i]	1.8E-06 4.0E-08 1.4E-05
					EP-331-09-S Total Dose:	**1.5E-05**
			400 Area			
437-1-61 (MASF; CHPRC; F019)	4,500 (2.12)	2.4E+09 (6.7E+097)	gross α gross β	≤0 2.3E-16	0 2.1E-08	0 5.0E-09
					437-1-61 Total Dose:	**5.0E-09**
437-MN&ST (MASF; CHPRC; F014)	11,287 (5.33)	5.9E+09 (1.7E+08)	gross α gross β	2.9E-15 7.2E-15	7.4E-07 1.9E-06	2.0E-06 4.6E-07
					437-MN&ST Total Dose:	**2.5E-06**

Table 2-2. Hanford Site Radionuclide Air Emissions from Minor Stacks in Calendar Year 2016
(Radiological Dose Potential of <0.1 mrem/yr EDE to Nearest Public Receptor)[a] (4 pages)

Stack (Facility; Contractor; EDP Code)[b]	Average Operating Flow Rate,[c] ft^3/min (m^3/s)	Volume, ft^3 (m^3)	Radionuclide or Type of Radioactivity	Average Operating Concentration,[d] µCi/mL	Emissions, Ci	EDE to MEI,[e] mrem
FFTF-CB-EX	NA	NA	^{3}H (HTO)	NA	1.6E-02[j]	1.7E-07
(MASF; CHPRC;			^{22}Na	NA	2.1E-10[j]	2.0E-11
F011)			^{137}Cs	NA	1.1E-11[j]	2.7E-12
[**Note:** No measured flow from stack. Curie values derived from residual radioactive sodium in primary coolant piping system of FFTF reactor. Not analyzed emission samples.]			^{239}Pu	NA	2.3E-13[j]	6.1E-13
					FFTF-CB-EX Total Dose:	**1.7E-07**

General definitions: ≤0 = analytical result equal to level of laboratory ambient background radioactivity or less than that level, which in practical terms means the radionuclide or type of radioactivity was not detected in the sample of the emission collected; Ci = curie; 1 Ci = 3.7E+10 becquerels (Bq); ft^3 = cubic feet; HTO is tritiated water vapor, or tritium in the form of condensable water vapor; m^3 = cubic meter; min = minute; mrem = millirem; 1 mrem=0.01 mSv; NA = not applicable; s = second; yr = year.

[a]Determining the potential prospective dose impact of each stack necessitated using nearest public receptors, who may differ from the annually determined Hanford Site MEI

[b]Abbreviations and acronyms in this column are: CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980; CHPRC = CH2M HILL Plateau Remediation Company; EDP code = electronic data processing code; ETF = 200 Area Effluent Treatment Facility; FFTF = Fast Flux Test Facility; MASF = Maintenance and Storage Facility; MSA = Mission Support Alliance, LLC; PNNL = Pacific Northwest National Laboratory; PFP = Plutonium Finishing Plant; TF = Tanks Farms; WCH = Washington Closure Hanford, LLC; WRPS = Washington River Protection Solutions, LLC; and WSCF = Waste Sampling and Characterization Facility.

[c]Reflects stack flow rate averaged over time of stack operation or averaged over the calendar year.

[d]Reflects concentration averaged over time of stack operation.

[e]EDE for MEI = effective dose equivalent for the maximally exposed individual; for calendar year 2016, the MEI was located at LSW, 3475 George Washington Way, in north Richland, Benton County, directly south of the Hanford Site 300 Area.

[f]Emissions from this stack are associated with cleanup operations conducted under the authority of CERCLA. Reporting these emissions in Table 2-2 demonstrates compliance with the requirements of 40 CFR 61, Subpart H, a substantively equivalent law (i.e., "applicable or relevant and appropriate requirement") as defined by CERCLA.

[g]Release value based on release records from annual PNNL Radioactive Gas Inventory database.

[h]Estimated volumetric flow rate.

[i]Release value was calculated using Appendix D method of 40 CFR 61 and annual PNNL material inventories.

[j]Value based on estimates of residual sodium in FFTF reactor primary coolant piping system.

Table 2-3. Hanford Site Major Stack Heights and Abatement Technology

Stack	Discharge Height, ft (m)	Abatement Technology[a]
		100 Area Major Stacks
105-KW Air Sparging Vent	48 (14.6)	HEPA[b]
		200 East Area Major Stacks
291-A-1	200 (61)	HEPAs (2), deep-bed fiberglass filter, fans (2)
296-A-19	12.9 (3.9)	HEPAs (2), fan
296-A-42	55 (16.8)	HEPAs (2), chiller pump, water chiller, high-efficiency mist eliminator, condenser, heater, fan
296-A-44	28 (8.6)	HEPAs (2), deentrainer, heater, prefilter, fan
296-A-45	28 (8.6)	HEPAs (2), deentrainer, heater, prefilter, fan
296-A-46	28 (8.6)	HEPAs (2), deentrainer, heater, prefilter, fan
296-A-47	28 (8.6)	HEPAs (2), deentrainer, heater, prefilter, fan
296-A-48	40 (12.9)	HEPAs (2), deentrainer, heater, prefilter, fan
296-A-49	40 (12.9)	HEPAs (2), deentrainer, heater, prefilter, fan
296-B-1	90 (27.4)	HEPAs (4), prefilters (2), fan (2)
296-B-10	75 (22.9)	HEPAs (2), demister, heater, prefilter, fan
296-H-212	75 (22.9)	HEPAs (2), fans (2)
296-P-47	40 (12.2)	HEPAs (2), demister, heater, prefilter, fan
296-P-48	40 (12.2)	HEPAs (2), demister, heater, prefilter, fan
296-P-107	28 (8.5)	HEPAs (2), demister, heater, prefilter, fan
		200 West Area Major Stacks
296-P-43	21 (6.4)	HEPAs (2), demister, heater, prefilter, fan
296-P-44	21 (6.4)	HEPAs (2), demister, heater, prefilter, fan
296-P-45	21 (6.4)	HEPAs (2), demister, heater, prefilter, fan
296-S-21	68 (20.7)	HEPAs (4), fan (4)
291-T-1	200 (61)	HEPAs (2), prefilter, fan (2)
296-W-4	47 (14.2)	HEPAs (4), prefilter, fans (2)
291-Z-1	200 (61)	HEPAs and fans (multiple parallel banks of each)
		300 Area Major Stacks
EP-324-01-S	150 (46)	HEPA and multiple parallel fans
EP-325-01-S	89 (27.1)	HEPA (2 in series), fan
EP-331-01-V	62 (18.9)	HEPA, fans (3 in parallel: 1 operational, 2 as backups)

[a]The operational efficiency of HEPA filters is ≥99.95%. The operational efficiencies of the other abatement technology are not known with certitude.
[b]The single HEPA filter is both the abatement device and the sample.

Table 2-4. Hanford Site Minor Stack Heights and Abatement Technology

Stack	Discharge Height, ft (m)	Abatement Technology[a]
		100 Area
105-KW Basin	42 (12.8)	None
		200 East Area
296-A-18	12.5 (3.8)	HEPAs (2), fan heater
296-A-20	15.7 (4.8)	HEPAs (4), fan, radial damper, heater (2)
296-A-21A	50 (15.2)	HEPAs (3), fans (2), prefilter (3)
296-A-22	63.6 (19.4)	HEPAs (2), prefilter, heater, deentrainer, fan
296-A-28	23.5 (7.1)	HEPAs (2), fan, deentrainer, heater
296-A-30	23.4 (7.1)	HEPAs (2), fan, deentrainer, heater
296-A-40	19.6 (6.0)	HEPAs (2), prefilter, fan, deentrainer, heater
296-A-41	29.2 (8.9)	HEPAs (2), fan, heater
296-A-43	35.5 (10.8)	HEPA, prefilter, fan, isolation damper
296-E-1	51 (15.5)	HEPAs (5), fans (3)
		200 West Area
291-S-1	200 (61)	Sand filter, fans (2 in parallel)
296-P-22	13.2 (4.0)	HEPAs (2), fan
296-P-23	17.3 (5.3)	HEPAs (2), deentrainer, prefilter, fan, heater (non-operational)
296-S-16	12.5 (3.8)	HEPA, fan
296-S-23	21.5 (6.6)	HEPAs (2), prefilter, fan
296-S-25	19 (5.8)	HEPAs (2), fan, prefilter, deentrainer, heater (non-operational)
296-T-7	28 (8.5)	HEPAs, prefilter, fan
		300 Area
EP-331-09-S	46 (14)	None
		400 Area
437-1-61	38.4 (11.7)	Fan
437-MN&ST	30 (9.1)	HEPAs (5), fans (2), prefilters (3)
FFTF-CB-EX	47 (14.3)	Fans (3)

[a]The operational efficiency of HEPA filters is ≥99.95% and of sand filters, ≥98%. The operational efficiencies of the other abatement technology are not known with certitude.

Table 2-5. Distances and Directions from Hanford Site Operational Areas to Receptors at Respective Nearest Residences and Farms[a]

Receptor		Distance (km [mi]) and Direction from Hanford Site Operational Area[b]				
		100 Area	200 East Area	200 West Area	300 Area	400 Area
Hanford Site MEI[c]		41.0 (25.5) SE	28.5 (17.7) SE	34.9 (21.7) SE	1.6 (1.0) S	11.0 (6.8) SE
Offsite Receptor	Sagemoor Road[d]	40.6 (25.2) SE	28.3 (17.6) SE	35.1 (21.8) SE	1.4 (0.87) E	10.8 (6.7) SE
	Nearest	10.5 (6.5) NNW	15.3 (9.5) ENE	13.7 (8.5) W	1.4 (0.87) E	8.1 (5.0) SSW
	Nearest in Prevailing Wind	21.5 (13.4) E	20.7 (12.8) ESE	22.0 (13.8) SE	1.6 (1.0) S	8.2 (5.1) ESE
Onsite Public Receptor	Nearest[e]	26.0 (16.1) SE	13.5 (8.4) SE	20.2 (12.6) SE	12.3 (7.6) NNW	4.3 (2.7) WNW
	Nearest in Prevailing Wind	26.0 (16.1) SE	16.7 (10.4) ESE	20.2 (12.6) SE	14.0 (8.8) NW	3.2 (2.0) NNE
Vegetable-Producing Farm	Nearest	9.0 (5.6) NW	15.3 (9.5) ENE	17.7 (11.0) NW	3.2 (2.0) E	8.0 (5.0) E
	Nearest in Prevailing Wind	20.3 (12.6) E	20.7 (12.8) ESE	29.9 (18.6) SE	4.0 (2.5) NE	8.1 (5.0) ESE
Milk-Producing Farm	Nearest	33.5 (20.8) E	25.8 (16.0) ENE	34.6 (21.5) S	5.8 (3.6) ESE	12.7 (7.9) E
	Nearest in Prevailing Wind	33.5 (20.8) E	28.3 (17.6) ESE	36.2 (22.5) ESE	9.2 (5.7) NE	15.3 (9.5) SE
Meat-producing farm	Nearest	17.6 (10.9) NW	20.9 (13.0) WNW	17.7 (11.0) WSW	2.3 (1.4) ESE	8.5 (5.3) SSW
	Nearest in prevailing wind	25.3 (15.7) E	28.3 (17.6) ESE	27.0 (16.8) SE	8.0 (5.0) NE	11.3 (7.0) SE

[a]The definition of residence includes dwelling, school, business, and office.

[b]All emission points within an emission area are assigned a single distance to the nearest receptor; km = kilometer; mi = mile.

[c]An offsite business, PNNL Site LSW, 3475 George Washington Way, directly south of the Hanford Site 300 Area.

[d]A member of the public who lives at a residence near Sagemoor Road, in Franklin County, directly across the Columbia River from the Hanford Site 300 Area. This location had been the MEI from 2005-2011.

[e]The nearest onsite receptor is employed at LIGO. This receptor, who from year to year could be but is not necessarily the MEI, is a member of the public not employed by DOE or its contractors and who works on the Hanford Site at a location to which access is not controlled by DOE. For radiological dose impacts from emissions in 2016, numerous offsite public receptors and onsite public receptors were evaluated. The evaluations determined that an offsite receptor at LSW, in north Richland, received the maximum dose due to air emissions from all Hanford Site sources during 2016. For onsite receptors, two employment locations were evaluated: LIGO and Energy NW.

3.0 STACK EMISSION DOSE ASSESSMENTS

3.1 DESCRIPTION OF STACK EMISSIONS DOSE MODEL

The year 1990 was the first year this annual report format was required to comply with the revised National Emission Standard for Hazardous Air Pollutants (NESHAP) for radionuclide emissions from DOE facilities, described in 54 Federal Register 16965, December 15, 1989. For 2016, *CAP88-PC Version 4 User Guide* (EPA 2015) was used to determine the compliance status of Hanford Site radionuclide air emissions with the 10 mrem/yr EDE standard of 40 CFR 61 Subpart H and of WAC 246-247.

Because the Hanford Site has numerous and widely separated emission points, it is necessary to determine the point at which the maximum dose would be estimated from the combined air emissions released from all locations (see DOE/RL-2007-53, *Methods for Calculating Doses to Demonstrate Compliance with Air Pathway Radiation Dose Standards at the Hanford Site*). To model the doses from those emissions, each of the five major operational areas is assigned within it a single reference facility having an emission point that typically is the source of maximum emissions from that area to the Hanford Site MEI. The straight-line distances and directions to the MEI from each of the five reference facilities are used in the dose calculations, which include annual meteorological data (refer to Appendix A). In 2016, those reference facilities were the 105-KE Building in the 100 Areas; the PUREX Facility in the 200 East Area; PFP in the 200 West Area; the 324 Building in the 300 Area; and FFTF in the 400 Area. Dose attributable to fugitive emissions originating from the 600 Area are discussed in Section 4.0.

For reports from 1990 through 1999, only offsite members of the public had been evaluated for dose. During this period, the annual MEI resided at these locations: from 1990 through 1992, Ringold, in Franklin County, east-southeast of the 200 Areas and northeast of the 300 Area; from 1993 through 1999, near Sagemoor Road, directly east and across the Columbia River from the 300 Area. Starting with the report for 2000, a new category of members of the public was evaluated in determining the MEI: non-DOE employees at work locations within the Hanford Site boundary. Private-sector reindustrialization at the Hanford Site forced a broadening of the MEI definition to include members of the public not employed by DOE and whose workplace is within the boundaries of the Hanford Site yet outside DOE-controlled areas. Under this new definition, the MEI location for 2000 shifted from what would have been the offsite residence near Sagemoor Road to a Washington State University (WSU) laboratory in the 300 Area, north of Richland. In 2001, the location changed to the 313 Building, also in the 300 Area. In early 2002, non-DOE employment at the WSU laboratory and the 313 Building ceased, causing the MEI to shift back to the offsite Sagemoor Road location in 2002 and 2003. For 2004, the MEI location shifted to Ringold, owing mainly to reduced point-source emissions of ^{3}H from the 300 Area. For 2005, the MEI location returned to the Sagemoor Road residence, where it remained through 2011, primarily due to consistently higher point-source emissions of ^{3}H from the 300 Area. From 2012 to 2014, PSF, on the DOE PNNL Richland Campus, was the location of the MEI. For 2015 and 2016, the MEI location is also on the DOE PNNL Richland Campus at LSW, which is slightly northward of PSF. Due to separate radiological air emission permits issued by the State of Washington and separate air emission monitoring programs managed by the Hanford Site and the PNNL Richland Campus (e.g., see PNNL-20436-6, *Pacific Northwest National Laboratory Campus Radionuclide Air Emissions Report for Calendar Year 2015*), the facilities on the PNNL Richland Campus were considered to be offsite business locations for purposes of the Hanford Site determination of compliance with 40 CFR Subpart H and WAC 246-247. The principal locations evaluated for the MEI of 2016 are shown in Figure 3-1.

Figure 3-1. Locations of Hanford Site Maximally Exposed Individual and Other Evaluated Receptor Locations for Calendar Year 2016

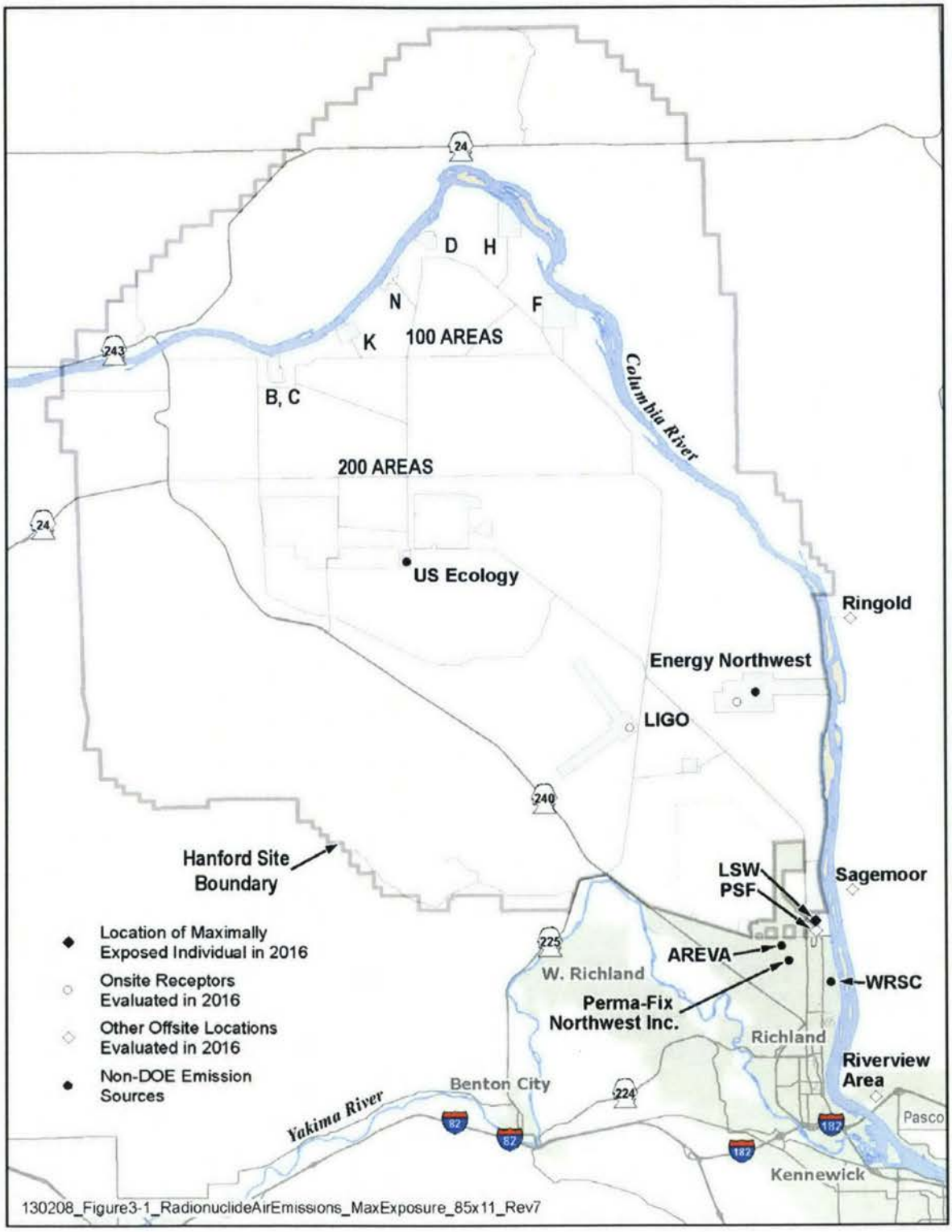
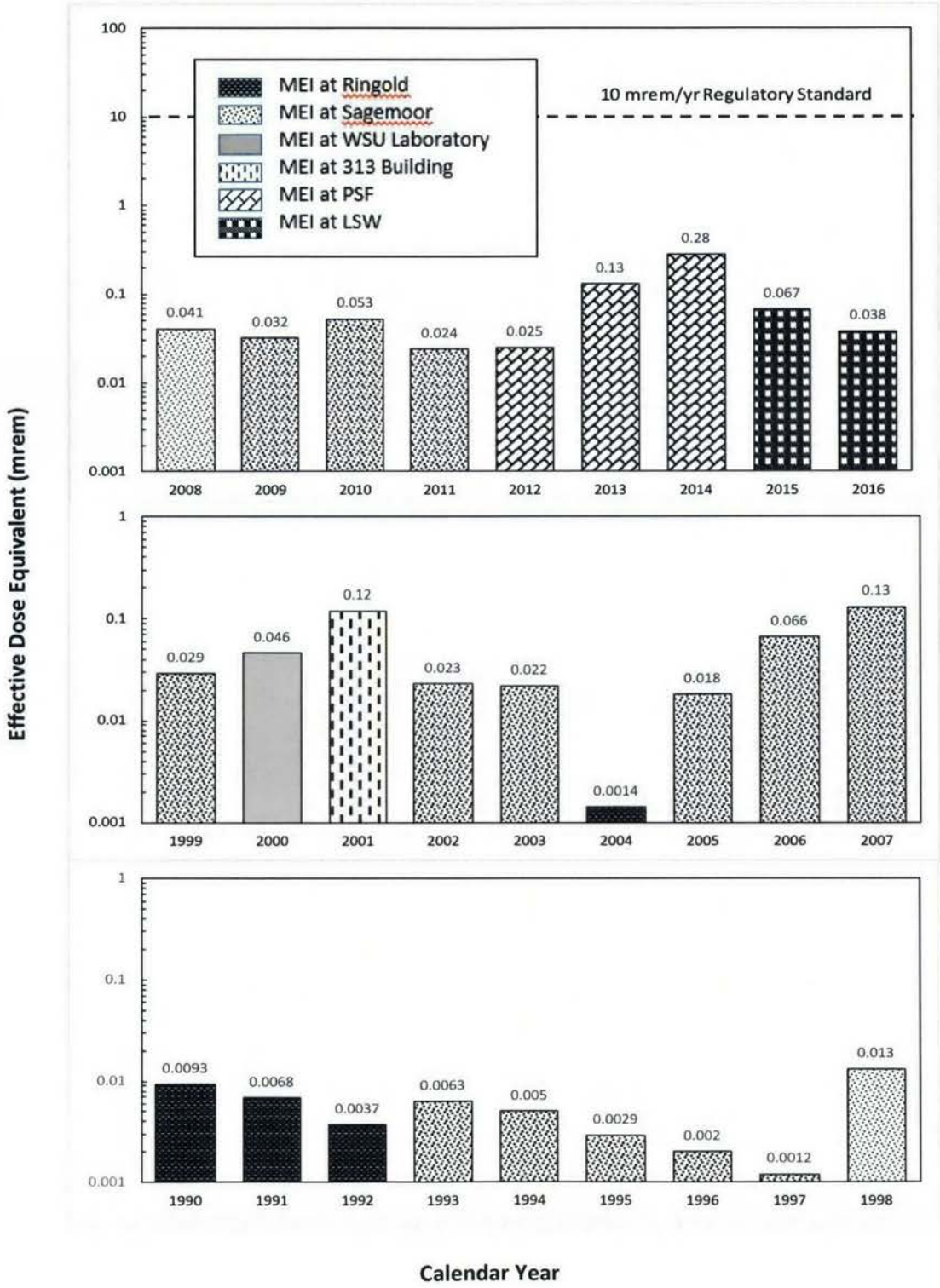


Figure 3-2 displays the MEI doses attributable to radionuclide emissions from Hanford Site stacks from 1990 through 2016.

Figure 3-2. Doses to the Maximally Exposed Individual Due to Point–Source Emissions of Radionuclides from the Hanford Site, 1990 through 2016



3.2 SUMMARY OF INPUT PARAMETERS

Past versions of CAP88-PC allowed dose calculations to be performed using established standard parameters for the Hanford Site and its environment (DOE/RL-2007-53). However, CAP88-PC, Version 4, does not allow as many parameters to be user-defined. Point-source emissions data by radionuclide and operational area that were used in the dose calculations are shown in Table 3-2. The calculations used a discharge height of 33 ft (10 m) for all stack release locations other than the 200 Area facilities. The 200 Area stack releases were assumed to have a release height of 200 ft (61 m), a conservative assumption that considers the physical release height of the tallest Hanford stacks (DOE/RL-2007-53). Emissions reported as gross alpha or gross beta were evaluated as $^{239/240}Pu$ or ^{137}Cs, respectively.

Additional data used for dose calculations are in Appendix A; all other radionuclide–specific parameters used were default values in CAP88-PC data libraries. The entire hypothetical MEI diet was constructed using the "local" food production option in CAP88-PC for ingestion-pathway parameters. Such an ingestion assumption greatly overestimates the ingestion dose to the 2016 MEI, a business receptor. For locations within the Hanford Site boundary, the ingestion dose would be estimated using regional parameters for the 50-mi (80-km) assessment area. Radionuclide air concentrations at receptor locations were determined using site–specific meteorological data for each representative release location. Joint-frequency distributions and CAP88–PC wind files were prepared from data collected at weather stations in each of the operational areas and represent the average of hourly data taken during 2016.

Table 3-1. Hanford Site Radionuclide Air Emissions from Stacks in Calendar Year 2016

Radionuclide	Releases, Ci					
	100 Areas	200 East Area	200 West Area	300 Area	400 Area	Total
^{3}H (as HT)[a]	NA	NA	NA	2.39E+01	NA	2.39E+01
^{3}H (as HTO)[b]	NA	NA	NA	2.42E+02	1.6E-02[c]	2.42E+02
^{14}C	NA	NA	NA	1.2E-04[d]	NA	1.2E-04
^{60}Co	NA	NA	NA	9.7E-08	NA	9.7E-08
^{22}Na	NA	NA	NA	NA	2.1E-10[c]	2.1E-10
^{85}Kr	NA	NA	NA	2.8E-07[e]	NA	2.8E-07
^{90}Sr	3.2E-06	2.2E-05	4.2E-07	1.7E-07	NA	2.6E-05
^{99}Tc	NA	NA	NA	4.1E-06[d]	NA	4.1E-06
^{106}Ru	ND	ND	ND	1.3E-09[d]	NA	1.3E-09
^{129}I	NA	9.8E-04	NA	NA	NA	9.8E-04
^{134}Cs	ND	ND	ND	NA	NA	ND
^{137}Cs	1.6E-05[f]	6.5E-05[f]	5.5E-06[f]	4.8E-06[f]	1.9E-06[c, f]	9.3E-05
^{152}Eu	ND	ND	ND	1.9E-09[d]	NA	1.9E-09
^{154}Eu	ND	ND	ND	1.1E-08[d]	NA	1.1E-08
^{153}Gd	NA	NA	NA	8.0E-11[d]	NA	8.0E-11
^{220}Rn	NA	NA	NA	1.78E+02[e]	NA	1.78E+02
^{226}Ra	NA	NA	NA	3.7E-10[d]	NA	3.7E-10
^{227}Ac	NA	NA	NA	3.1E-10[d]	NA	3.1E-10
^{231}Pa	NA	ND	NA	NA	NA	ND
^{232}U	NA	NA	NA	8.6E-09[d]	NA	8.6E-09
^{233}U	NA	NA	NA	2.7E-08[d]	NA	2.7E-08
^{237}Np	NA	NA	NA	1.4E-08[d]	NA	1.4E-08
^{238}Pu	5.0E-07	ND	1.4E-07	3.7E-08[d]	NA	6.8E-07
$^{239/240}Pu$	1.3E-05[g]	1.6E-06[g]	3.6E-05[g]	1.0E-07[g]	7.5E-07[c, g]	5.1E-05
^{241}Pu	8.8E-06	ND	9.9E-08	ND	NA	8.9E-06
^{241}Am	2.7E-06	1.2E-07	2.1E-06	4.8E-10	NA	4.9E-06
^{243}Am	NA	NA	NA	4.9E-08[d]	NA	4.9E-08
$^{243/244}Cm$	NA	NA	NA	ND	NA	ND

General Definitions: 1 Ci = 1 curie = 3.7E+10 becquerels (Bq); ND = not detected (i.e., either the radionuclide was not detected in any sample during the year or the average of all the measurements for that given radionuclide or type of radioactivity made during the year was below background levels); NA = not applicable.

[a]HT = tritium in the form of incondensable gas.

[b]HTO = tritium in the form of incondensable water vapor.

[c]Release from the FFTF-CB-EX stack that is based on estimated radionuclide inventory in residual sodium within the FFTF reactor primary coolant piping systems.

[d]Release calculation based on annual material inventory and on Appendix D method of 40 CFR 61; for ^{243}Am, the release was measured at the EP-325-01-S stack (8.9E-09 Ci) and calculated at the EP-331-01-V vent (4.0E-08 Ci); for ^{238}Pu the release was measured at the EP-325-01-S stack (3.9E-10 Ci) and calculated at the EP-331-01-V Vent (3.7E-08 Ci).

[e]Release based on release records from annual PNNL Radioactive Gas Inventory database.

[f]This release value includes data on gross beta emissions.

[g]This release value includes data on gross alpha emissions; the 400 Area value consists of gross alpha emissions from the 437-1-61 and 437-MN&ST stacks and from a calculated $^{239/240}Pu$ emission value for the FFTF-CB-EX stack.

3.3 COMPLIANCE ASSESSMENT

3.3.1 40 CFR 61, Subpart H: Regulatory Standard

The regulatory standard for a maximum dose to any member of the public is 10 mrem/yr EDE. The standard is in 40 CFR 61, Subpart H, and applies to radionuclide air emissions, other than radon, from DOE facilities. For calendar year 2016, the Hanford Site MEI location was LSW, an offsite business on the PNNL Richland Campus in north Richland, Benton County, Washington, directly south of the Hanford Site 300 Area. The combined dose to the MEI from routine and nonroutine Hanford Site point-source emissions was 0.038 mrem (0.00038 mSv) EDE. The majority of that dose (i.e., 99.3 percent) is attributable to ^{3}H point-source emissions from the 300 Area (Table 3-2).

3.3.2 Washington Administrative Code 246–247

For Hanford Site radionuclide air emissions, Washington State has adopted the federal dose standard of 10 mrem/yr EDE in WAC 246–247–040(1). In addition to the dose contributed by stacks, WAC 246-247-040(6) also requires the dose to the MEI to include doses from fugitive emissions, radon, and nonroutine events. Sampling data from ambient air samplers stationed at the perimeter of the Hanford Site were used to estimate emissions from fugitive sources. The reportable fugitive emission dose was calculated for the MEI at LSW because that is the location of the MEI for emissions from stacks (refer to Section 4.0). The doses from releases of radon are discussed in Section 3.6.3. No known instances of significant nonroutine emissions occurred in 2016 that would have discernibly contributed to the cumulative emissions from the Hanford Site (refer to Section 3.5). Thus, the total dose to the MEI at LSW in 2016 from all Hanford Site radionuclide emissions was 0.070 mrem (0.00070 mSv) EDE. This dose is the sum of doses from Hanford Site stacks, 0.038 mrem (0.00038 mSv) EDE, fugitive sources, 0.0060 mrem (0.000060 mSv) EDE, and radon sources 0.026 mrem (0.00026 mSv) EDE.

The dose to an individual at an actual residential location more realistically indicates the maximum dose that an individual at a self-sufficient farm might incur. This is best represented by a historic Hanford Site MEI location at Sagemoor Road. The dose to a Sagemoor Road receptor from all Hanford Site radionuclide emissions from stacks, fugitive sources, radon, and any nonroutine emissions, was 0.042 mrem (0.00042 mSv) EDE. This dose is the sum of doses from Hanford Site stacks, 0.022 mrem (0.00022 mSv) EDE, fugitive sources, 0.0060 mrem (0.000060 mSv) EDE, and radon sources 0.014 mrem (0.00014 mSv) EDE.

Table 3-2. CAP88-PC Effective Dose Equivalent Estimates for the Maximally Exposed Individual at LSW, Resulting from Hanford Site Point–Source Radionuclide Air Emissions in Calendar Year 2016

Radionuclide	Distances, Directions, and Effective Dose Equivalent (mrem) to the Offsite MEI, by Radionuclide and Operational Area[a]					EDE (40 CFR 61, Subpart H) by Radionuclide	
	100 Area 41 km[a] SE	200 East Area 29 km SE	200 West Area 35 km SE	300 Area 1.6 km S	400 Area 11 km SE	EDE Total (mrem)	Percent of EDE Total
^{3}H (HT)	NA	NA	NA	3.08E-03	NA	3.08E-03	8.074
^{3}H (HTO)	NA	NA	NA	3.48E-02	1.7E-07	3.48E-02	91.262
^{14}C	NA	NA	NA	1.9E-06	NA	1.9E-06	0.005
^{22}Na	NA	NA	NA	NA	2.0E-11	2.0E-11	<0.001
^{60}Co	NA	NA	NA	2.3E-07	NA	2.3E-07	0.001
^{85}Kr	NA	NA	NA	3.4E-13	NA	3.4E-13	<0.001
^{90}Sr	5.4E-08	9.0E-07	1.8E-08	4.5E-07	NA	1.4E-06	0.004
^{99}Tc	NA	NA	NA	1.6E-06	NA	1.6E-06	0.004
^{106}Ru	ND	ND	ND	1.7E-10	NA	1.7E-10	<0.001
^{129}I	NA	1.9E-04	NA	NA	NA	1.9E-04	0.506
^{134}Cs	ND	ND	ND	ND	NA	ND	0
^{137}Cs	3.3E-07[b]	3.3E-06[b]	3.0E-07[b]	1.6E-05[b]	4.5E-07[b]	2.1E-05	0.054
^{152}Eu	ND	ND	ND	4.2E-09	NA	4.2E-09	<0.001
^{154}Eu	ND	ND	ND	1.9E-08	NA	1.9E-08	<0.001
^{153}Gd	NA	NA	NA	1.2E-12	NA	1.2E-12	<0.001
^{226}Ra	NA	NA	NA	4.9E-09	NA	4.9E-09	<0.001
^{227}Ac	NA	NA	NA	1.8E-08	NA	1.8E-08	<0.001
^{231}Pa	NA	ND	NA	NA	NA	ND	0
^{232}U	NA	NA	NA	1.0E-07	NA	1.0E-07	<0.001
^{233}U	NA	NA	NA	6.7E-08	NA	6.7E-08	<0.001
^{237}Np	NA	NA	NA	2.7E-07	NA	2.7E-07	0.001
^{238}Pu	9.3E-08	ND	7.1E-08	1.4E-06	NA	1.5E-06	0.004
$^{239/240}$Pu	2.6E-06[c]	8.3E-07[c]	2.0E-05[c]	4.1E-06[c]	2.0E-06[c]	3.0E-05	0.077
^{241}Pu	3.2E-08	ND	1.0E-09	ND	NA	3.3E-08	<0.001
^{241}Am	4.5E-07	5.1E-08	9.6E-07	1.6E-08	NA	1.5E-06	0.004
^{243}Am	NA	NA	NA	1.7E-06	NA	1.7E-06	0.004
$^{243/244}$Cm	NA	NA	NA	ND	NA	ND	0
Dose Totals	3.5E-06	2.0E-04	2.1E-05	3.8E-02	2.6E-06	3.8E-02	▼
Percent of Total Dose	0.009	0.519	0.056	99.409	0.007	▶ **Percent Total: 100**	

[a]1 mrem = 0.01 mSv; 1 km = 0.621 mi.; NA = not applicable; ND = not detected.
[b]Dose includes data from gross beta emissions.
[c]Dose includes data from gross alpha emissions.
Notes: Particulate radionuclides (i.e., excluding ^{3}H, ^{85}Kr, and ^{129}I) contributed 6.1E-05 mrem/yr, or 0.159%, of the total stack dose, which more precisely is 3.82E-02 mrem/yr.
Slight differences in totals are due to rounding.

Table 3-3 shows the contribution to the MEI dose in 2016 from each major stack, grouped by operational area.

Table 3-3. Percent of the Total Dose from Hanford Site Major Point–Sources in Calendar Year 2016

Source Identification (Contractor)	Effective Dose Equivalent (mrem)[a]	Percent of Total Dose[b]
200 East Area		
291-A-1 (CHPRC)	2.0E-04	0. 52636
296-A-19 (WRPS)	2.7E-10	<0.00000
296-A-42 (WRPS)	1.5E-10	<0.00000
296-A-44/-45 (WRPS)	7.6E-10	<0.00000
296-A-46/-47 (WRPS)	9.4E-10	<0.00000
296-A-48/-49 (WRPS)	9.2E-11	<0.00000
296-B-1 (CHPRC)	3.4E-10	<0.00000
296-B-10 (CHPRC)	3.9E-06	0.01020
296-H-212 (CHPRC)	0.0E+00	<0.00000
296-P-47 (WRPS)	1.3E-09	<0.00000
296-P-48 (WRPS)	DNO	NA
296-P-107 (WRPS)	9.6E-10	<0.00000
200 West Area		
291-T-1 (CHPRC)	1.9E-06	0.00489
291-Z-1 (CHPRC)	1.9E-05	0.05032
296-P-43 (WRPS)	DNO	NA
296-P-44 (WRPS)	DNO	NA
296-P-45 (WRPS)	0.0E+00	<0.00000
296-S-21 (WRPS)	3.7E-08	0.00010
296-W-4 (CHPRC)	6.6E-10	<0.00000
300 Area		
EP-324-01-S (WCH)	5.1E-07	0.00134
EP-325-01-S (PNNL)	3.7938006E-02[c]	99.33546[c]
EP-331-01-V (PNNL)	5.3E-06	0.01382
Major Point-Source Totals ▶	**≈ 3.8E-02**	**≈ 100**

[a]1 mrem = 0.01 mSv
[b]Of the ≈0.038 mrem total for all stacks, the portion from major stacks is 3.82E-02 mrem (99.94% of the total stack dose) and from minor stacks is 2.2E-05 mrem (0.057% of total stack dose).
[c]Additional decimal places displayed because this is the dominant dose.
DNO = did not operate; NA = not applicable.

Table 3–4 ranks each stack by the dose attributable to its emissions compared to the Hanford Site MEI dose for calendar year 2016 of 0.038 mrem (0.00038 mSv) EDE from all stack emissions. The table presents the EP-325-01-S dose to seven decimal places since its emissions are responsible for over 99% of the Hanford Site stack dose.

Table 3-4. Ranking of Stack Doses from Hanford Site Stack Radionuclide Air Emissions for Calendar Year 2016

Rank	Stack	Major or minor	Contractor	Operating Area	EDE (mrem/yr)[a]	Percent of Total Dose
1	**EP-325-01-S**	**Major**	PNNL	300	3.7938E-02	99.3354810[b]
2	**291-A-1**	**Major**	CHPRC	200 East	2.0E-04	0.5263591
3	**291-Z-1**	**Major**	CHPRC	200 West	1.9E-05	0.0503223
4	**EP-331-09-S**	minor	PNNL	300	1.5E-05	0.0403228
5	**EP-331-01-V**	**Major**	PNNL	300	5.3E-06	0.0138185
6	**296-B-10**	**Major**	CHPRC	200 East	3.9E-06	0.0102001
7	105-KW Basin	minor	CHPRC	100-KW	3.6E-06	0.0092873
8	437-MN&ST	minor	CHPRC	400	2.5E-06	0.0064412
9	**291-T-1**	**Major**	CHPRC	200 West	1.9E-06	0.0048885
10	**EP-324-01-S**	**Major**	WCH/CHPRC	300	5.1E-07	0.0013354
11	291-S-1	minor	CHPRC	200 West	3.7E-07	0.0009688
12	296-E-1	minor	CHPRC	200 East	1.2E-07	0.0003011
13	**296-S-21**	**Major**	WRPS	200 West	3.7E-08	0.0000980
14	296-A-28	minor	WRPS	200 East	3.6E-08	0.0000943
15	296-A-30	minor	WRPS	200 East	1.1E-08	0.0000291
16	296-P-23 & -S-25	minor	WRPS	200 West	6.7E-09	0.0000175
17	437-1-61	minor	CHPRC	400	5.0E-09	0.0000131
18	296-A-41	minor	WRPS	200 East	3.2E-09	0.0000084
19	296-A-22	minor	WRPS	200 East	1.7E-09	0.0000044
20	296-A-40	minor	WRPS	200 East	1.4E-09	0.0000036
21	296-P-22	minor	WRPS	200 East	1.3E-09	0.0000034
22	**296-P-47**	**Major**	WRPS	200 East	1.3E-09	0.0000034
23	**296-P-107**	**Major**	WRPS	200 East	9.6E-10	0.0000025
24	**296-A-46/-47**	**Major**	WRPS	200 East	9.4E-10	0.0000025
25	296-A-18	minor	WRPS	200 East	9.2E-10	0.0000024
26	296-A-20	minor	WRPS	200 East	8.2E-10	0.0000021
27	**296-A-44/-45**	**Major**	WRPS	200 East	7.6E-10	0.0000020
28	**296-W-4**	**Major**	CHPRC	200 West	6.6E-10	0.0000017
29	**296-B-1**	**Major**	CHPRC	200 East	3.4E-10	0.0000009
30	296-S-16	minor	WRPS	200 West	2.7E-10	0.0000007
31	**296-A-19**	**Major**	WRPS	200 East	2.7E-10	0.0000007
32	**296-A-42**	**Major**	WRPS	200 East	1.5E-10	0.0000004
33	296-T-7	minor	CHPRC	200 West	9.2E-11	0.0000002
34	**296-A-48/-49**	**Major**	WRPS	200 East	9.2E-11	0.0000002
35	**296-H-212**	**Major**	CHPRC	200 East	0	0
36	**296-P-45**	**Major**	WRPS	200 West	0	0
37	296-A-21A	minor	WRPS	200 East	0	0
38	296-A-43	minor	WRPS	200 East	0	0
NA	**296-P-43**	**Major**	WRPS	200 West	DNO	NA
NA	**296-P-44**	**Major**	WRPS	200 West	DNO	NA
NA	**296-P-48**	**Major**	WRPS	200 East	DNO	NA
				Totals[c] ▶	**≈ 3.8E-02**	**≈ 100**

[a]EDE = effective dose equivalent; 1 mrem = 0.01 mSv

[b]Extra decimal places are displayed for this stack because in comparison to all other stacks the largest percentage of the total dose is attributable to it.

[c]Slight differences in totals are due to rounding.

DNO = did not operate; NA = not applicable.

3.4 METEOROLOGICAL DATA

Radionuclide air emissions disperse once they enter the atmosphere. Atmospheric dispersion models predict the degree of dilution and the magnitude of resulting air concentrations at downwind locations. Site-specific measurements of the occurrence frequencies for wind speed, wind direction, and atmospheric stability are used in the models. The dispersion models yield annual average dispersion factors, in units of seconds per cubic meter (s/m^3). Combining these factors with annual average release rates yields predictions of average radionuclide air concentrations for the year. Meteorological data for 2016 are presented in Appendix A as joint frequency of wind speed, wind direction, and stability category for stations located at the 200, 300, and 400 Areas. A new, 100-K meteorological station was operational during calendar year 2016 and was used for 100 Area emissions modeling.

3.5 NONROUTINE RELEASES OF RADIONUCLIDES TO THE ATMOSPHERE

No known instances of significant nonroutine emissions were reported in 2016. Any unreported nonroutine emissions would be part — and for all intents and purposes an indistinguishable part — of the cumulative emissions from the Hanford Site. Such nonroutine emissions, if elevated enough, would have been detected at ambient air monitoring stations located onsite or along the Hanford Site perimeter were they of measurable concentration. The impacts of this type of emission would therefore be accounted for in the dose estimates for fugitive sources, as described in Section 4.2.

3.6 ADDITIONAL COMPLIANCE INFORMATION

3.6.1 Applicability of Stack Emissions Data to Air Emission Permits and Licenses

The portions of the Hanford Site MEI dose attributable to individual stacks as listed in Section 2.0 are appropriate for use in demonstrating the compliance of abated stack emissions with applicable terms of the Hanford Site AOP, FF-01, and any underlying NOC approvals.

3.6.2 Construction Projects and Modifications Exempted from 40 CFR 61.96

No exemptions to the approval process under 40 CFR 61.96 were granted in 2016. In 1992, the EPA determined that some emission units at the Hanford Site were out of compliance with requirements in Subpart H of 40 CFR 61. As a result, a NESHAP Federal Facility Compliance Agreement (FFCA) was made between DOE-RL and EPA Region 10. In 1994, EPA stated it would not grant any exemptions until all FFCA milestones were completed, which occurred by the end of 2005. Since then, EPA has continued requiring approval for all construction or modification projects, including those with a radiological dose potential of less than 0.1 mrem/yr EDE.

3.6.3 Radon–220 and Radon–222 Emissions

Radon–220 was emitted from the 325 Building in the 300 Area via the EP-325-01-S major stack. No ^{222}Rn was emitted from Hanford Site operations other than as progeny of ^{226}Ra emissions. The release values were calculated using a conservative engineering estimate and gas inventory database; they were not derived from actual emission sample measurements. Radon is exempted from consideration in determining compliance with the dose standard of Subpart H of 40 CFR 61, yet is encompassed by state regulation WAC 246-247, which provides no exemption for radon: "Emissions of radionuclides in the air shall not cause a maximum effective dose equivalent of more than 10 mrem/yr to the whole body to any member of the public." The radon doses for 2016 to the MEI at LSW are presented in Table 3-5.

Table 3-5. Emissions of ^{220}Rn and ^{222}Rn from the EP-325-01-S Major Stack in Calendar Year 2016

Stack (Facility; Contractor)	Radionuclide	Emissions, Ci	EDE to MEI,[a] mrem
EP-325-01-S (325 Building; PNNL)	^{220}Rn	1.78E+02[b]	2.6E-02
	^{222}Rn	0	0
		Total Dose ▶	**2.6E-02**

[a]EDE = effective dose equivalent; MEI = maximally exposed individual, which in this case is at LSW, an offsite business on the PNNL Site, directly south of the Hanford Site 300 Area.
[b]Release based on records from PNNL Radioactive Gas Inventory database.

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4.0 FUGITIVE SOURCES OF EMISSIONS

For radiological dose effects to members of the public, Subpart H of 40 CFR 61 imposes a dose standard of 10 mrem/yr EDE, to which compliance is required for radionuclide emissions emanating from point and fugitive sources. Measuring and modeling these emissions are fundamental to demonstrating compliance with the standard.

Beginning in 1991, the Hanford Site has annually apprised regulators of its methods for estimating fugitive emissions and modeling the resulting doses to a member of the public. An EPA–funded guidance document on methods to estimate fugitive emissions (EPA 2004, *Methods for Estimating Fugitive Air Emissions of Radionuclides from Diffuse Sources at DOE Facilities*) is available. The Hanford Site method is summarized in that document, along with methods used at other DOE sites. The guidance document does not pass judgment on the methods, instead leaving individual sites free to choose a method most suitable to their unique operations, locations, and configurations.

For purposes of this report, the term fugitive emission refers to any potential source of radioactive material that is not actively monitored at the point of release. Such potential emission sources have been defined in various EPA and WDOH regulations as "diffuse," "fugitive," or "non–point" sources, arguably without definitions sufficient to guide a person to distinguish with certainty one type of emission from another. Thus, within this report, "fugitive emission" will also represent "diffuse emission" and "non-point emission." EPA defines fugitive emissions as "those emissions which could not reasonably pass through a stack, vent, or other functionally equivalent opening" (40 CFR 70.2, "State Operating Permit Programs"). WDOH similarly defines fugitive emissions, but with a significant qualification: "'Fugitive emissions' means radioactive air emissions which do not and could not reasonably pass through a stack, vent, or other functionally equivalent structure, and which are not feasible to directly measure and quantify" (WAC 246-247-030(12)). The WAC provides no definition of "non-point" sources; thus, such sources are assumed to be equivalent to diffuse sources as defined in DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*: "Diffuse Source is a source or sources of radioactive contaminants (emissions) released into the atmosphere that do not have a defined point (origin) of release (i.e., non–point source). Such sources are also known as area sources." The dose-modeling method used at Hanford is not dependent on the regulatory distinctions among these types of sources for estimating fugitive emissions and their resulting contributions to the total dose from airborne radionuclides.

In general, fugitive sources of radioactive emissions are sources not actively ventilated, are not sealed to prevent the escape of volatile or resuspended radioactive material to the ambient air, and are not amenable to routine sampling in a controlled manner as stacks commonly are. Examples of sources of fugitive radioactive emissions are passively ventilated tank vents, vented containers, outdoor surface contamination areas, cracks between cover blocks, decommissioned buildings, etc. Emissions released from buildings to the ambient air via passive ventilation systems are also considered fugitive because they lack a measurable flow. Emissions from fugitive sources are monitored by the Hanford Site Near-Field Monitoring (NFM) and Far-Field Monitoring (FFM) Programs, as described in Section 4.1. These emissions mix with ambient air, which may also have added to it emissions from stacks. Fugitive emission sources in and around Hanford Site facilities are described in Section 4.3. That section also describes the monitoring program and use of monitoring data for characterizing fugitive emissions and the estimated maximum EDE to the public attributable to those emissions.

Measuring emissions from stacks is ordinarily a prescriptive process, using well-defined technical methods, as described in Subpart H of 40 CFR 61, or alternatives approved by EPA and WDOH, and

includes applying atmospheric transport models to emissions measured at the facility stack. Subpart H monitoring methods, however, are not intended for or amenable to measuring fugitive emissions. Moreover, assessing offsite doses from fugitive emissions is not nearly as straightforward as it typically is for stacks. It is complicated by such factors as (1) the difficulty in accurately quantifying air flow from the source, (2) the greater complexity in the influences from meteorological conditions, and (3) distinguishing radionuclides released from fugitive sources from preexisting low concentrations of radionuclides in ambient air, the origins of which could be background radioactive material and radionuclides from stacks.

To address the shortcomings inherent in monitoring fugitive emissions, EPA and DOE developed a mutual inter-agency Memorandum of Understanding (MOU) ("Memorandum of Understanding Between the U.S. Environmental Protection Agency and the U.S. Department of Energy Concerning the Clean Air Act Emission Standards for Radionuclides 40 CFR Part 61 Including Subparts H, I, Q & T" [DOE 1995]). A principal agreement in this MOU was that the Subpart H dose standard applies not only to the radiological effects from point-source emissions but from fugitive emissions as well. A further aspect of this agreement is that DOE facilities nationwide were to develop methods for evaluating fugitive emissions. Before the MOU was published, the Hanford Site had developed such a method, and thus has been in compliance with that condition in the MOU since its inception. The current FF-01 discusses the acceptability of using Hanford Site ambient air monitoring data for demonstrating compliance with radiological dose limits. Also, the FF–01 prescriptively describes in fair detail the Hanford Site method of estimating fugitive emissions and the corresponding radiological dose to the MEI. Section 5.0 of the FF-01, "Method for Monitoring and Reporting of Diffuse and Fugitive Emissions," directs that the "average aggregate emissions from diffuse sources will then be used to estimate the dose at the Hanford Site perimeter with the CAP88-PC code." Compliance to this direction was achieved for 2016, as well as for earlier years.

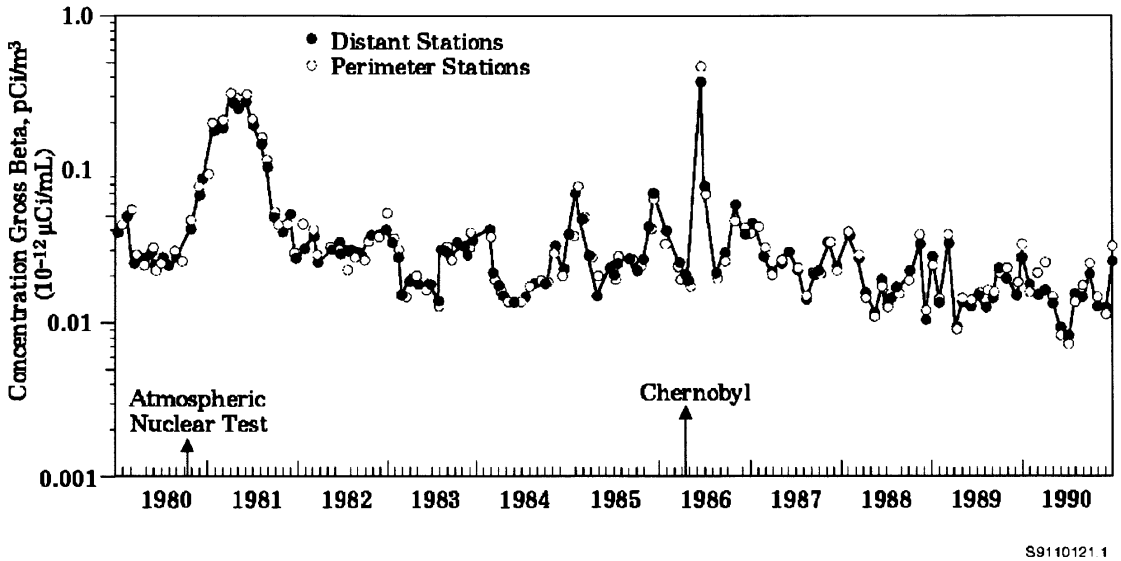
With respect to dose effects from fugitive emissions, WDOH regulations are consistent with the MOU, as evidenced by WAC 246-247-010(2), which states that the Subpart H dose standard applies to "point sources, nonpoint sources, and fugitive emissions." However, WAC 246-247-030(12) acknowledges that fugitive emissions "are not feasible to directly measure and quantify." This admission underscores the technical difficulties and inherent complexities in estimating fugitive emissions and their dose effects. Despite such challenges, the Hanford Site method affords a defensible and conservative estimate of fugitive radionuclide emissions and resulting doses, which are reported annually, both individually and in combination with the maximum dose from stack emissions, radon doses, and, as warranted, the doses from nonroutine airborne releases. Summing the doses from all of these radiological sources of emissions assures a comprehensive compliance determination against the Subpart H and WAC 246-247 dose standards.

Currently, all nuclear material production facilities at the Hanford Site have been shut down, are undergoing cleanup and demolition, or are in surveillance and maintenance status. Only waste minimization, stabilization processes, research activities, environmental remediation, and D&D continue. In the past, when the Hanford Site was operating at or near full capacity, point-source emissions were easily detected. Now, however, radioactive materials released from stacks have in large measure diminished to effectively background levels found in the ambient environment remote from the Hanford Site. As a consequence, the contribution from fugitive emissions has become a greater percentage of total emissions from the Hanford Site, even though fugitive emissions have thus far remained relatively small and constant.

Passively ventilated point sources, breather vents and other openings on tanks, vaults, vented containers, and other structures are potential conduits of fugitive radioactive emissions. Airborne radionuclides inside vented structures can be released through passive air exchanges, typically caused by changes in atmospheric pressure and temperature. It is difficult, however, to accurately assess radionuclide releases that might occur under such conditions, particularly when a vent opening is irregularly shaped or when multiple openings are in close proximity. This difficulty in accurately and readily quantifying passively ventilated emissions is the main reason why these sources are not routinely sampled using conventional point-source sampling methods. However, low emissions can be verified using other approved means such as smears, non–destructive analysis, occupational continuous air monitors, and direct radiation measurement using hand–held instruments. As an alternative to routine record sampling, estimates of radionuclides discharged as fugitive emissions from such sources are made based on data collected from a stable network of ambient air samplers around the downwind perimeter of the Hanford Site. Fugitive radionuclide release estimates are then calculated using these data. Section 4.2 contains the release estimates and resulting doses for Hanford Site fugitive emissions in 2016.

For this report, doses have been calculated for emissions from both actively ventilated stacks and from fugitive sources. Dose results for each type of release are presented separately, in addition to the totals for all sources of radioactive emissions. Historical gross beta data displayed in Figure 4-1 are illustrative of the impacts distant nuclear events in the world had on regional concentrations of airborne radioactivity, measured by the former Hanford Site Surface Environmental Surveillance Project (PNL-7346, *Hanford Site Environmental Report for Calendar Year 1990*). For perspective, ambient air concentrations measured at sample locations along the Hanford Site perimeter differ little from concentrations measured at locations distant from the Hanford Site.

Figure 4-1. Historical Impact of Gross Beta Radioactivity in Hanford Site Ambient Air Samples, 1979 through 1990



4.1 FUGITIVE EMISSIONS MONITORING

MSA manages both the NFM and FFM Programs, along with analysis of radionuclide samples collected in the environment at locations on and off the Hanford Site. Further program and project information is presented in the remainder of this section.

4.1.1 Near–Field Monitoring

NFM is defined as monitoring of the environment done near facilities and work sites that have potentially dispersible radioactivity. The monitoring locations include nuclear facilities, active remediation work sites, and waste storage or disposal facilities such as container storage, burial grounds, underground tanks (i.e., Tank Farms), ponds, cribs, trenches, and ditches.

Routine monitoring activities include the sampling and monitoring of ambient air, surface contamination, external radiation doses, soil, vegetation, and animals. Samples are collected from known or expected effluent transport pathways, which are generally downwind of potential or actual airborne releases and downgradient of liquid discharges. Ambient air sampling is the primary method used in monitoring fugitive emissions, with other media samples possibly useful as secondary indicators.

In 2016, airborne radioactivity was sampled by a network of 60 near-field ambient air samplers operated as continuously as possible near facilities and work sites, as shown in the following list:

- 100-K Area 6
- 200 Areas 45
- ERDF 3
- 300 Area 1
- 600 Area 1
- 618-10 4

Figure 4–2 identifies the locations of the ambient air samplers used for NFM, as well as FFM. The station at the Wye Barricade is collocated with samplers operated by MSA and WDOH. Eight other stations also have WDOH samplers collocated with them: four in proximity to the PFP in 200 West Area; one each at 100-KE, at ERDF, at the 618-10 Burial Ground Project, and at ETF in the 200 East Area. Additional samplers are also used to support specific environmental remediation tasks. Ambient air samplers are primarily located at or near (within about 1,600 ft [500 m]) sites and facilities having the potential for or history of radionuclide releases to the environment.

Particulate air samples are analyzed for gross alpha activity, gross beta activity, gamma-emitting isotopes, ^{90}Sr, uranium isotopes (^{234}U, ^{235}U, and ^{238}U), and plutonium isotopes (^{238}Pu and ^{239}/^{240}Pu). The primary gamma-emitting isotopes reported over the years include ^{60}Co, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{154}Eu, and ^{155}Eu. Samples collected at selected locations are also analyzed for ^{241}Am and/or ^{241}Pu. More detailed descriptions of these monitoring activities can be found in DOE/RL-2017-24, *Hanford Site Environmental Report for Calendar Year 2016* [in press].

4.1.2 Far–Field Monitoring

FFM encompasses sampling and analyzing for radiological contaminants at locations in four surveillance zones in the environment on and off the Hanford Site. The first surveillance zone extends from the NFM locations to the Hanford Site perimeter. The second zone consists of a series of perimeter sampling

stations near or just inside the Hanford Site boundary and along State Highway 240. The third zone consists of nearby community sampling locations within a 30-mi (48–km) radius of the Hanford Site. The fourth zone (i.e., background locations) currently consists of a single distant community location upwind of the Hanford Site and considered unaffected by its operations.

Routine surveillance activities include the sampling and monitoring of air, surface water, groundwater, food and farm products, fish and wildlife, soil and vegetation, and external radiation. Like the near–field monitoring program, ambient air sampling is the primary method used in monitoring fugitive emissions.

The air surveillance network consists of 40 sampling stations, of which 21 are onsite, 11 at the Hanford Site perimeter, 7 in nearby communities, and 1 in a distant community considered a background location. This program routinely monitors for radioactive vapors, gases, and aerosols, which at selected locations includes sampling for ^{3}H in the ambient air. The surveillance network located around the 300 and 400 Areas functions as a near-field network.

Airborne particulate radionuclides at all sampling stations are sampled and analyzed. Most particulate air samples are routinely analyzed for gross alpha activity, gross beta activity, gamma-emitting isotopes, ^{90}Sr, uranium isotopes (^{234}U, ^{235}U, and ^{238}U), plutonium isotopes (^{238}Pu and $^{239/240}Pu$), and ^{241}Am. Gamma-emitting isotope concentrations reported in 2016 include ^{60}Co, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, and ^{155}Eu. A more detailed description of this program can be found in DOE/RL-91-50, *Environmental Monitoring Plan*.

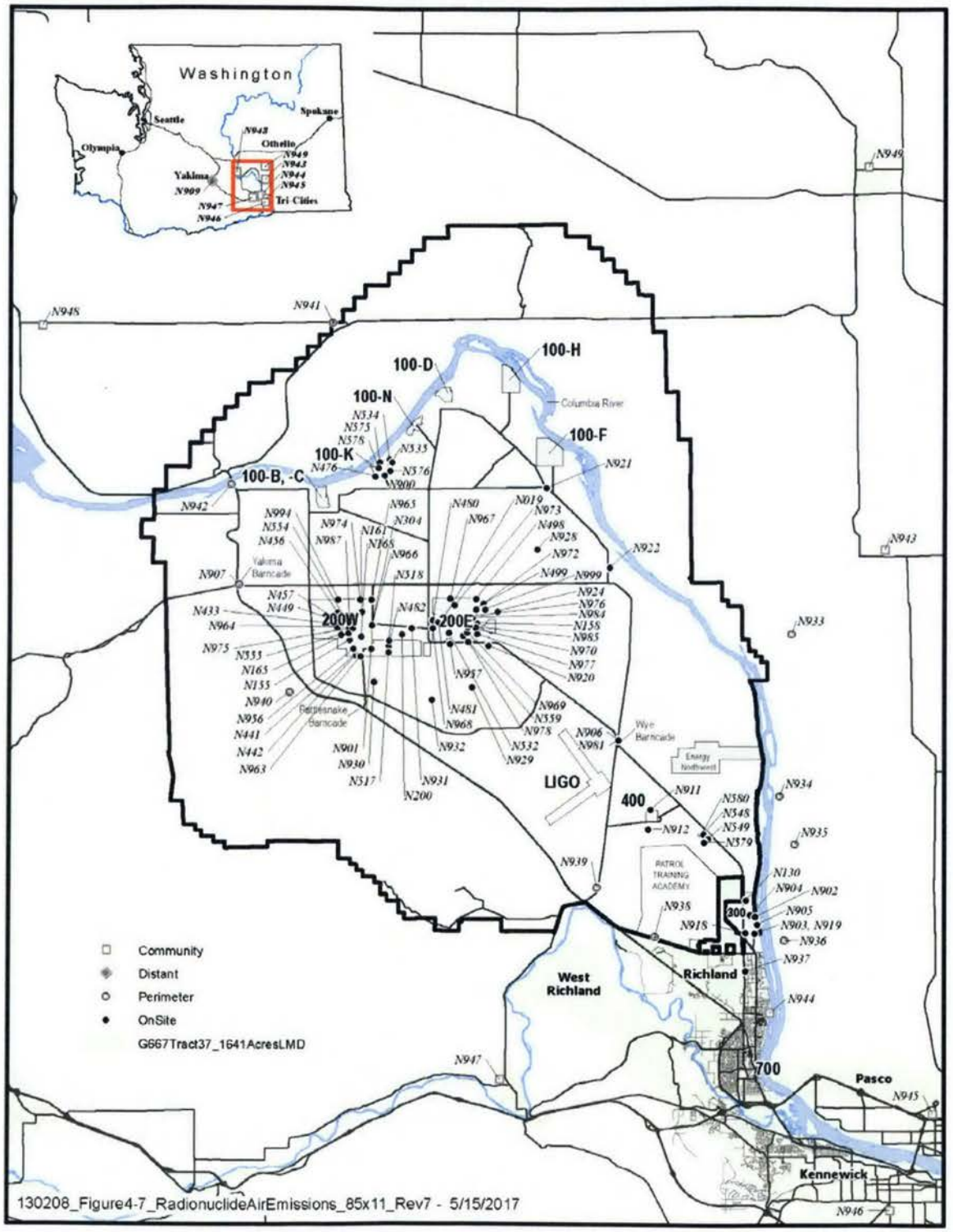
4.2 ESTIMATED DOSES FROM FUGITIVE EMISSIONS

Potential releases from fugitive sources and the resulting dose to an offsite member of the public were estimated using ambient air monitoring data from FFM air sampling locations along the Hanford Site perimeter. Data from the Yakima background station and 13 of the perimeter and nearby community sample locations required by the FF-01 Tables 4-1 and 4-2 were considered in the assessment of fugitive emissions in 2016. Refer to Figure 4-2, N909, N907, N933-N939, N941, N943-N946. Additional FFM air sampling location data were also reviewed to determine any substantial impact.

4.2.1 Dose Assessment Method

The method currently used to estimate emissions from fugitive sources at the Hanford Site, and the subsequent dose to a maximally exposed member of the public, is based on measured ambient air concentrations at the site perimeter. Contributions from monitored stack emissions and background radioactivity are subtracted from ambient air concentrations measured for each radionuclide. If the difference is positive, the result is attributed to fugitive sources. From the adjusted ambient air concentrations, CAP88-PC is used to back-calculate fugitive releases in curies (Ci) per year, conservatively assumed to emanate from a single, centralized location in the 200 West Area, an assumption that yields the largest release estimate.

Figure 4-2. Ambient Air Monitoring Locations



This is an indirect method for estimating fugitive emissions, but is subject to less uncertainty in estimating dose to a member of the public because it uses actual monitoring data from the site perimeter where members of the public could be located. This method is also far more cost effective than estimating fugitive emissions from the resuspension of particulate radionuclides from over 1,000 potential fugitive emission sources at the Hanford Site. Current information on the extent and characteristics of onsite soil contamination is insufficient to use radionuclide resuspension estimates in conjunction with transport and dose modeling for many potential sources of fugitive emissions. The ambient air sampling results consisted of measured air concentrations for radionuclides that could be released from Hanford Site operations and fugitive sources. Hanford Site radionuclides requiring assay of ambient air samples include ^{3}H, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{154}Eu, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239/240}Pu$, and ^{241}Am (DOE/RL-91-50).

An additional set of gamma–emitters found during laboratory analyses of the ambient air samples are also available in air sample reports; these include ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{152}Eu, and ^{155}Eu, as well as the ever-present ^{40}K, which is primordial in origin.

A document was published in 2007 that not only details the method and procedures used to estimate Hanford Site radiological doses to the MEI from both radioactive point-source and fugitive-source emissions, but also offers a brief history of relevant federal and state regulations and agency agreements (refer to DOE/RL-2007-53). This document evolved out of several DOE discussions with EPA and WDOH on the topic of the Hanford Site MEI. WDOH personnel participated in the review phase of the document and accepted the manner in which their resulting comments had been incorporated.

Using the CAP88-PC atmospheric dispersion modeling code, radionuclide air concentrations resulting from monitored stack emissions at Hanford Site facilities and other nearby non-DOE sources were calculated for the perimeter and nearby community sampling locations indicated in the FF-01. The modeled airborne radionuclide concentrations attributable to the stack emissions were subtracted from the ambient monitoring results. Average regional background concentrations for each radionuclide were calculated from the air sample results obtained at the distant community sampling station in Yakima, Washington, outside the 80-km (50-mile) radius and historically upwind from Hanford Site sources. The average background concentration at that station was subtracted from the ambient monitoring results. The contribution of emissions from fugitive sources is then assumed to be the net air concentrations at the site perimeter, adjusted to account for monitored emission sources and background concentrations.

Hypothetical releases of radionuclides from fugitive sources are estimated using the net perimeter air concentrations attributable to fugitive emissions and by performing a back-calculation using CAP88-PC. The 200 West Area near the center of the Hanford Site is assumed to be the source of all fugitive emissions. This assumption results in a conservatively high estimate of releases and doses from all fugitive sources. The average of the estimated emissions for each perimeter monitoring station is then modeled with CAP88-PC to estimate the dose at various candidate MEI locations. Table 4-1 displays results from the member-of-the-public location having the highest estimated dose from fugitive emissions, as well as the dose at the location of the member of the public who received the highest dose from monitored point-source emissions. A combined dose to a member of the public comprising the highest dose from monitored point-source emissions and the dose at that location from estimated fugitive-source and radon emissions is reported and evaluated for compliance with the 10 mrem/yr standards in Subpart H of 40 CFR Part 61 and in WAC-246-247.

Table 4-1. Estimated Hanford Site Fugitive Emissions and Resulting Effective Dose Equivalents for Calendar Year 2016[a]

Radionuclide[b]	Estimated Fugitive Emissions (Ci)[c]	Location	
		Estimated Dose to MEI at LSW (mrem)[d]	Estimated Dose at LIGO (mrem)[d,e]
^{3}H	-2.1E+02	0	0
^{60}Co	-1.0E-01	0	0
^{90}Sr	-1.3E-02	0	0
^{106}Ru	3.5E-01	7.5E-04[f]	2.8E-03[f]
^{125}Sb	-5.4E-01	0	0
^{134}Cs	-2.0E-01	0	0
$^{137}Cs/^{137m}Ba$	5.4E-02	3.0E-03[f]	1.1E-02[f]
^{152}Eu	-1.5E-01	0	0
^{154}Eu	-1.8E-01	0	0
^{155}Eu	-1.2E-03	0	0
Total U	1.7E-03	7.9E-05[f]	2.9E-04[f]
^{238}Pu	-2.1E-03	0	0
$^{239/240}Pu$	3.6E-03	2.2E-03[f]	8.0E-03[f]
^{241}Am	-6.0E-02	0	0
	Total ▶	6.0E-03	2.2E-02

[a] These fugitive emissions estimates have had Hanford Site stack emissions, background radioactivity, and emissions from Perma-Fix Northwest, Inc., AREVA Federal Services LLC, US Ecology, and Energy NW subtracted from them. Negative values for releases indicate that fugitive air concentrations are lower than the combined air concentrations from natural background and monitored stack releases.

[b]Not all radionuclides listed were evaluated at every sampling station.

[c]1 Ci = 3.7E+10 Bq. Emissions from fugitive sources are assumed to originate in the Hanford Site 200 West Area and have a release height of 1 m. The 300 Area also has potential sources for the resuspension of uranium from soil, along with naturally occurring uranium isotopes found throughout the area. Uranium releases were modeled as if the total inventory were from the 200 Areas, because it was not possible to determine the source of uranium isotopes detected at offsite sample stations.

[d]1 mrem = 0.01 mSv; these doses are based on air monitoring results for sample stations at the Site perimeter. Radionuclides with negative releases consequently have a zero dose.

[e]The highest estimated dose to a member of the public from fugitive emissions was at LIGO. LIGO was evaluated but disqualified as the MEI location because the total dose there attributable to CY16 emissions from stacks, fugitive sources, and of radon is 0.026 mrem (i.e., the summation of 0.0019 mrem from stacks, 0.022 mrem from fugitive sources, and 0.0016 mrem from radon), which is less than that combined dose of 0.070 mrem to the LSW receptor.

[f]The indicated ^{106}Ru, $^{137}Cs/^{137m}Ba$, total uranium (sum of ^{234}U, ^{235}U, and ^{238}U), and $^{239/240}Pu$ doses, conservatively reported, result from the procedure adopted for calculating and reporting fugitive dose. This dose estimate derives from consideration of nuclide measurements at background, perimeter, and nearby community monitoring stations. The procedure uses air sample results whether they are above or below detection levels.

4.2.2 Results of Dose Assessment

During 2016, the measured annual average ambient air concentrations of ^{106}Ru, ^{137}Cs, $^{239/240}Pu$, and total uranium (^{234}U, ^{235}U, and ^{238}U; modeled as ^{235}U) at the perimeter and nearby community sampling locations, were assessed to be greater than the combined contributions of these analytes from stack releases and the annual average air concentration measured at the background station. Thus, calculating the net fugitive air concentrations for these isotopes resulted in positive values. Calculating the net fugitive air concentrations for ^{3}H, ^{60}Co, ^{90}Sr, ^{125}Sb, ^{134}Cs, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{238}Pu, and ^{241}Am resulted in negative values. All of the net air concentrations, both positive and negative, for each radionuclide were used in back–calculating fugitive releases from the 200 West Area.

The calculated fugitive–source release estimates shown in Table 4–1 represent the average of the individual release estimates calculated from each of the perimeter and nearby community locations for each radionuclide. Note that not all radionuclides were evaluated at every sampling station; the estimated release of a radionuclide is based on analytical data associated with those stations from which samples were analyzed for that particular radionuclide.

When the resulting release estimate in Table 4-1 is less than zero for an individual radionuclide, the average of the air concentrations at the perimeter stations was smaller than the combined concentrations expected as a result of stack emissions and regional background. In such cases, it is unlikely that fugitive sources contributed significantly to the offsite measured air concentrations for those radionuclides. Where the release estimate for a particular radionuclide was less than zero, the dose estimate for that nuclide was set to zero before combining the contributions of all radionuclides to obtain the total dose at each location.

The calculated hypothetical fugitive release results in an estimated mean dose of 0.0060 mrem (0.000060 mSv) EDE to the Hanford Site MEI, shown in Table 4-1. The fugitive releases for the sampled radionuclides were also used to calculate the dose to a hypothetical receptor at a number of sampling stations. An individual at the Yakima Barricade station (N907), considered a perimeter location, had the highest estimated dose of 0.020 mrem (0.00020 mSv) EDE. An individual at the LIGO onsite location had the highest estimated member-of-the-public dose of 0.022 mrem (0.00022 mSv) EDE. The Ringold MEI (see Ringold in Figure 3-1) was the potential offsite MEI or offsite sampling station with the highest dose estimate from Hanford Site fugitive emissions, 0.011 mrem (0.00011 mSv) EDE. Dose estimates were between the MEI and Yakima Barricade values at six sampling stations (Basin City, Ringold Met Tower, West End of Fir Road, Dogwood Met Tower, Horn Rapids Substation, and Prosser Barricade [monitoring locations N943, N933, N934, N935, N938, and N939 respectively, in Figure 4-2]) and at the Ringold and Energy NW potential MEI locations (see Figure 3-1). Fugitive dose estimates at all other sampling stations and potential MEI locations were the same or lower than those estimated at the LSW MEI location.

For purposes of demonstrating compliance with the MEI dose standard, the dose at LSW from fugitive sources was chosen instead of the LIGO dose for adding to the point-source dose at the MEI location. The reason is two-fold. One, regardless of the size difference between doses from point-source emissions and from fugitive-source emissions, the method used to calculate the dose from point-source emissions is given primacy because it is based on agency-approved sampling of emissions from agency-permitted stacks, whereas the method used to calculate the fugitive emission dose is hypothetical, conservative, and includes sample results at or below detectable levels. Of the locations evaluated, the combined dose from stacks and fugitive sources was highest at LSW. And two, the fugitive-dose method centers on a single point of origin for all fugitive emissions, which adds to the conservative quality of the

method, whereas the point-source method is accepted as more reflective of actual emissions because it uses mostly measured emission values from five different geographical operating zones across the Hanford Site.

For 2016, the total estimated dose to the offsite MEI at LSW was 0.070 mrem (0.00070 mSv) EDE, which is well below the federal and state 10 mrem/yr standard. The MEI dose derived was 0.038 mrem (0.00038 mSv) EDE from point–source emissions, 0.0060 mrem (0.000060 mSv) EDE from fugitive emissions, and 0.026 mrem (0.00026 mSv) EDE from radon (e.g., ^{220}Rn and ^{222}Rn) emissions. To compare the 2016 and 2015 MEI doses, the total LSW estimated MEI dose for 2015 was 0.15 mrem (0.0015 mSv) EDE, comprising 0.067 mrem (0.00067 mSv) EDE from point–source emissions, 0.022 mrem (0.00022 mSv) EDE from fugitive emissions, and 0.064 mrem (0.00064 mSv) EDE from radon emissions.

In addition to the site-wide fugitive emissions estimates, fugitive tritium emissions from a 200 Area source during 2016 were estimated to determine their contribution to the public radiological dose. Tritium emissions from the 200 Area Tank Farms were estimated at less than 6 Ci/yr (2E+11 Bq/yr), but assumed to be 6 Ci/yr for dose estimation. Emissions were assumed to be in the form of tritiated water (HT) vapor. For 2016, the resulting dose to the Hanford Site MEI from estimated 200 Area fugitive tritium emissions from the 200 Area Tank Farms was 2.5E-5 mrem (2.5E-7 mSv) EDE. Also, two permitted fugitive emission units in the 300 Area, J-318 and J-361, may emit low levels of radioactive particulates and gases. All emissions from J-318 are accounted for in the Table 4-1 results. J-361 had no emissions in 2016.

4.2.3 Discussion of Bias in Dose Assessment

It should be noted that the release estimates for fugitive sources in Table 4-1 were obtained using CAP88–PC, which incorporates a continuous-release Gaussian-plume dispersion model. Releases from fugitive sources would be expected to occur primarily under conditions that are very different from the annual average assumptions used by CAP88-PC. This is particularly true for emissions that are a function of wind speed, such as resuspension of contaminated soil and evaporation from ponds. Because release rates from such sources are greatest under conditions that favor atmospheric dispersion, use of an annual average continuous release model to back-calculate the release quantities might introduce a significant bias into these estimates. The dose estimates for sources of this type might also be affected by seasonal variation in the resuspension rates caused by the prevalence of strong winds during certain seasons of the year. If those seasonal episodes occur primarily during times when crop production is minimal, some of the exposure pathways incorporated into the CAP88-PC code (direct deposition on human and animal food crops, for example) would not be applicable. The release and dose estimates reported for fugitive sources in this evaluation should therefore be viewed as approximations whose accuracy is limited by a number of factors inherent in the sampling and modeling process.

4.3 FUGITIVE EMISSION SOURCES

The Hanford Site consists of 580 mi^2 (1,502 km^2) of semiarid shrub-steppe land, of which approximately 6 percent (about 32 mi^2 [83 km^2], or 20,000 acres [8,090 ha]) has been disturbed and/or actively used. This 6 percent of land is distributed into large operational and support areas: the 100, 200 Areas (which includes the 200 East and 200 West Areas), 300, 400, and 600 Areas.

Almost all point and fugitive sources of radionuclide emissions are located in the five operational Areas (i.e., 100, 200 East, 200 West, 300, and 400 Areas). For dose modeling purposes, sources outside those operational areas are combined with sources within the nearest operational area. Most point-source emissions are measured directly, but at a few facilities they are conservatively calculated from process

knowledge. Emissions from fugitive sources are estimated using sample results from a network of environmental surveillance monitoring systems located along the Hanford Site perimeter and at several receptor locations. In some instances, emissions from specific fugitive emission sources are based on known inventories and/or release records.

The Hanford Site was acquired by the federal government in 1943 and dedicated to producing plutonium for national defense and managing the resulting production wastes. Restoring the Hanford Site environment is the new mission that has largely supplanted the previous operational objectives for national defense. The environmental restoration effort will entail activities such as decontaminating and decommissioning over 100 facilities and cleaning up and restoring about 1,500 waste sites. Until the restoration and cleanup work is completed, radioactive emissions may be released from hundreds of fugitive sources, in addition to monitored stacks.

Besides both measuring and modeling point-source emissions to determine public doses, environmental surveillance is conducted. Environmental and food-chain pathways are monitored near facilities emitting radionuclides from either stacks or fugitive sources.

The environmental pathways for all air emissions from the Hanford Site are monitored using a stratified sampling approach. Samples are collected and radiation measured according to four surveillance zones. These zones extend from main onsite operational areas to offsite regions (DOE/RL-2014-52, *Hanford Site Environmental Report for Calendar Year 2014*).

The first surveillance zone begins near the operating facilities and ends at the Hanford Site perimeter. Fugitive emissions generally will be most concentrated and easier to detect in this area before diluting further as they drift offsite.

The second surveillance zone is a series of sampling stations that surround the Hanford Site near its perimeter. Because a person could live as close to the Hanford Site as some of these stations, their data represent the maximum exposures for a member of the public. Therefore, ambient air sampling data from the perimeter locations most closely reflect the actual impacts of radionuclide air emissions from stacks and fugitive sources at the Hanford Site.

The third surveillance zone encompasses nearby and distant communities within a 50-mi (80–km) radius of the center of the Hanford Site but beyond its boundaries. Surveillance is conducted in communities to provide measurements at those locations where the most people are potentially exposed. This surveillance ensures radionuclide levels are well below standards established to protect the public health.

Finally, the fourth surveillance zone comprises distant locations at which background concentrations are measured. These concentrations are compared with onsite, perimeter, and community locations to indicate the effects of Hanford Site activities. Background locations are essentially unaffected by Hanford Site emissions but contain similar levels of radioactivity originating naturally and from nuclear-testing fallout.

The goal of environmental surveillance at the Hanford Site is to verify compliance with DOE, EPA, and WDOH radiological dose standards for public protection. This goal is accomplished by measuring radionuclides and consequent exposure in the onsite and offsite environment. The environmental surveillance criteria are derived from (1) the collected environmental surveillance data on radionuclides and doses, (2) applicable regulations other than DOE Orders, (3) DOE Order 458.1, *Radiation Protection of the Public and the Environment*, and (4) DOE-HDBK-1216-2015. The surveillance project was

established on these criteria and the pathway analyses that provide information on radionuclides and media contributing to human dose. Experience from Hanford Site environmental surveillance activities and studies conducted over the past 45 years has built an invaluable technical repository of information for planning and data interpretation.

4.3.1 Description of Fugitive Emission Sources

The presently identified actual or potential categorical sources of fugitive radionuclide emissions to the environment at the Hanford Site are described in this section. Among the sources that could release radioactive fugitive emissions are several types of waste handling and disposal facilities such as cribs, ponds, ditches, trenches, retention basins, valve pits, French drains, reverse wells, tanks, vented containers, and burial grounds. Over 1,000 of these types of sources have been identified, of which more than 95 percent are inactive (DOE/RL-88-30, *Hanford Site Waste Management Units Report*). Facilities that are operating on standby or are inactive can also be sources of radioactive fugitive emissions. These following activities can also cause fugitive radioactive emissions: deactivation, decontamination, decommissioning, and demolition of facilities; characterization of waste sites and areas; and cleanup of inactive waste sites. Each waste site or facility usually has one or more features or characteristics that could contribute to the fugitive release of emissions. The features may be passive vents, risers, equipment and personnel access doors, and exhausters, whereas characteristics may include an undetected leak, unburied waste, or an absence of intrusion barriers. Rates of fugitive emissions could be influenced by a variety of environmental conditions, such as (1) changing atmospheric pressures, (2) wind speed, (3) erosion, (4) evaporation, (5) percolation, and (6) biotic intrusion. Range fires present another cause of fugitive emissions, by way of smoke from burned material that contained radioactive particles and the resultant loss of vegetative cover, which had served to retard the resuspension of surface soil contaminants.

The general types of sites and facilities and their potential primary sources of fugitive emissions are briefly described in the following sections. Additional relatively current information and status detail on the remediation of fugitive emission sources can be found in DOE/RL-2017-24, the *Hanford Site Environmental Report for Calendar Year 2016 [in press]*.

4.3.1.1 Crib

Low-level liquid waste was discharged to cribs, which are subsurface systems similar to sanitary drain fields that allow the liquid component of the waste to percolate into the soil. The natural properties of the soil were used to remove radioactive material from the effluent water through filtration, ion-exchange, and precipitation reactions.

Many cribs are vented to the atmosphere through vents and pipe risers. Some cribs, however, have had vents and pipe risers either blanked or removed. Those engineered structures promoted the downward flow of liquids disposed of in cribs but also provide pathways to the surface and atmosphere. Secondary causes of fugitive emissions include erosion and uptake and intrusion by biota, followed by wind-caused particle resuspension.

4.3.1.2 Ditch

A ditch is an open, unlined excavation formerly used for disposing of liquid effluents or transporting liquid effluents to ponds for disposal. Most ditches have been filled with soil. Fugitive emissions from ditches occur primarily from wind-caused particle resuspension, vegetative uptake, biota intrusion, and erosion.

4.3.1.3 Trench

Early disposal practices included disposing of liquid effluents into unlined trenches and over time filling the structures with soil. Those trenches were mostly replaced by cribs such as the BC-cribs, now retired. Fugitive emissions from trenches are primarily caused by erosion, uptake and intrusion by biota, followed by wind-caused particle resuspension.

4.3.1.4 Retention Basin

Similar to trenches, retention basins generally were lined with concrete and used to hold liquid before routing it to ditches or ponds. Fugitive emissions from retention basins are caused primarily by wind-caused particle resuspension.

4.3.1.5 Diversion Box

A diversion box is usually an underground concrete structure formed around a junction of transfer lines carrying liquid effluent. When diversion boxes are accessed for operations or maintenance, radioactively contaminated material might be released in the form of fugitive emissions.

4.3.1.6 Valve Pit

A valve pit is similar in structure to a diversion box, but contains piping valves. When valve pits are accessed for maintenance or operations, radioactively contaminated material might be released in the form of fugitive emissions.

4.3.1.7 French Drain and Reverse Well

A French drain is a rock-filled encasement inserted in the ground. A reverse well is an ordinary well formerly used for mixing liquid waste with groundwater. These subsurface systems were used to dispose of potentially contaminated liquid waste by promoting percolation into the soil. The natural filtration properties of the soil removed radioactive material from effluent water. Fugitive emissions from French drains and reverse wells might occur through erosion or uptake and intrusion by biota, followed by wind-caused particle resuspension.

4.3.1.8 Tank

A tank generally is a large reinforced metal structure that receives liquid effluent for storage. Examples are DSTs and SSTs. Pathways for fugitive emissions from tanks include passively ventilated point sources and inactive exhausters open to the atmosphere. Transport mechanisms for these emissions include deposition and subsequent particle resuspension.

4.3.1.9 Burial Ground

Burial grounds are trenches in which contaminated solid waste is buried. Waste packaging procedures and burial practices used depend on the type of waste. Fugitive emissions occur at burial grounds through direct release to the atmosphere before the waste is buried, but could occur after burial by way of erosion, vegetative uptake, biota intrusion, and wind-caused particle resuspension.

4.3.1.10 Deactivation, Decontamination, Decommissioning, and Demolition Activities

Deactivation, decontamination, decommissioning, and demolition activities are conducted to minimize the potential release or spread of contamination from facilities and equipment. Deactivation activities are intended to remove facility systems and/or areas from operational service to make them ready for the facility transition phase in which facilities are either converted to another use or placed in a permanent shutdown condition. Activities could include removal of spent nuclear fuel; draining and/or de-energizing of systems; removal of accessible stored radioactive and hazardous material; and other actions that place the facility systems and/or areas in a safe and stable condition. Deactivation reduces the risk to the public and the environment until the ultimate disposition of each facility is decided and implemented, and allows the surveillance-and-maintenance program to be conducted more cost effectively.

Decontamination primarily consists of physically removing contaminants, but can also include fixing contaminants in place, to the extent they are not smearable, to prevent their mobility during demolition. Methods might include washing with water, scraping, sandblasting, or fixing the contamination in place by painting, applying asphalt, etc. Demolition involves destroying and removing the structure and might include excavating its foundation. In some cases, contaminated material might be exposed to the atmosphere, but proper planning and controls should minimize these exposures. Monitors around demolition sites are used to measure or indicate the effectiveness of controls.

4.3.1.11 Waste Site Characterization and Cleanup Activities

Characterization is performed to determine the extent of contamination. Cleanup activities are conducted to minimize the potential release or spread of contamination from inactive waste sites. Contaminated soils and structures are excavated and transported to ERDF and/or other disposal sites. Contaminated materials are exposed to the atmosphere during excavation and disposal activities. Proper planning and controls such as water sprays and fixatives are used to minimize the potential for airborne emissions. The waste sites are backfilled after excavation and the disposed material is covered with soil.

4.3.1.12 Radioactively Contaminated Outdoor Surface Areas

Radiological surveys are routinely conducted at these types of radioactively contaminated outdoor surface areas: burial grounds, cribs, trenches, retention basins, and known unplanned release sites. The surveys are performed at least annually, but more frequently when needed. The areal magnitude of outdoor surface contamination varies, despite continuing efforts to clean, stabilize, or remediate them. Newly identified contamination can be the result of preexisting contamination having migrated, by way of wind-caused resuspension or by biological intrusion, to previously uncontaminated areas or because radiological screening criteria have become more stringent. Fugitive emissions originating from contaminated soil are primarily caused by erosion, plant uptake, biota intrusion, and wind-caused particle resuspension.

4.3.1.13 Structures with Radioactive Contamination

Structures having indoor contamination and not actively ventilated through a stack could be sources for fugitive emissions. Many structures control fugitive emissions with ventilation systems and contamination control practices. Ventilation systems generally help maintain a negative indoor air pressure and can significantly reduce airborne contaminants from leaving the building by use of pollution abatement systems. Many structures with ventilation systems discharge air to the atmosphere

via an emission control device, typically a HEPA filter. Facilities with a potential-to-emit radioactive contaminants and that have actively ventilated, filtered, and routinely sampled stacks are not considered a source of fugitive emissions. This type of facility has the potential, though lesser in extent than facilities not equipped with active ventilation systems but with a comparable source term. The Hanford Site has many old structures with radioactive contamination and no building ventilation. Contaminants can sometimes migrate outdoors via human entry and exit. Also, contaminants can migrate outdoors via passive ventilation or animal intrusion because these structures often have cracks and gaps that serve as pathways to the outdoors. Once the contaminants are transported outdoors, they can become airborne by wind-caused resuspension.

4.3.1.14 PNNL 300 Area Non-Point Sources

Two permitted non-point source emission units are located in the 300 Area, at the 361 Building Modular Equipment Shelter and the 318 Building (J-361 and J-318, respectively; see Figure 1-5). The 318 Building is the Radiological Calibrations Laboratory that has the capacity for work with sealed sources and low-activity research material. The 361 Building Modular Equipment Shelter is a pre-cast concrete portable structure permanently located in the southwest corner of the 300 Area. Sampling equipment is installed in the 361 Building to sample atmospheric gases. Periodically, radioactive calibration gases may be used to confirm operability of equipment.

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5.0 SUPPLEMENTAL INFORMATION

This section has supplemental information related to Hanford Site radionuclide air emissions in 2016 and consists of the following:

- Collective (population) dose estimate
- Compliance status with respect to Subparts Q and T of 40 CFR 61
- Periodic confirmatory measurements related to NOCs
- Ambient air sampling measurements
- Quality assurance (QA) program status of compliance with 40 CFR 61, Appendix B, Method 114.

5.1 COLLECTIVE DOSE ESTIMATE

Collective doses to the population surrounding the Hanford Site in calendar year 2016 are provided below. CAP88-PC v4.0.1.17 was used to estimate collective dose from the emissions listed in Table 3.1. The 50-mile population distributions are centered at each Hanford operational area, with the 200E and 200W Areas being combined into one operational area centered at the Hanford Meteorological Station (PNNL-20631). CAP88-PC input values are similar to that of the MEI, with the exception of applying only 10-meter emission heights and a regional agriculture option. The largest population distribution, 586,500 persons, is within 50 miles of the 200 Areas. The 300 Area 50-mile population, 432,120 persons, accounted for over 80 percent of the collective dose. The total collective dose from all operational areas represents a greater-than 50-mile population estimate because operational areas are so far apart on the Hanford Site (e.g., the 100K and 300 Areas are 25 miles apart).

• 100K Area emissions result in a collective dose of	0.0015 person-rem (0.000015 person-Sv)
• 200E and 200W Areas emissions result in a collective dose of	0.0537 person-rem (0.000537 person-Sv)
• 300 Area emissions result in a collective dose of	0.2370 person-rem (0.002370 person-Sv)
• 400 Area emissions result in a collective dose of	0.0002 person-rem (0.000002 person-Sv)
Total	0.2924 person-rem (0.002924 person-Sv)

Radon-220 (178 Ci) and radon-222 (none) emissions from the 300 Area would result in an additional 0.23 person-rem (0.0023 person-Sv) of collective dose.

5.2 COMPLIANCE STATUS WITH 40 CFR 61, SUBPARTS Q AND T

In 40 CFR 61, Subpart Q, "National Emission Standards for Radon Emissions from Department of Energy Facilities," paragraph 61.190 states that the provisions of Subpart Q apply to the design and operation of all storage and disposal facilities for radium-bearing material that emits ^{222}Rn to the air. Paragraph 61.191(b) states that a source means any building, structure, pile, impoundment, or area used for interim storage or disposal that is or contains waste material containing radium in sufficient concentration to emit ^{222}Rn in excess of a standard of 20 pCi/m^2/s. The known quantities of ^{226}Ra (the immediate precursor to ^{222}Rn) stored at the Hanford Site were evaluated and found to decay to ^{222}Rn at a rate below the standard.

Activities at the Hanford Site were evaluated for compliance with 40 CFR 61, Subpart T, "National Emissions Standards for Radon Emissions from the Disposal of Uranium Mill Tailings." In paragraph 61.220, "Designation of Facilities," owners and operators of such facilities are subject to the provisions in Subpart T: those whose sites were used for the disposal of tailings and that managed residual radioactive material or uranium byproduct materials during and following the processing of uranium ores and that are listed in or designated by the Secretary of Energy under Title I of the Uranium Mill Tailings Control Act of 1978 or regulated under Title II of that act. Since no uranium milling and uranium-ore processing activities are conducted at the Hanford Site, Subpart T does not apply.

5.3 PERIODIC CONFIRMATORY MEASUREMENTS

This section contains measurement data related to point-source emission abatement media. The data are indicative of low emissions from those sources, a condition for which confirmatory measurements are periodically made as required by NOCs and other regulatory agreements.

Table 5-1 presents data from the nondestructive analysis of the primary HEPA filter associated with the Site-wide Guzzler.

Table 5-1. Nondestructive Analysis Results for Calendar Year 2016

Location	Filtration	Analysis Date	Radionuclide	µCi
Site-wide guzzler	HEPA	10/10/16	^{60}Co ^{137}Cs	ND ND

1 Ci = 1 curie = 3.7E+10 Bq; ND = not detected; NA = not applicable.

Table 5-2 has data indicative of low emissions from a work area where an air sparger is located inside the 105-KW Basin. The data derive from the destructive analysis of a passively ventilated HEPA filter in a vent connected to that work area.

Table 5-2. 105-KW Basin Destructive Analysis Results for Calendar Year 2016

Emission Unit (Location; EDP Code)	Filter Medium	Analytes	Activity
105-KW Air Sparging Vent (105-KW Basin; Y249) CERCLA	HEPA	gross α, gross β, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239/240}Pu$, ^{241}Pu, and ^{241}Am	Only gross β detected at 494 pCi

HEPA = high-efficiency particulate air

Table 5-3 presents the periodic confirmatory measurements for the WESF Ventilation Upgrades Project W-130. In accordance with the respective WDOH licenses, it provides the sample concentrations and corresponding Ci totaled for each portable emission unit used during the course of the project. Project W-130 is a fugitive source of emissions and as such the emissions and resulting dose are accounted for and reported under the Near-Filed Ambient Air Monitoring system.

Table 5-3. WESF Ventilation Upgrade Project W130 Periodic Confirmatory Measurements for Calendar Year 2016 (2 pages)

Emission Unit (EDP code; WDOH EU-ID)	Analytes	Sample Results (µCi/mL)	Emissions[1] (Ci)
Truck Port (B610; 1431)	gross α	1.7E-14	3.6E-08
	gross β	3.6E-14	7.5E-08
	^{90}Sr	ND	0.0E+00
	^{137}Cs	ND	0.0E+00
Hot Cell A (B611; 1427)[2]	gross α	8.5E-15	1.0E-08
	gross β	1.5E-13	1.8E-07
	^{90}Sr	2.1E-14	2.5E-08
	^{137}Cs	1.4E-15	1.7E-09
Hot Cell B (B611; 1428)[2]	gross α	8.5E-15	1.0E-08
	gross β	1.5E-13	1.8E-07
	^{90}Sr	2.1E-14	2.5E-08
	^{137}Cs	1.4E-15	1.7E-09
Hot Cell C (B611; 1429)[2]	gross α	8.5E-15	1.0E-08
	gross β	1.5E-13	1.8E-07
	^{90}Sr	2.1E-14	2.5E-08
	^{137}Cs	1.4E-15	1.7E-09
Stack Tent at K3 Duct & Stack (B612; 1431)	gross α	7.5E-15	1.1E-09
	gross β	1.7E-14	2.6E-09
	^{90}Sr	ND	0.0E+00
	^{137}Cs	ND	0.0E+00
Tank 100 (B613; 1431)	gross α	8.3E-15	5.7E-10
	gross β	5.6E-14	3.8E-09
	^{90}Sr	ND	0.0E+00
	^{137}Cs	ND	0.0E+00
Hot Cells D, & E (B614; 1430)[3]	gross α	5.4E-15	6.5E-09
	gross β	7.2E-13	8.7E-07
	^{90}Sr	1.4E-13	1.7E-07
	^{137}Cs	1.9E-15	2.3E-09
Hot Cells F, & G (B614; 1426)[3]	gross α	5.4E-15	6.5E-09
	gross β	7.2E-13	8.7E-07
	^{90}Sr	1.4E-13	1.7E-07
	^{137}Cs	1.9E-15	2.3E-09
K3 Duct & Fan (B615; 1431)	gross α	3.5E-15	5.0E-09
	gross β	1.1E-14	1.6E-08
	^{90}Sr	ND	0.0E+00
	^{137}Cs	ND	0.0E+00

	gross α	7.4E-14	1.6E-10
K3 Filter Pit	gross β	5.1E-13	1.1E-09
(B616; 1432)	^{90}Sr	ND	0.0E+00
	^{137}Cs	ND	0.0E+00

[1]Gross alpha and gross beta emissions are calculated using the sum of all positively detected sample concentrations multiplied by the total exhaust volume for the location;
isotopic emissions are calculated using positively identified nuclides from a single composite of all samples for that location multiplied by the total exhaust volume for that location.
[2]Hot Cells A, B & C were connected together and exhausted through one HEPA filtered negative air machine. Total emissions data collected from the single fixed head sampler is applied to each individual emission unit.
[3]Hot Cells D, E, F, & G were connected together and exhausted through one HEPA filtered negative air machine. Total emissions data collected from the single fixed head sampler is applied to each individual emission unit.

5.4 AMBIENT AIR SAMPLING MEASUREMENTS

The NFM and FFM programs comprise a comprehensive network of monitoring locations near facilities and projects at the Hanford Site as well as at other onsite, perimeter, and offsite locations. The programs monitor ambient air, soil, vegetation, and biota that may contain radionuclides dispersed there by onsite activities. NFM also uses thermoluminescent dosimeters to measure ambient dose rates at the locations where they are placed. Emissions from many NOC activities are not measured directly at the source, as are emissions from facilities outfitted with forcibly ventilated stacks equipped with calibrated sampling and/or monitoring devices. Such activities can create fugitive emissions not directly quantifiable as are stack emissions. To that point, WDOH states that "fugitive emissions....are not feasible to directly measure or quantify" (see Washington Administrative Code for "Radiation Protection-Air Emissions," Chapter 246-247-30(12)). Strategically placed ambient air stations measure radionuclides dispersed from those activities at distances from the sources both near and far. Comparisons to distantly measured concentrations enable assessments of whether emissions that can be associated with Hanford Site activities are low or not; ambient air sampled onsite, in nearby communities, and at Hanford Site perimeter stations unavoidably may contain radionuclides from stacks, which could have co-mingled with fugitive emissions. Concentrations are considered low if they are beneath respective radionuclide concentrations in Table 2 of Appendix E to 40 CFR 61, Subpart I.

WDOH requires that emissions from NOC activities be measured periodically to confirm whether or not their levels are low. A variety of measurement methods are used to confirm that emissions are low, including evaluating data from the NFM program, dose–rate surveys, surface smears, continuous air monitor sampling, and both nondestructive and destructive analysis of HEPA filters. Further confirmatory methods are allowed, provided they are first approved by WDOH.

Summarized in Table 5–4 is the analytical data measured from NFM ambient air samples collected during 2016. The data are organized by general emission unit, which for regulatory purposes is construed as equivalent to an operational area such as the 100, 200, 300, 400, or 600 Area. Radionuclides with concentrations that fell below analytical detection limits in both the first and second half of the semi–annual composite samples were not listed in the tables.

Table 5-5 has ambient air results from samples collected at monitoring stations that support the FFM program. These stations are located onsite, at the Hanford Site perimeter, and in nearby and distant communities. One of the sub-tables in Table 5-5 has data required by the FF-01 for use in calculating the radiological fugitive-emission dose to the Hanford Site MEI.

The following definitions apply to abbreviations and units of measure found in Tables 5–4 and 5–5:

- EDP = Electronic Data Processing [code] (these alpha–numeric codes, such as "N464," serve as sampler location identifiers)
- "1st half" and "2nd half" refer to approximate 6-month periods of the calendar year; i.e., January 1 through June 30 and July 1 through December 31, respectively
- 1 Ci = 1 curie = 3.7E+10 becquerels (Bq)
- pCi = picocurie =E-12 Ci
- m^3 = cubic meter pCi/m^3 = picocuries per cubic meter (pCi =E-12 curies)
- NA = not applicable (because up to 26 samples were analyzed each half year, but this table shows only a single isotopic result obtained for that period)
- ND = not detected (i.e., result less than zero, less than its overall analytical error, or no peak detected). Results below detection limits are not reported here. However, the method used to calculate fugitive emission dose considers all results.

Table 5-4. Hanford Site Near–Field Monitoring Air Sampling Results for Calendar Year 2016
(9 sub–tables on 6 pages)

100 Areas

EDP Code	Radionuclide or Type of Radioactivity	Sludge Treatment Project Concentration, pCi/m^3			
		1st Half	2nd Half	Average	Maximum
N476	gross α	NA	NA	1.3E-03	3.3E-03
	gross β	NA	NA	1.5E-02	4.1E-02
N534	gross α	NA	NA	1.6E-03	3.4E-03
	gross β	NA	NA	1.6E-02	5.1E-02
	^{234}U	ND	1.9E-05	1.9E-05	1.9E-05
N535	gross α	NA	NA	1.5E-03	3.7E-03
	gross β	NA	NA	1.5E-02	3.9E-02
N575	gross α	NA	NA	1.5E-03	3.2E-03
	gross β	NA	NA	1.6E-02	4.9E-02
	^{238}U	ND	1.2E-05	1.2E-05	1.2E-05
N576	gross α	NA	NA	1.5E-03	4.9E-03
	gross β	NA	NA	1.6E-02	4.2E-02
N578	gross α	NA	NA	1.4E-03	3.4E-03
	gross β	NA	NA	1.7E-02	4.6E-02
N900 (100-K Area)	gross α	NA	NA	1.0E-03	3.8E-03
	gross β	NA	NA	1.7E-02	4.6E-02
	^{3}H	NA	NA	9.4E+00	9.4E+00

200 Area

EDP Code	Radionuclide or Type of Radioactivity	200 East Area Concentration, pCi/m³ 1st Half	2nd Half	Average	Maximum
N019	gross α	NA	NA	1.7E-03	4.6E-03
	gross β	NA	NA	1.5E-02	4.0E-02
	^{238}U	ND	1.9E-05	1.9E-05	1.9E-05
N158	gross α	NA	NA	1.6E-03	5.2E-03
	gross β	NA	NA	2.4E-02	1.8E-01
	^{90}Sr	ND	ND	5.2E-03	5.2E-03
	^{137}Cs	2.1E-03	ND	2.1E-03	2.1E-03
	^{234}U	3.5E-05	ND	3.5E-05	3.5E-05
	^{238}U	3.6E-05		3.6E-05	3.6E-05
N498	gross α	NA	NA	1.3E-03	3.1E-03
	gross β	NA	NA	1.5E-02	4.3E-02
	^{238}U	ND	2.1E-05	2.1E-05	2.1E-05
N499	gross α	NA	NA	1.5E-03	3.8E-03
	gross β	NA	NA	1.6E-02	5.6E-02
	^{234}U	4.4E-05	1.8E-05	3.1E-05	4.4E-05
N532	gross α	NA	NA	1.3E-03	3.4E-03
	gross β	NA	NA	1.6E-02	4.2E-02
N559	gross α	NA	NA	1.3E-03	2.8E-03
	gross β	NA	NA	1.5E-02	4.0E-02
N582	gross α	NA	NA	1.4E-03	3.5E-03
	gross β	NA	NA	1.4E-02	3.2E-02
N957	gross α	NA	NA	1.5E-03	4.5E-03
	gross β	NA	NA	1.4E-02	3.74E-02
N967	gross α	NA	NA	1.6E-03	3.7E-03
	gross β	NA	NA	1.6E-02	4.0E-02
N968	gross α	NA	NA	1.5E-03	3.2E-03
	gross β	NA	NA	1.5E-02	4.4E-02
N969	gross α	NA	NA	1.6E-03	3.9E-03
	gross β	NA	NA	1.4E-02	3.7E-02
	^{234}U	ND	1.5E-05	1.5E-05	1.5E-05
N970	gross α	NA	NA	1.6E-03	3.2E-03
	gross β	NA	NA	1.5E-02	3.5E-02
	^{234}U	1.8E-05	ND	1.8E-05	1.8E-05
	^{238}U	1.6E-05	ND	1.6E-05	1.6E-05
N972	gross α	NA	NA	1.6E-03	3.3E-03
	gross β	NA	NA	1.6E-02	4.8E-02
N973	gross α	NA	NA	1.2E-03	2.0E-03
	gross β	NA	NA	1.5E-02	3.8E-02
	^{234}U	4.9E-05	ND	4.9E-05	4.9E-05

200 East Area					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N976	gross α	NA	NA	1.4E-03	4.4E-03
	gross β	NA	NA	1.6E-02	5.2E-02
	^{238}U	ND	1.9E-05	1.9E-05	1.9E-05
N977	gross α	NA	NA	1.4E-03	3.0E-03
	gross β	NA	NA	1.5E-02	4.4E-02
	^{234}U	ND	1.8E-05	1.8E-05	1.8E-05
	^{238}U	1.5E-05	ND	1.5E-05	1.5E-05
N978	gross α	NA	NA	1.4E-03	3.6E-03
	gross β	NA	NA	1.5E-02	3.8E-02
N984	gross α	NA	NA	1.5E-03	3.3E-03
	gross β	NA	NA	1.5E-02	4.3E-02
N985	gross α	NA	NA	1.4E-03	3.1E-03
	gross β	NA	NA	1.5E-02	4.4E-02
N999	gross α	NA	NA	1.5E-03	3.9E-03
	gross β	NA	NA	1.5E-02	3.7E-02
	^{137}Cs	ND	1.2E-03	1.2E-03	1.2E-03

Canister Storage Building (200 East Area)					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N480	gross α	NA	NA	1.3E-03	3.8E-03
	gross β	NA	NA	1.4E-02	3.6E-02
N481	gross α	NA	NA	1.3E-03	3.3E-03
	gross β	NA	NA	1.5E-02	4.1E-02
	^{234}U	3.1E-05	ND	3.1E-05	3.1E-05

200 West Area					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N155	gross α	NA	NA	1.4E-03	3.2E-03
	gross β	NA	NA	1.4E-02	3.4E-02
	^{238}U	ND	1.3E-05	1.3E-05	1.3E-05
N161	gross α	NA	NA	1.5E-03	3.2E-03
	gross β	NA	NA	1.4E-02	3.7E-02
	^{235}U	6.9E-05	ND	6.9E-05	6.9E-05
N165	gross α	NA	NA	1.7E-03	4.7E-03
	gross β	NA	NA	1.4E-02	3.4E-02

EDP Code	Radionuclide or Type of Radioactivity	200 West Area Concentration, pCi/m³ 1st Half	2nd Half	Average	Maximum
	$^{239/240}Pu$	6.3E-05	2.1E-04	1.4E-04	2.1E-04
	^{241}Am	ND	3.6E-05	3.6E-05	3.6E-05
N168	gross α	NA	NA	1.5E-03	4.6E-03
	gross β	NA	NA	1.5E-02	4.0E-02
N200	gross α	NA	NA	1.6E-03	2.0E-03
	gross β	NA	NA	2.2E-02	3.2E-02
N304	gross α	NA	NA	1.4E-03	2.8E-03
	gross β	NA	NA	1.4E-02	3.9E-02
	^{234}U	3.6E-05	ND	3.6E-05	3.6E-05
N433	gross α	NA	NA	1.7E-03	5.8E-03
	gross β	NA	NA	1.5E-02	4.6E-02
	$^{239/240}Pu$	3.8E-05	ND	3.8E-05	3.8E-05
N441	gross α	NA	NA	1.6E-03	4.0E-03
	gross β	NA	NA	1.5E-02	4.0E-02
N442	gross α	NA	NA	1.6E-03	4.4E-03
	gross β	NA	NA	1.4E-02	4.1E-02
	^{238}U	3.9E-05	ND	3.9E-05	3.9E-05
N449	gross α	NA	NA	1.6E-03	4.7E-03
	gross β	NA	NA	1.4E-02	3.1E-02
	^{234}U	4.7E-05	ND	4.7E-05	4.7E-05
N456	gross α	NA	NA	1.5E-03	3.5E-03
	gross β	NA	NA	1.5E-02	3.4E-02
N457	gross α	NA	NA	1.4E-03	4.9E-03
	gross β	NA	NA	1.4E-02	3.7E-02
	^{234}U	3.0E-05	ND	3.0E-05	3.0E-05
	^{238}U	ND	1.5E-05	1.5E-05	1.5E-05
N554	gross α	NA	NA	1.2E-03	2.4E-03
	gross β	NA	NA	1.4E-02	4.8E-02
N555	gross α	NA	NA	1.3E-03	3.3E-03
	gross β	NA	NA	1.4E-02	3.3E-02
N956	gross α	NA	NA	1.6E-03	4.2E-03
	gross β	NA	NA	1.6E-02	3.4E-02
N963	gross α	NA	NA	1.6E-03	4.8E-03
	gross β	NA	NA	1.5E-02	3.7E-02
N964	gross α	NA	NA	1.6E-03	5.8E-03
	gross β	NA	NA	1.4E-02	3.6E-02
N965	gross α	NA	NA	1.5E-03	3.8E-03
	gross β	NA	NA	1.4E-02	4.0E-02
N966	gross α	NA	NA	1.4E-03	3.8E-03
	gross β	NA	NA	1.4E-02	4.0E-02

200 West Area					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N974	gross α	NA	NA	1.6E-03	4.0E-03
	gross β	NA	NA	1.5E-02	4.2E-02
N975	gross α	NA	NA	1.4E-03	3.2E-03
	gross β	NA	NA	1.5E-02	4.0E-02
N987	gross α	NA	NA	1.6E-03	3.6E-03
	gross β	NA	NA	1.5E-02	3.1E-02
N994	gross α	NA	NA	1.5E-03	3.4E-03
	gross β	NA	NA	1.4E-02	4.6E-02

Environmental Restoration Disposal Facility					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N482	gross α	NA	NA	1.0E-03	1.8E-03
	gross β	NA	NA	1.3E-02	3.7E-02
N517	gross α	NA	NA	1.2E-03	2.7E-03
	gross β	NA	NA	1.4E-02	4.3E-02
N518	gross α	NA	NA	1.1E-03	3.2E-03
	gross β	NA	NA	1.4E-02	4.0E-02
N168	gross α	NA	NA	1.5E-03	4.6E-03
	gross β	NA	NA	1.5E-02	4.0E-02
N963	gross α	NA	NA	1.6E-03	4.8E-03
	gross β	NA	NA	1.5E-02	3.7E-02

300 Area

300-FF-2 Field Remediation and 300 Area D4 Projects					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N130	gross α	NA	NA	1.6E-03	3.9E-03
	gross β	NA	NA	1.5E-02	3.6E-02

400 Area

FFTF Ambient Air Samplers					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N911 (400 N)	gross α	NA	NA	9.1E-04	3.2E-03
	gross β	NA	NA	1.7E-02	4.5E-02
N912 (400 S)	gross α	NA	NA	8.3E-04	2.5E-03
	gross β	NA	NA	1.7E-02	4.7E-02
	^{3}H	NA	NA	9.7E+00	9.7E+00

600 Area

618-10 Burial Ground					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N548	gross α	NA	NA	1.4E-03	4.9E-03
	gross β	NA	NA	1.7E-02	5.4E-02
	$^{239/240}Pu$	ND	7.3E-05	7.3E-05	7.3E-05
N549	gross α	NA	NA	1.2E-03	4.3E-03
	gross β	NA	NA	1.7E-02	4.7E-02
N579	gross α	NA	NA	1.1E-03	2.9E-03
	gross β	NA	NA	1.6E-02	4.1E-02
N580	gross α	NA	NA	1.3E-03	3.6E-03
	gross β	NA	NA	1.6E-02	4.5E-02

Wye Barricade					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N981	gross α	NA	NA	1.5E-03	3.7E-03
	gross β	NA	NA	1.5E-02	4.0E-02

Table 5-5. Hanford Site Far-Field Monitoring Ambient Air Sampling Results for Calendar Year 2016 (2 sub-tables, 4 pages)

Far-Field Monitoring Ambient Air Sampling Results: Onsite, Perimeter, Nearby Community, and Distant Locations					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
Onsite					
N900 (100-K Area)	gross α	NA	NA	1.0E-03	3.8E-03
	gross β	NA	NA	1.7E-02	4.6E-02
	^{3}H	NA	NA	9.4E+00	9.4E+00
N901 (200-W Southeast)	gross α	NA	NA	8.4E-04	3.2E-03
	gross β	NA	NA	1.6E-02	5.8E-02
	^{234}U	6.0E-05	ND	6.0E-05	6.0E-05
	^{238}U	ND	4.1E-05	4.1E-05	4.1E-05
N902 (300 NE)	gross α	NA	NA	9.3E-04	3.0E-03
	gross β	NA	NA	1.7E-02	4.3E-02
	^{3}H	NA	NA	1.5E+01	3.4E+01
	^{234}U	5.5E-05	7.4E-05	6.5E-05	7.4E-05
	^{238}U	ND	6.0E-05	6.0E-05	6.0E-05
N903 (300 South Gate)	gross α	NA	NA	9.1E-04	2.8E-03
	gross β	NA	NA	1.7E-02	4.5E-02
	^{3}H	NA	NA	9.1E+00	1.0E+01
	^{234}U	1.1E-04	3.8E-05	7.3E-05	1.1E-04
	^{238}U	5.7E-05	5.3E-05	5.5E-05	5.7E-05
N904 (300 Trench)	gross α	NA	NA	9.8E-04	4.0E-03
	gross β	NA	NA	1.8E-02	4.4E-02
	^{3}H	NA	NA	1.6E+01	2.8E+01
	^{106}Ru	ND	6.4E-03	6.4E-03	6.4E-03
	^{234}U	4.4E-05	6.3E-05	5.3E-05	6.3E-05
	^{238}U	ND	3.6E-05	3.6E-05	3.6E-05
N905 (300 Water Intake)	gross α	NA	NA	9.4E-04	3.5E-03
	gross β	NA	NA	1.7E-02	4.6E-02
	^{3}H	NA	NA	6.9E-03	7.5E+00
	^{234}U	ND	7.5E-05	7.5E-05	7.5E-05
	^{238}U	4.9E-05	3.1E-05	4.0E-05	4.9E-05
N906 (WYE Barricade)	gross α	NA	NA	9.8E-04	4.6E-03
	gross β	NA	NA	1.7E-02	4.6E-02
	^{234}U	4.4E-05	4.0E-05	4.2E-05	4.4E-05
	^{238}U	2.6E-05	6.5E-05	4.6E-05	6.5E-05
N918 (300 South West)	gross α	NA	NA	9.0E-04	3.2E-03
	gross β	NA	NA	1.7E-02	4.3E-02
	^{3}H	NA	NA	2.0E+01	2.2E+01
	^{234}U	ND	5.1E-05	5.1E-05	5.1E-05
	^{238}U	ND	4.7E-05	4.7E-05	4.7E-05

Far-Field Monitoring Ambient Air Sampling Results: Onsite, Perimeter, Nearby Community, and Distant Locations					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N920 (200-E Area)	gross α	NA	NA	8.2E-04	3.3E-03
	gross β	NA	NA	1.7E-02	5.8E-02
	^{3}H	NA	NA	1.4E+01	1.4E+01
	^{234}U	1.3E-04	ND	1.3E-04	1.3E-04
	^{238}U	ND	6.8E-05	6.8E-05	6.8E-05
N921 (100-F Met Tower)	gross α	NA	NA	7.1E-04	2.1E-03
	gross β	NA	NA	1.6E-02	4.6E-02
N922 (Hanford Townsite)	gross α	NA	NA	8.1E-04	1.4E-03
	gross β	NA	NA	1.7E-02	4.6E-02
N924 (B Pond)	gross α	NA	NA	8.6E-04	3.2E-03
	gross β	NA	NA	1.7E-02	6.1E-02
	^{234}U	ND	5.2E-05	5.2E-05	5.2E-05
	^{238}U	ND	4.6E-05	4.6E-05	4.6E-05
N927 (100-D Area)	gross α	NA	NA	9.1E-04	2.9E-03
	gross β	NA	NA	1.7E-02	4.5E-02
N928 (Gable Mountain)	gross α	NA	NA	7.8E-04	2.7E-03
	gross β	NA	NA	1.6E-02	4.5E-02
	^{238}U	ND	4.2E-05	4.2E-05	4.2E-05
N929 (South of 200-E)	gross α	NA	NA	8.3E-04	3.9E-03
	gross β	NA	NA	1.7E-02	5.6E-02
	^{234}U	6.8E-05	ND	6.8E-05	6.8E-05
	^{238}U	6.0E-05	4.9E-05	5.5E-05	6.0E-05
N930 (Army Loop Camp)	gross α	NA	NA	9.1E-04	3.6E-03
	gross β	NA	NA	1.7E-02	5.9E-02
N931 (200 Tel. Exchange)	gross α	NA	NA	7.8E-04	2.7E-03
	gross β	NA	NA	1.6E-02	5.6E-02
	^{238}U	4.3E-05	4.4E-05	4.3E-05	4.4E-05
N932 (Southwest of B/C Cribs)	gross α	NA	NA	9.2E-04	5.8E-03
	gross β	NA	NA	1.9E-02	6.1E-02
	^{234}U	5.3E-05	7.0E-05	6.1E-05	7.0E-05
	^{238}U	ND	4.0E-05	4.0E-05	4.0E-05
Perimeter					
N940 (Rattlesnake Springs)	gross α	NA	NA	9.0E-04	4.1E-03
	gross β	NA	NA	1.6E-02	3.8E-02

Far-Field Monitoring Ambient Air Sampling Results: Onsite, Perimeter, Nearby Community, and Distant Locations					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N942 (South of Vernita Bridge)	gross α	NA	NA	8.4E-04	3.6E-03
	gross β	NA	NA	1.6E-02	6.1E-02
Nearby Community					
N947 (Benton City)	gross α	NA	NA	8.3E-04	2.5E-03
	gross β	NA	NA	1.7E-02	4.0E-02
N948 (Mattawa)	gross α	NA	NA	9.2E-04	3.7E-03
	gross β	NA	NA	1.7E-02	6.7E-02
N949 (Othello)	gross α	NA	NA	8.9E-04	3.5E-03
	gross β	NA	NA	1.7E-02	5.8E-02
	^{234}U	ND	9.0E-05	9.0E-05	9.0E-05
	^{238}U	5.3E-05	5.7E-05	5.5E-05	5.7E-05
Distant					
N909 (Yakima)	gross α	NA	NA	8.4E-04	3.3E-03
	gross β	NA	NA	1.5E-02	5.2E-02
	^{3}H	NA	NA	5.7E+00	5.7E+00
	^{234}U	8.8E-05	6.5E-05	7.7E-05	8.8E-05
	^{238}U	4.1E-05	ND	4.1E-05	4.1E-05

FF-01-Required Far-Field Monitoring Station Locations Used in the Fugitive Dose Calculation					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N907 (Yakima Barricade)	gross α	NA	NA	9.1E-04	4.7E-03
	gross β	NA	NA	1.6E-02	5.2E-02
N933 (Ringold Met. Tower)	gross α	NA	NA	8.3E-04	3.5E-03
	gross β	NA	NA	1.7E-02	6.4E-02
N934 (West End of Fir Road)	gross α	NA	NA	8.0E-04	3.0E-03
	gross β	NA	NA	1.7E-02	6.3E-02
	^{234}U	4.1E-05	5.2E-05	4.7E-05	5.2E-05
	^{238}U	4.7E-05	4.5E-05	4.6E-05	4.7E-05

FF-01-Required Far-Field Monitoring Station Locations Used in the Fugitive Dose Calculation					
EDP Code	Radionuclide or Type of Radioactivity	Concentration, pCi/m³			
		1st Half	2nd Half	Average	Maximum
N935 (Dogwood Met. Tower)	gross α	NA	NA	9.5E-04	206E-03
	gross β	NA	NA	1.7E-02	5.9E-02
	^{234}U	ND	4.9E-05	4.9E-05	4.9E-05
	^{238}U	ND	5.0E-05	5.0E-05	5.0E-05
N936 (Byers Landing)	gross α	NA	NA	8.6E-04	3.7E-03
	gross β	NA	NA	1.7E-02	6.3E-02
	^{3}H	NA	NA	9.8E+00	9.8E+00
	^{234}U	ND	9.0E-05	9.0E-05	9.0E-05
	^{238}U	ND	3.1E-05	3.1E-05	3.1E-05
N937 (Battelle Complex)	gross α	NA	NA	8.9E-04	3.1E-03
	gross β	NA	NA	1.7E-02	6.4E-02
	^{3}H	NA	NA	1.4E+01	1.7E+01
	^{234}U	5.5E-05	5.0E-05	5.2E-05	5.5E-05
	^{238}U	6.4E-05	4.9E-05	5.7E-05	6.4E-05
N938 (Horn Rapids Substation)	gross α	NA	NA	8.9E-04	4.0E-03
	gross β	NA	NA	1.7E-02	5.1E-02
N939 (Prosser Barricade)	gross α	NA	NA	8.8E-04	2.9E-03
	gross β	NA	NA	1.8E-02	3.9E-02
	^{3}H	NA	NA	2.7E+01	2.7E+01
N941 (Wahluke Slope)	gross α	NA	NA	7.9E-04	2.8E-03
	gross β	NA	NA	1.7E-02	5.9E-02
N943 (Basin City School)	gross α	NA	NA	7.3E-04	2.5E-03
	gross β	NA	NA	1.8E-02	7.2E-02
	^{234}U	3.4E-05	8.6E-05	6.0E-05	8.6E-05
	^{238}U	ND	6.7E-05	6.7E-05	6.7E-05
N944 (Leslie Groves Richland)	gross α	NA	NA	8.6E-04	2.0E-03
	gross β	NA	NA	1.7E-02	6.6E-02
	^{3}H	NA	NA	3.5E+01	5.8E+01
	^{234}U	ND	6.6E-05	6.6E-05	6.6E-05
	^{238}U	7.0E-05	5.3E-05	6.1E-05	7.0E-05
N945 (Pasco)	gross α	NA	NA	9.0E-04	3.3E-03
	gross β	NA	NA	1.8E-02	6.2E-02
	^{234}U	ND	1.1E-04	1.1E-04	1.1E-04
	^{238}U	ND	6.5E-05	6.5E-05	6.5E-05
N946 (Kennewick-Ely Street)	gross α	NA	NA	7.7E-04	1.8E-03
	gross β	NA	NA	1.7E-02	6.3E-02
	^{234}U	ND	5.2E-05	5.2E-05	5.2E-05
	^{238}U	8.1E-05	7.4E-05	7.7E-05	8.1E-05

5.5 QUALITY ASSURANCE

Air emission data reported in this document are partly the product of having applied QA principles identified in the QA plans cited below, which serve to assure compliance with the QA criteria of 40 CFR 61, Appendix B, Method 114. Applying these principles positively influences the collecting, handling, tracking, analyzing, verifying, validating, and reporting of radionuclide air emission samples.

EM-QA-01, *Effluent Management Quality Assurance Plan*

ENV-1-1.15, *Quality Assurance Project Plan for Radiological Air Emissions Monitoring*, Section 6.1

ETD-001, *Quality Assurance Project Plan for the Hanford Site Surface Environmental Surveillance and the Drinking Water Monitoring Project*

GL-QS-B-001, *GEL Laboratories, LLC, Quality Assurance Plan*

MSC–23333, *Environmental Quality Assurance Program Plan*

TFC–PLN–71, *Quality Assurance Program Plan for Tank Farm Contractor Radioactive Air Emissions.*

The effluent monitoring quality assurance elements described in the above plans are compatible with one or more of the following documents:

- 10 CFR 830
- 40 CFR 61, Appendix B, "Method 114 – Test Methods for Measuring Radionuclide Emissions from Stationary Sources"
- ASME NQA-1, Quality Assurance Requirements for Nuclear Facility Applications
- DOE Order 414.1D, *Quality Assurance*
- DOE Order 458.1, *Radiation Protection of the Public and the Environment*
- DOE-HNBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*

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6.0 REFERENCES

10 CFR 830, "Nuclear Safety Management," Title 10, *Code of Federal Regulations*, Part 830, as amended.

40 CFR 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," Title 40, *Code of Federal Regulations*, Part 61, as amended.

40 CFR 70, "State Operating Permit Programs," Title 40, *Code of Federal Regulations*, Part 70, as amended.

ANSI N13.1–1969, 1970, *Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities*, American National Standards Institute, New York, New York.

ANSI/HPS N13.1–1999, 1999 (reaffirmed in 2011), *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*, Health Physics Society, McLean, Virginia.

ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications*, 2000 Edition, American Society of Mechanical Engineers, New York, New York.

DOE, 1995, "Memorandum of Understanding Between the U.S. Environmental Protection Agency and the U.S. Department of Energy Concerning the Clean Air Act Emission Standards for Radionuclides 40 CFR Part 61 Including Subparts H, I, Q & T," (letter to E. Ramona, U.S. Environmental Protection Agency) from Raymond Berube, U.S. Department of Energy, Washington, D.C., May 16.

DOE Order 414.1D, *Quality Assurance*, "Contractor Requirements Document," U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE Order 458.1, *Radiation Protection of the Public and the Environment*, U.S. Department of Energy, Washington, D.C.

DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

DOE/RL-88-30, *Hanford Site Waste Management Units Report*, Rev. 19, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-91-50, *Hanford Site Environmental Monitoring Plan,* U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-29, *Calculating Potential-to-Emit Radiological Releases and Doses*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-53, *Methods for Calculating Doses to Demonstrate Compliance with Air Pathway Radiation Dose Standards at the Hanford Site*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2014-52, *Hanford Site Environmental Report for Calendar Year 2014,* U.S. Department of Energy–Richland Operations Office, Richland, Washington.

DOE/RL-2017-24, *Hanford Site Environmental Report for Calendar Year 2016*, U.S. Department of Energy–Richland Operations Office, Richland, Washington. [in press]

EM-QA-01, *Effluent Management Quality Assurance Plan*, Pacific Northwest National Laboratory, Richland, Washington.

ENV-1-1.15, *Quality Assurance Project Plan for Radiological Air Emissions Monitoring*, Washington Closure Hanford, LLC, Richland, Washington.

EPA, 2004, *Methods for Estimating Fugitive Air Emissions of Radionuclides from Diffuse Sources at DOE Facilities*, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

EPA, 2015, *CAP88–PC Version 4.0 User Guide*, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

ETD-001, 2005, *Quality Assurance Project Plan for the Hanford Site Surface Environmental Surveillance and the Drinking Water Monitoring Project*, Rev. 7, Pacific Northwest National Laboratory, Richland, Washington.

Hanford Site Air Operating Permit 00-05-06, Renewal 2, Washington State Department of Ecology, Olympia, Washington.

Hanford Site Radioactive Air Emissions License #FF-01, Washington State Department of Ecology, Olympia, Washington.

MSC-23333, *Environmental Quality Assurance Program Plan*, Rev. 2, Mission Support Alliance, LLC, Richland, Washington.

PNL-8148, *Hanford Site Environmental Report for Calendar Year 1991*, Pacific Northwest Laboratory, Richland, Washington.

PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20436-6, *Pacific Northwest National Laboratory Campus Radionuclide Air Emissions Report for Calendar Year 2015*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20631, *Hanford Site Regional Population–2010 Census,* Pacific Northwest National Laboratory, Richland, Washington.

TFC-PLN-71, *Quality Assurance Program Plan for Tank Farm Contractor Radioactive Air Emissions*, Washington River Protection Solutions, LLC, Richland, Washington.

WAC 246-247, "Radiation Protection – Air Emissions," Washington Administrative Code, Olympia, Washington.

APPENDIX A

DOSE MODELING AND METEOROLOGICAL DATA

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Figure A-1. Meteorological Stations in 2016

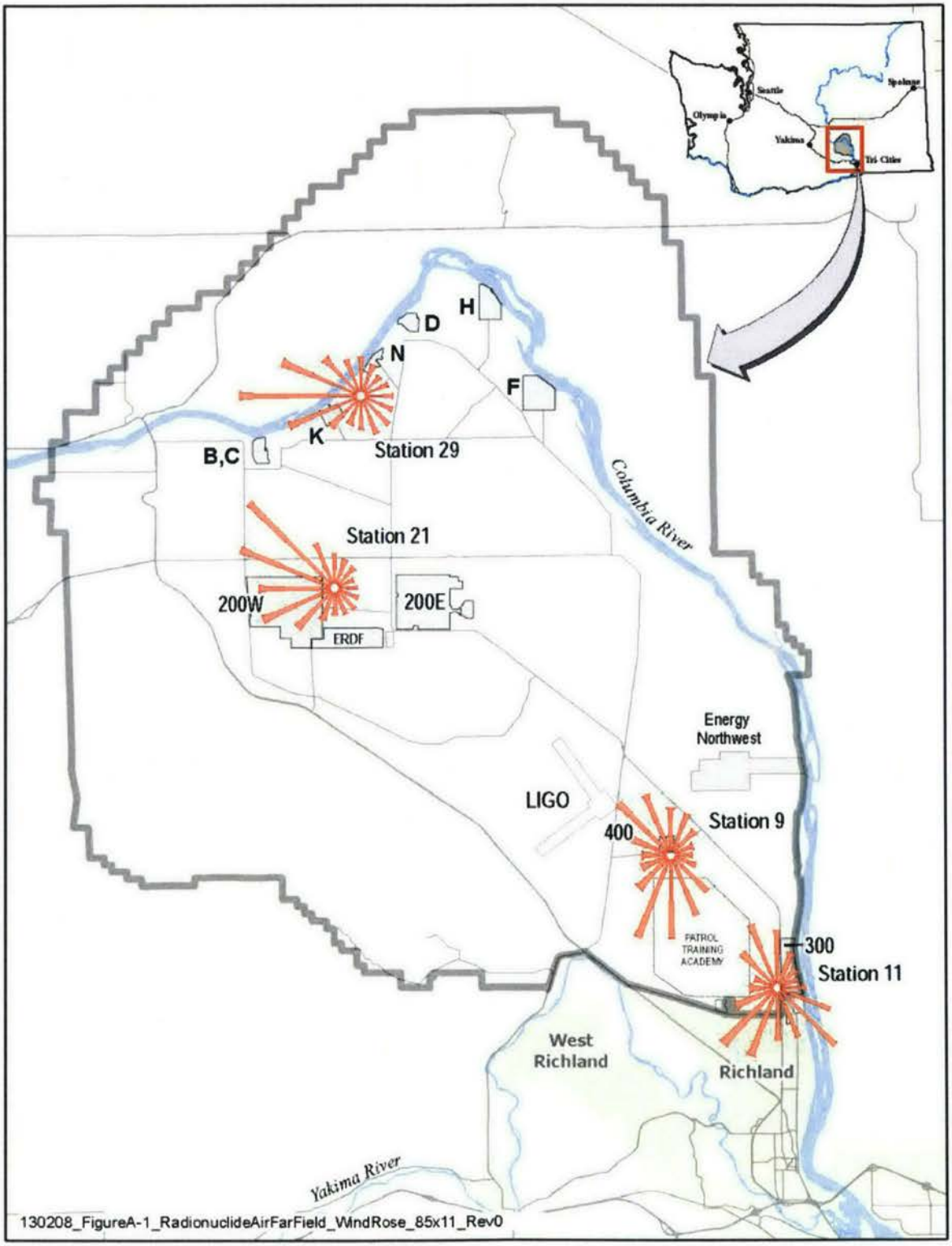

Figure A-2. 100 Area Wind Rose and Histogram

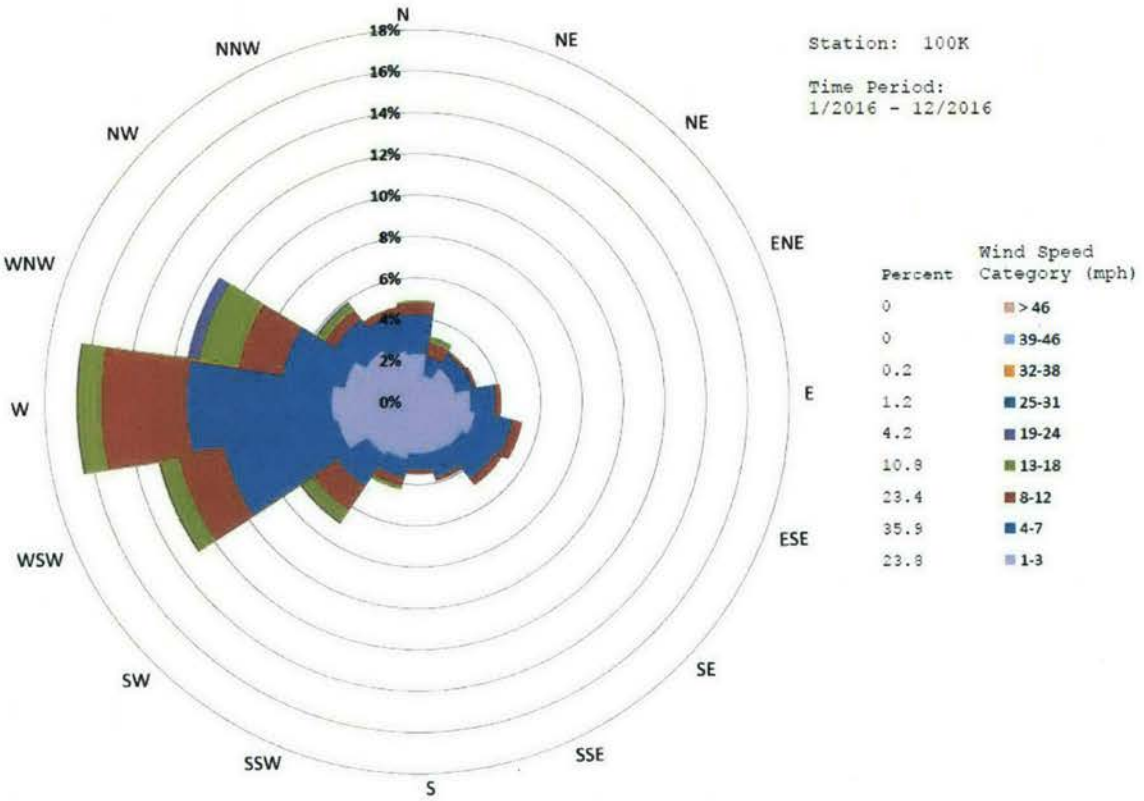

Figure A-3. 200 Area Wind Rose and Histogram

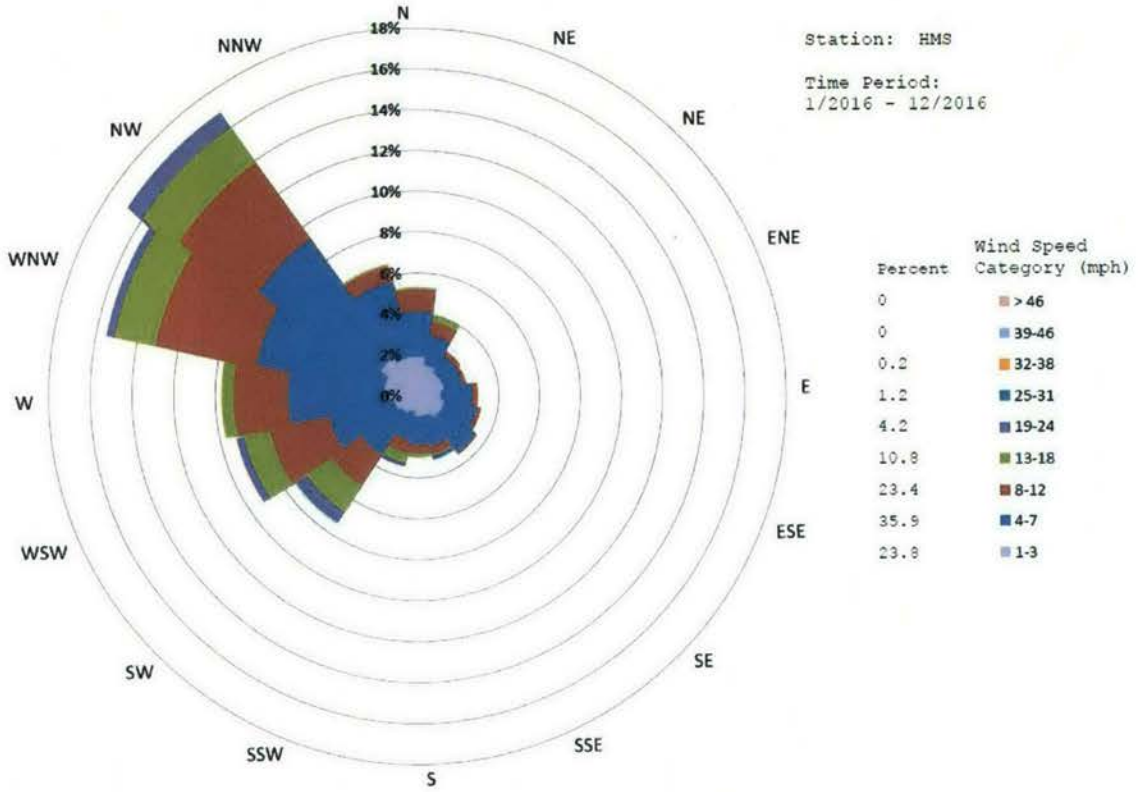

Figure A-4. 300 Area Wind Rose and Histogram

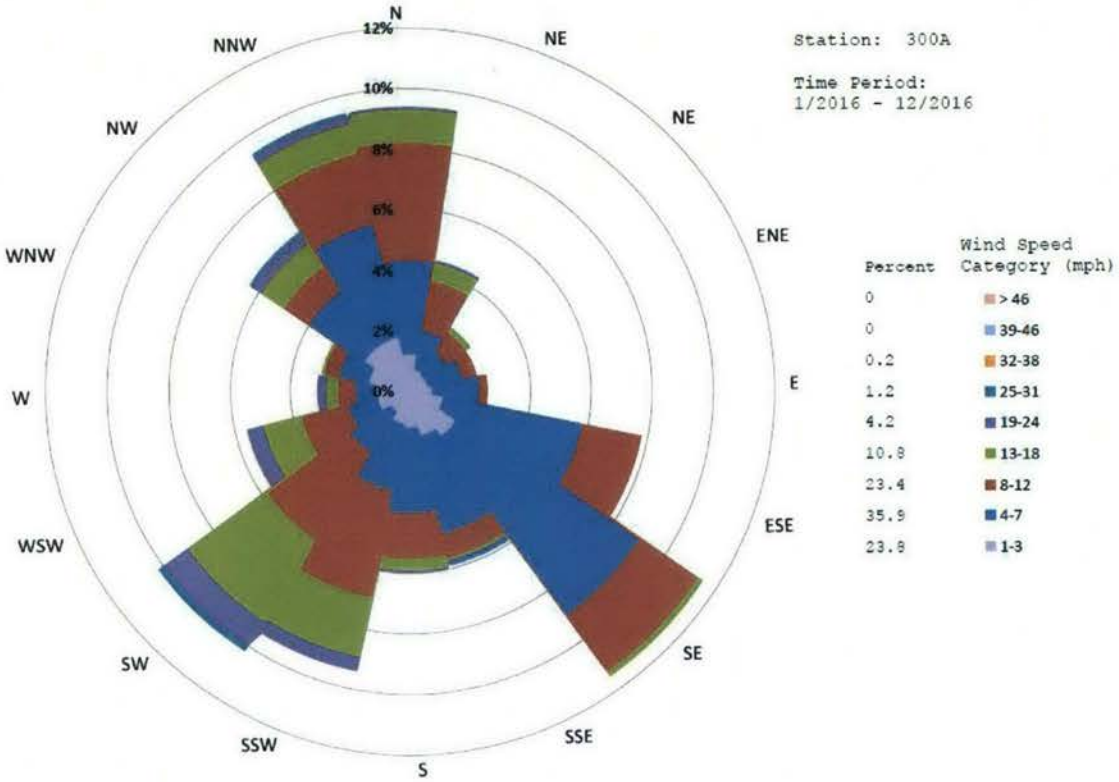

Figure A-5. 400 Area Wind Rose and Histogram

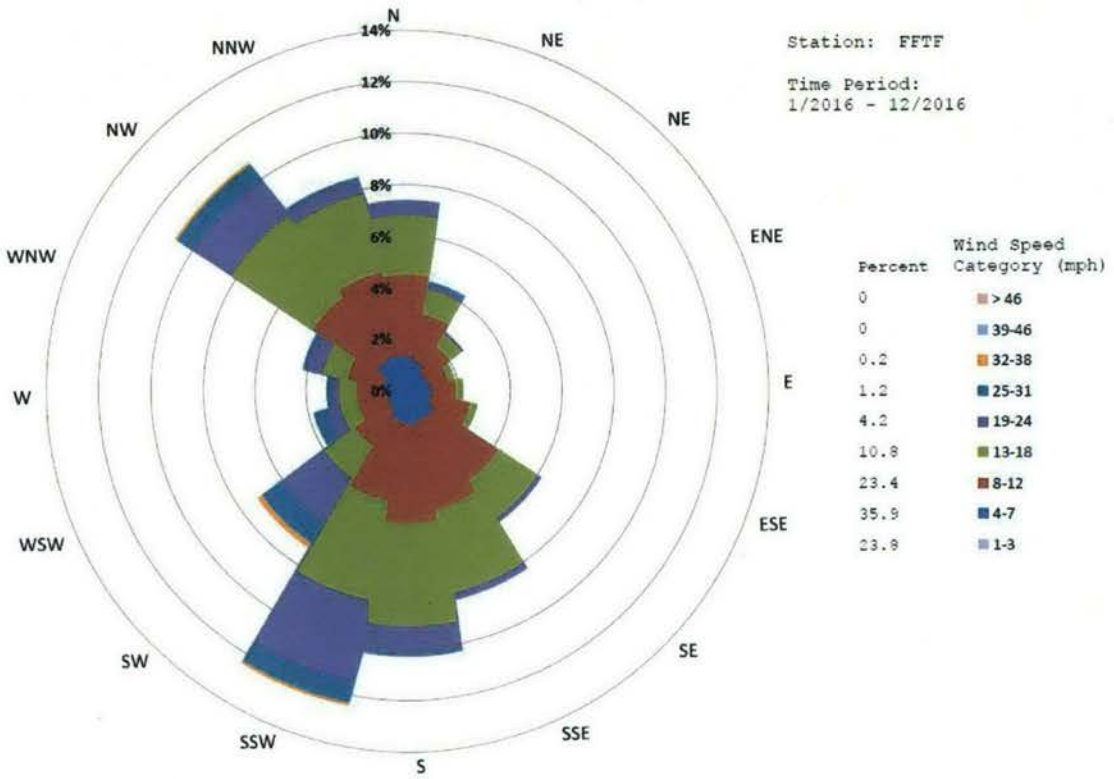

Table A-1. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 100–K Area (Station 29) at the 3-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
0.89	A	0.18	0.12	0.09	0.12	0.15	0.21	0.13	0.12	0.05	0.06	0.07	0.12	0.21	0.29	0.29	0.23	2.44
	B	0.18	0.13	0.08	0.05	0.07	0.07	0.10	0.06	0.07	0.06	0.06	0.10	0.14	0.26	0.26	0.20	1.89
	C	0.39	0.19	0.18	0.13	0.18	0.09	0.12	0.13	0.09	0.06	0.08	0.12	0.21	0.41	0.57	0.44	3.39
	D	0.91	0.50	0.57	0.53	0.52	0.53	0.50	0.44	0.36	0.38	0.45	0.59	0.72	0.75	0.88	0.94	9.57
	E	0.40	0.22	0.52	0.68	0.85	0.92	0.79	0.84	0.72	0.84	0.79	1.06	1.30	1.04	0.55	0.51	12.03
	F	0.23	0.19	0.41	0.34	0.63	0.90	0.72	0.76	0.97	1.04	1.12	1.44	1.18	0.77	0.43	0.22	11.35
	G	0.10	0.03	0.08	0.13	0.25	0.27	0.32	0.28	0.37	0.46	0.54	0.72	0.58	0.17	0.07	0.01	4.38
	Total	**2.39**	**1.38**	**1.93**	**1.98**	**2.65**	**2.99**	**2.68**	**2.63**	**2.63**	**2.90**	**3.11**	**4.15**	**4.34**	**3.69**	**3.05**	**2.55**	**45.05**
2.65	A	0.29	0.20	0.15	0.16	0.17	0.17	0.12	0.07	0.06	0.13	0.17	0.30	0.47	0.32	0.26	0.30	3.34
	B	0.39	0.18	0.19	0.16	0.16	0.15	0.16	0.06	0.05	0.04	0.08	0.17	0.27	0.26	0.36	0.55	3.23
	C	0.48	0.13	0.12	0.11	0.16	0.24	0.18	0.09	0.05	0.09	0.13	0.18	0.32	0.34	0.46	0.44	3.52
	D	0.48	0.26	0.26	0.28	0.32	0.39	0.47	0.23	0.17	0.25	0.26	0.86	1.22	0.93	0.40	0.34	7.12
	E	0.17	0.05	0.05	0.14	0.28	0.64	0.62	0.43	0.29	0.19	0.56	2.48	3.24	1.01	0.26	0.14	10.55
	F	0.07	0.04	0.04	0.04	0.05	0.20	0.30	0.28	0.13	0.18	0.42	1.27	1.25	0.27	0.08	0.08	4.70
	G	0.00	0.01	0.00	0.00	0.03	0.03	0.04	0.02	0.06	0.01	0.19	0.48	0.25	0.01	0.00	0.00	1.13
	Total	**1.88**	**0.87**	**0.81**	**0.89**	**1.17**	**1.82**	**1.89**	**1.18**	**0.81**	**0.89**	**1.81**	**5.74**	**7.02**	**3.14**	**1.82**	**1.85**	**33.59**
4.7	A	0.22	0.27	0.09	0.01	0.02	0.03	0.02	0.01	0.05	0.11	0.41	0.18	0.22	0.35	0.14	0.05	2.18
	B	0.11	0.07	0.04	0.03	0.09	0.08	0.03	0.00	0.02	0.02	0.08	0.14	0.16	0.18	0.06	0.05	1.16
	C	0.05	0.05	0.02	0.05	0.04	0.08	0.06	0.01	0.02	0.02	0.18	0.18	0.23	0.16	0.05	0.02	1.22
	D	0.18	0.15	0.03	0.07	0.14	0.18	0.17	0.09	0.05	0.09	0.21	0.45	0.79	0.68	0.21	0.15	3.64
	E	0.02	0.18	0.03	0.00	0.04	0.09	0.08	0.09	0.05	0.11	0.44	0.97	2.49	0.79	0.09	0.05	5.52
	F	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.27	0.22	0.03	0.03	0.03	0.68
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.03
	Total	**0.62**	**0.74**	**0.21**	**0.16**	**0.33**	**0.46**	**0.36**	**0.20**	**0.20**	**0.35**	**1.35**	**2.20**	**4.13**	**2.19**	**0.58**	**0.35**	**14.43**

Table A-1. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 100–K Area (Station 29) at the 3-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
7.15	A	0.06	0.20	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.09	0.26	0.23	0.15	0.41	0.18	0.02	1.63
	B	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.09	0.07	0.18	0.02	0.00	0.49
	C	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.08	0.02	0.12	0.05	0.00	0.38
	D	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.05	0.19	0.22	0.33	0.62	0.09	0.00	1.54
	E	0.02	0.02	0.00	0.00	0.03	0.01	0.04	0.04	0.00	0.03	0.12	0.22	0.53	0.60	0.02	0.00	1.68
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.03
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
	Total	**0.13**	**0.27**	**0.00**	**0.00**	**0.03**	**0.04**	**0.05**	**0.04**	**0.01**	**0.19**	**0.71**	**0.87**	**1.11**	**1.93**	**0.36**	**0.02**	**5.76**
9.8	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.01	0.01	0.17	0.05	0.00	0.31
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.05	0.01	0.00	0.09
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.02
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.05	0.01	0.22	0.07	0.00	0.42
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.05	0.11	0.00	0.00	0.18
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.00**	**0.02**	**0.14**	**0.06**	**0.10**	**0.55**	**0.13**	**0.00**	**1.02**
12.7	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.04**	**0.00**	**0.00**	**0.05**

Table A-1. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 100–K Area (Station 29) at the 3-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
15.6	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
19	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total	A	0.75	0.79	0.33	0.29	0.34	0.42	0.28	0.20	0.17	0.40	0.97	0.84	1.06	1.54	0.92	0.60	9.90
	B	0.68	0.40	0.31	0.24	0.32	0.30	0.29	0.12	0.14	0.14	0.32	0.50	0.66	0.94	0.71	0.80	6.87
	C	0.95	0.40	0.32	0.29	0.38	0.41	0.36	0.23	0.16	0.18	0.44	0.57	0.79	1.03	1.13	0.90	8.54
	D	1.59	0.91	0.86	0.88	0.98	1.12	1.14	0.76	0.58	0.77	1.18	2.17	3.07	3.23	1.65	1.43	22.32
	E	0.61	0.47	0.60	0.82	1.20	1.66	1.53	1.42	1.06	1.17	1.91	4.73	7.61	3.55	0.92	0.70	29.96
	F	0.34	0.25	0.45	0.38	0.68	1.10	1.02	1.04	1.11	1.22	1.57	3.00	2.66	1.07	0.54	0.33	16.76
	G	0.10	0.04	0.08	0.13	0.28	0.30	0.36	0.30	0.43	0.47	0.73	1.22	0.85	0.18	0.07	0.01	5.55
	Total	**5.02**	**3.26**	**2.95**	**3.03**	**4.18**	**5.31**	**4.98**	**4.07**	**3.65**	**4.35**	**7.12**	**13.03**	**16.70**	**11.54**	**5.94**	**4.77**	**99.90**

Note: A shorter, 3-meter meteorological station was installed at 100-K, after guy-wire failure of its long-standing, taller 10-meter tower.

Table A-2. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 200 West Area PFP (Station 19) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
0.89	A	0.17	0.13	0.10	0.08	0.12	0.05	0.12	0.05	0.03	0.07	0.05	0.03	0.06	0.07	0.07	0.08	1.28
	B	0.11	0.13	0.06	0.08	0.08	0.07	0.11	0.09	0.06	0.06	0.07	0.12	0.08	0.09	0.09	0.09	1.39
	C	0.11	0.32	0.17	0.21	0.17	0.10	0.08	0.11	0.09	0.05	0.05	0.05	0.09	0.05	0.13	0.12	1.90
	D	0.91	0.76	0.54	0.31	0.24	0.55	0.34	0.33	0.33	0.32	0.37	0.39	0.42	0.46	0.57	0.66	7.50
	E	0.86	0.66	0.52	0.47	0.34	0.53	0.53	0.49	0.46	0.51	0.55	1.04	1.47	1.29	1.13	0.98	11.83
	F	0.73	0.59	0.26	0.24	0.24	0.36	0.51	0.36	0.37	0.47	0.58	0.67	1.08	1.12	1.04	0.57	9.19
	G	0.33	0.19	0.19	0.08	0.08	0.13	0.10	0.07	0.15	0.20	0.16	0.28	0.37	0.37	0.37	0.32	3.39
	Total	**3.22**	**2.78**	**1.84**	**1.47**	**1.27**	**1.79**	**1.79**	**1.50**	**1.49**	**1.68**	**1.83**	**2.58**	**3.57**	**3.45**	**3.40**	**2.82**	**36.48**
2.65	A	0.42	0.32	0.15	0.17	0.20	0.27	0.15	0.08	0.05	0.07	0.07	0.08	0.09	0.21	0.35	0.51	3.19
	B	0.47	0.25	0.20	0.17	0.24	0.34	0.19	0.11	0.08	0.04	0.06	0.06	0.08	0.08	0.21	0.58	3.16
	C	0.91	0.40	0.14	0.12	0.35	0.27	0.23	0.07	0.14	0.13	0.13	0.13	0.12	0.18	0.28	0.76	4.36
	D	0.97	0.49	0.32	0.23	0.31	0.42	0.46	0.14	0.19	0.25	0.22	0.42	0.63	1.05	1.32	1.13	8.55
	E	0.52	0.24	0.12	0.06	0.18	0.36	0.23	0.11	0.07	0.17	0.34	0.84	2.44	3.30	1.61	0.86	11.45
	F	0.51	0.16	0.04	0.02	0.06	0.22	0.18	0.05	0.01	0.00	0.10	0.37	1.25	2.45	0.77	0.43	6.62
	G	0.19	0.16	0.01	0.00	0.00	0.03	0.04	0.02	0.01	0.00	0.01	0.07	0.51	0.76	0.13	0.05	1.99
	Total	**3.99**	**2.02**	**0.98**	**0.77**	**1.34**	**1.91**	**1.48**	**0.58**	**0.55**	**0.66**	**0.93**	**1.97**	**5.12**	**8.03**	**4.67**	**4.32**	**39.32**
4.7	A	0.40	0.22	0.20	0.01	0.00	0.05	0.03	0.03	0.04	0.07	0.26	0.35	0.15	0.19	0.53	0.22	2.75
	B	0.11	0.09	0.01	0.03	0.06	0.12	0.03	0.02	0.02	0.07	0.12	0.16	0.12	0.08	0.19	0.19	1.42
	C	0.08	0.04	0.01	0.01	0.05	0.11	0.08	0.00	0.01	0.07	0.21	0.19	0.18	0.10	0.20	0.19	1.53
	D	0.30	0.07	0.05	0.08	0.14	0.19	0.14	0.08	0.10	0.11	0.28	0.59	0.58	0.53	1.01	0.37	4.62
	E	0.17	0.08	0.01	0.02	0.01	0.05	0.09	0.08	0.16	0.14	0.27	0.62	1.16	1.22	1.04	0.12	5.24
	F	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.08	0.15	0.10	0.12	0.12	0.60
	G	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
	Total	**1.09**	**0.50**	**0.28**	**0.15**	**0.26**	**0.53**	**0.37**	**0.21**	**0.33**	**0.46**	**1.14**	**1.99**	**2.34**	**2.22**	**3.09**	**1.22**	**16.18**

Table A-2. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 200 West Area PFP (Station 19) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
7.15	A	0.06	0.16	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.14	0.40	0.56	0.15	0.08	0.31	0.09	2.00
	B	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.11	0.21	0.10	0.01	0.05	0.01	0.54
	C	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.09	0.01	0.02	0.07	0.01	0.35
	D	0.02	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.30	0.37	0.21	0.18	0.68	0.01	1.85
	E	0.00	0.00	0.00	0.00	0.02	0.07	0.05	0.01	0.01	0.02	0.32	0.30	0.10	0.36	0.42	0.00	1.68
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.03
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.10**	**0.25**	**0.00**	**0.00**	**0.03**	**0.08**	**0.08**	**0.01**	**0.03**	**0.21**	**1.23**	**1.55**	**0.58**	**0.65**	**1.53**	**0.12**	**6.45**
9.8	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.16	0.07	0.02	0.00	0.08	0.01	0.40
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.03	0.00	0.05	0.00	0.17
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.03	0.01	0.00	0.01	0.00	0.13
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.12	0.04	0.02	0.16	0.00	0.41
	E	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.08	0.10	0.01	0.04	0.04	0.00	0.32
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.03**	**0.00**	**0.00**	**0.00**	**0.09**	**0.40**	**0.39**	**0.11**	**0.06**	**0.34**	**0.01**	**1.45**
12.7	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.04
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.04
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.04**	**0.06**	**0.01**	**0.00**	**0.00**	**0.00**	**0.13**

Table A-2. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 200 West Area PFP (Station 19) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
15.6	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**
19	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total	A	1.05	0.83	0.45	0.26	0.32	0.37	0.33	0.16	0.14	0.42	0.95	1.09	0.47	0.55	1.34	0.91	9.64
	B	0.69	0.49	0.27	0.28	0.39	0.53	0.33	0.22	0.16	0.20	0.38	0.62	0.41	0.26	0.59	0.87	6.69
	C	1.12	0.79	0.32	0.34	0.57	0.48	0.39	0.18	0.24	0.27	0.55	0.52	0.41	0.35	0.69	1.08	8.30
	D	2.20	1.36	0.91	0.62	0.69	1.17	0.94	0.55	0.62	0.72	1.25	1.91	1.88	2.24	3.74	2.17	22.97
	E	1.55	0.98	0.65	0.55	0.57	1.04	0.90	0.69	0.70	0.84	1.57	2.92	5.19	6.21	4.24	1.96	30.56
	F	1.26	0.75	0.30	0.26	0.30	0.59	0.69	0.41	0.38	0.47	0.68	1.14	2.49	3.67	1.93	1.12	16.44
	G	0.53	0.35	0.20	0.08	0.08	0.16	0.14	0.09	0.16	0.20	0.19	0.35	0.88	1.13	0.50	0.38	5.42
	Total	**8.40**	**5.55**	**3.10**	**2.39**	**2.92**	**4.34**	**3.72**	**2.30**	**2.40**	**3.12**	**5.57**	**8.55**	**11.73**	**14.41**	**13.03**	**8.49**	**100.02**

Table A-3. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 200 East Area (Station 6) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
0.89	A	0.11	0.15	0.08	0.10	0.07	0.08	0.06	0.05	0.03	0.02	0.04	0.03	0.03	0.04	0.07	0.16	1.12
	B	0.12	0.20	0.06	0.05	0.13	0.13	0.08	0.04	0.03	0.01	0.02	0.02	0.02	0.04	0.05	0.06	1.06
	C	0.29	0.21	0.19	0.17	0.21	0.15	0.10	0.02	0.07	0.04	0.05	0.11	0.09	0.07	0.08	0.14	1.99
	D	0.60	0.58	0.38	0.46	0.45	0.53	0.42	0.31	0.24	0.16	0.11	0.23	0.25	0.39	0.57	0.46	6.14
	E	0.30	0.31	0.39	0.44	0.42	0.40	0.42	0.40	0.32	0.41	0.32	0.41	0.52	0.70	0.52	0.48	6.76
	F	0.15	0.13	0.10	0.07	0.22	0.29	0.32	0.34	0.29	0.18	0.24	0.23	0.42	0.52	0.42	0.25	4.17
	G	0.09	0.05	0.00	0.04	0.06	0.10	0.08	0.08	0.08	0.04	0.07	0.10	0.15	0.17	0.12	0.07	1.30
	Total	**1.66**	**1.63**	**1.20**	**1.33**	**1.56**	**1.68**	**1.48**	**1.24**	**1.06**	**0.86**	**0.85**	**1.13**	**1.48**	**1.93**	**1.83**	**1.62**	**22.54**
2.65	A	0.24	0.15	0.07	0.09	0.23	0.33	0.37	0.12	0.08	0.08	0.12	0.11	0.10	0.20	0.38	0.27	2.94
	B	0.37	0.31	0.13	0.10	0.29	0.27	0.34	0.10	0.12	0.05	0.06	0.12	0.11	0.18	0.23	0.31	3.09
	C	0.41	0.22	0.11	0.18	0.34	0.43	0.35	0.18	0.08	0.06	0.16	0.05	0.16	0.25	0.39	0.58	3.95
	D	0.52	0.20	0.24	0.18	0.42	0.61	0.84	0.42	0.16	0.13	0.17	0.40	0.36	0.87	1.53	0.88	7.93
	E	0.13	0.05	0.05	0.08	0.26	0.40	0.56	0.59	0.34	0.29	0.50	0.64	1.19	2.17	1.25	0.36	8.86
	F	0.06	0.02	0.01	0.03	0.05	0.20	0.53	0.61	0.32	0.30	0.31	0.69	1.09	1.83	0.76	0.12	6.93
	G	0.01	0.02	0.00	0.00	0.01	0.06	0.32	0.21	0.07	0.09	0.09	0.17	0.42	0.56	0.17	0.00	2.20
	Total	**1.74**	**0.97**	**0.61**	**0.66**	**1.60**	**2.30**	**3.31**	**2.23**	**1.17**	**1.00**	**1.41**	**2.18**	**3.43**	**6.06**	**4.71**	**2.52**	**35.90**
4.7	A	0.24	0.38	0.15	0.03	0.04	0.12	0.13	0.07	0.02	0.10	0.21	0.28	0.20	0.30	0.37	0.08	2.72
	B	0.15	0.08	0.02	0.02	0.10	0.14	0.23	0.03	0.04	0.00	0.09	0.09	0.11	0.16	0.20	0.15	1.61
	C	0.11	0.04	0.02	0.02	0.12	0.11	0.23	0.07	0.02	0.03	0.13	0.17	0.12	0.12	0.17	0.07	1.55
	D	0.34	0.11	0.04	0.07	0.20	0.24	0.25	0.17	0.16	0.08	0.22	0.48	0.30	1.21	0.89	0.28	5.04
	E	0.14	0.10	0.01	0.00	0.01	0.05	0.17	0.33	0.15	0.12	0.28	0.68	1.83	3.67	0.83	0.13	8.50
	F	0.05	0.01	0.00	0.00	0.00	0.02	0.12	0.26	0.12	0.01	0.13	0.48	0.91	2.41	0.45	0.10	5.07
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.15	0.05	0.01	0.03	0.27	0.28	0.86	0.15	0.00	1.83
	Total	**1.03**	**0.72**	**0.24**	**0.14**	**0.47**	**0.68**	**1.16**	**1.08**	**0.56**	**0.35**	**1.09**	**2.45**	**3.75**	**8.73**	**3.06**	**0.81**	**26.32**

Table A-3. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 200 East Area (Station 6) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
7.15	A	0.06	0.21	0.01	0.02	0.00	0.00	0.01	0.02	0.08	0.08	0.19	0.43	0.17	0.20	0.44	0.06	1.98
	B	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.07	0.14	0.06	0.08	0.07	0.01	0.51
	C	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.05	0.13	0.04	0.18	0.10	0.00	0.59
	D	0.03	0.03	0.02	0.01	0.00	0.00	0.01	0.03	0.06	0.05	0.14	0.38	0.43	0.67	0.49	0.03	2.38
	E	0.05	0.02	0.00	0.00	0.00	0.02	0.05	0.08	0.05	0.11	0.22	0.48	0.67	2.60	0.58	0.00	4.93
	F	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.13	0.01	0.00	0.23
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.00	0.07
	Total	**0.21**	**0.29**	**0.05**	**0.03**	**0.00**	**0.02**	**0.08**	**0.14**	**0.20**	**0.28**	**0.67**	**1.60**	**1.41**	**3.92**	**1.69**	**0.10**	**10.69**
9.8	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.17	0.19	0.09	0.05	0.17	0.02	0.74
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.12	0.06	0.02	0.05	0.00	0.30
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.09	0.01	0.00	0.04	0.01	0.19
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.19	0.13	0.37	0.40	0.00	1.17
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.00	0.08	0.19	0.03	0.58	0.26	0.00	1.21
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02
	Total	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	**0.04**	**0.05**	**0.44**	**0.78**	**0.32**	**1.02**	**0.92**	**0.03**	**3.64**
12.7	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.00	0.00	0.02	0.00	0.08
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.03	0.00	0.06
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.02	0.06	0.18	0.00	0.33
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.00	0.02	0.04	0.02	0.04	0.04	0.00	0.25
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.04**	**0.05**	**0.03**	**0.05**	**0.12**	**0.07**	**0.10**	**0.28**	**0.00**	**0.74**

Table A-3. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 200 East Area (Station 6) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
15.6	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.02**	**0.00**	**0.00**	**0.00**	**0.04**
19	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total	A	0.65	0.90	0.31	0.24	0.34	0.53	0.57	0.26	0.21	0.34	0.76	1.05	0.59	0.79	1.45	0.59	9.58
	B	0.66	0.60	0.22	0.17	0.52	0.54	0.65	0.18	0.20	0.10	0.28	0.49	0.38	0.48	0.63	0.53	6.63
	C	0.84	0.49	0.33	0.37	0.67	0.69	0.69	0.27	0.17	0.15	0.43	0.56	0.43	0.62	0.79	0.80	8.30
	D	1.49	0.92	0.68	0.72	1.07	1.38	1.52	0.93	0.62	0.42	0.72	1.76	1.49	3.57	4.06	1.65	23.00
	E	0.62	0.48	0.45	0.52	0.69	0.87	1.20	1.47	0.95	0.93	1.42	2.44	4.28	9.76	3.48	0.97	30.53
	F	0.28	0.16	0.11	0.10	0.27	0.51	0.97	1.21	0.73	0.49	0.69	1.43	2.46	4.89	1.64	0.47	16.41
	G	0.10	0.07	0.00	0.04	0.07	0.16	0.43	0.44	0.20	0.14	0.21	0.55	0.85	1.65	0.44	0.07	5.42
	Total	**4.64**	**3.62**	**2.10**	**2.16**	**3.63**	**4.68**	**6.03**	**4.76**	**3.08**	**2.57**	**4.51**	**8.28**	**10.48**	**21.76**	**12.49**	**5.08**	**99.87**

Table A-4. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 300 Area (Station 11) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																Total
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	
0.89	A	0.06	0.07	0.06	0.02	0.05	0.06	0.10	0.04	0.03	0.03	0.02	0.02	0.06	0.03	0.08	0.11	0.84
	B	0.02	0.01	0.00	0.02	0.01	0.04	0.01	0.02	0.01	0.01	0.00	0.01	0.02	0.02	0.00	0.04	0.24
	C	0.07	0.05	0.07	0.08	0.07	0.03	0.15	0.09	0.05	0.01	0.02	0.04	0.01	0.03	0.07	0.07	0.91
	D	0.26	0.12	0.11	0.12	0.13	0.31	0.35	0.32	0.20	0.19	0.23	0.24	0.15	0.28	0.31	0.31	3.63
	E	0.29	0.22	0.24	0.20	0.20	0.37	0.65	0.60	0.47	0.51	0.41	0.48	0.51	0.56	0.69	0.64	7.04
	F	0.39	0.18	0.10	0.12	0.18	0.19	0.37	0.38	0.33	0.26	0.10	0.29	0.28	0.33	0.50	0.48	4.48
	G	0.14	0.04	0.08	0.03	0.05	0.12	0.18	0.13	0.13	0.08	0.02	0.03	0.04	0.13	0.20	0.14	1.54
	Total	**1.23**	**0.69**	**0.66**	**0.59**	**0.69**	**1.12**	**1.81**	**1.58**	**1.22**	**1.09**	**0.80**	**1.11**	**1.07**	**1.38**	**1.85**	**1.79**	**18.68**
2.65	A	0.21	0.17	0.20	0.14	0.23	0.34	0.30	0.14	0.11	0.12	0.14	0.06	0.05	0.04	0.07	0.13	2.45
	B	0.06	0.12	0.12	0.33	0.29	0.32	0.26	0.12	0.12	0.11	0.16	0.02	0.01	0.03	0.05	0.07	2.19
	C	0.15	0.14	0.25	0.39	0.28	0.37	0.62	0.26	0.25	0.25	0.13	0.03	0.01	0.02	0.05	0.13	3.33
	D	0.75	0.42	0.24	0.24	0.50	1.13	1.27	0.61	0.50	0.52	0.41	0.30	0.15	0.14	0.58	0.88	8.64
	E	1.14	0.28	0.07	0.08	0.20	1.28	1.95	0.93	1.04	0.85	0.58	0.40	0.35	0.49	0.82	1.42	11.88
	F	0.63	0.18	0.03	0.03	0.09	1.02	2.15	0.93	0.62	0.33	0.19	0.14	0.10	0.17	0.49	0.91	8.01
	G	0.21	0.04	0.00	0.00	0.02	0.24	0.61	0.34	0.11	0.07	0.04	0.02	0.03	0.07	0.18	0.29	2.27
	Total	**3.15**	**1.35**	**0.91**	**1.21**	**1.61**	**4.70**	**7.16**	**3.33**	**2.75**	**2.25**	**1.65**	**0.97**	**0.70**	**0.96**	**2.24**	**3.83**	**38.77**
4.7	A	0.23	0.45	0.23	0.04	0.02	0.23	0.25	0.11	0.18	0.41	0.46	0.15	0.04	0.04	0.05	0.12	3.01
	B	0.15	0.38	0.32	0.16	0.12	0.34	0.32	0.15	0.14	0.32	0.25	0.11	0.04	0.02	0.02	0.05	2.89
	C	0.18	0.27	0.18	0.14	0.09	0.25	0.24	0.15	0.09	0.50	0.42	0.17	0.02	0.03	0.04	0.06	2.83
	D	0.84	0.25	0.06	0.09	0.06	0.35	0.36	0.13	0.36	0.85	0.84	0.43	0.15	0.14	0.35	0.88	6.14
	E	1.51	0.21	0.02	0.04	0.01	0.26	0.47	0.21	0.50	1.04	1.02	0.58	0.24	0.23	0.47	0.67	7.48
	F	0.65	0.10	0.00	0.01	0.00	0.34	0.37	0.07	0.22	0.39	0.38	0.11	0.06	0.02	0.05	0.38	3.15
	G	0.35	0.03	0.00	0.00	0.00	0.19	0.31	0.03	0.03	0.05	0.08	0.03	0.01	0.00	0.02	0.22	1.35
	Total	**3.91**	**1.69**	**0.81**	**0.48**	**0.30**	**1.96**	**2.32**	**0.85**	**1.52**	**3.56**	**3.45**	**1.58**	**0.56**	**0.48**	**1.00**	**2.38**	**26.85**

Table A-4. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 300 Area (Station 11) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																Total
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	
7.15	A	0.11	0.38	0.07	0.01	0.00	0.01	0.03	0.01	0.06	0.34	0.72	0.33	0.03	0.03	0.10	0.14	2.37
	B	0.11	0.07	0.01	0.00	0.00	0.01	0.00	0.00	0.05	0.17	0.33	0.11	0.06	0.00	0.02	0.00	0.94
	C	0.09	0.05	0.02	0.00	0.00	0.00	0.01	0.01	0.04	0.27	0.30	0.13	0.03	0.01	0.04	0.03	1.03
	D	0.26	0.05	0.00	0.01	0.00	0.00	0.01	0.00	0.13	0.63	0.77	0.44	0.17	0.03	0.33	0.46	3.29
	E	0.32	0.03	0.03	0.03	0.00	0.01	0.10	0.05	0.10	0.42	0.86	0.22	0.11	0.04	0.36	0.31	2.99
	F	0.20	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.17	0.20	0.04	0.00	0.00	0.05	0.08	0.78
	G	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.03	0.01	0.00	0.00	0.00	0.20
	Total	**1.15**	**0.61**	**0.14**	**0.05**	**0.00**	**0.03**	**0.15**	**0.07**	**0.40**	**2.02**	**3.24**	**1.30**	**0.41**	**0.11**	**0.90**	**1.02**	**11.60**
9.8	A	0.02	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.13	0.27	0.23	0.05	0.00	0.03	0.02	0.85
	B	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.06	0.08	0.07	0.00	0.00	0.00	0.31
	C	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.07	0.05	0.03	0.00	0.00	0.00	0.19
	D	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.20	0.19	0.16	0.09	0.04	0.21	0.22	1.17
	E	0.01	0.04	0.00	0.00	0.00	0.00	0.02	0.09	0.04	0.13	0.34	0.06	0.02	0.00	0.12	0.09	0.96
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.06
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.06
	Total	**0.10**	**0.15**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.09**	**0.10**	**0.54**	**1.03**	**0.58**	**0.26**	**0.04**	**0.36**	**0.33**	**3.60**
12.7	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.01	0.00	0.00	0.00	0.00	0.08
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.00	0.01	0.00	0.07
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.05
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.06	0.04	0.12
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.09	0.00	0.00	0.00	0.03	0.01	0.19
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.03
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.06**	**0.00**	**0.02**	**0.21**	**0.04**	**0.05**	**0.00**	**0.11**	**0.06**	**0.55**

Table A-4. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 300 Area (Station 11) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																Total
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	
15.6	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
19	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total	A	0.63	1.14	0.56	0.21	0.30	0.64	0.68	0.30	0.41	1.05	1.66	0.80	0.23	0.14	0.33	0.52	9.60
	B	0.35	0.61	0.45	0.51	0.42	0.71	0.59	0.29	0.33	0.66	0.82	0.34	0.23	0.07	0.10	0.16	6.64
	C	0.51	0.51	0.52	0.61	0.44	0.65	1.02	0.51	0.44	1.04	0.95	0.43	0.11	0.09	0.21	0.30	8.34
	D	2.15	0.85	0.41	0.46	0.69	1.79	1.99	1.06	1.20	2.39	2.44	1.58	0.72	0.63	1.84	2.79	22.99
	E	3.27	0.78	0.36	0.35	0.41	1.92	3.19	1.94	2.15	2.95	3.30	1.74	1.23	1.32	2.49	3.14	30.54
	F	1.87	0.48	0.14	0.16	0.27	1.55	2.89	1.38	1.18	1.17	0.94	0.58	0.44	0.52	1.09	1.85	16.51
	G	0.76	0.12	0.08	0.03	0.07	0.55	1.10	0.50	0.28	0.22	0.27	0.11	0.09	0.20	0.40	0.65	5.43
	Total	**9.54**	**4.49**	**2.52**	**2.33**	**2.60**	**7.81**	**11.46**	**5.98**	**5.99**	**9.48**	**10.38**	**5.58**	**3.05**	**2.97**	**6.46**	**9.41**	**100.05**

Table A–5. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 400 Area (Station 9) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
0.89	A	0.13	0.11	0.11	0.10	0.09	0.17	0.11	0.09	0.07	0.09	0.02	0.02	0.03	0.02	0.09	0.17	1.42
	B	0.03	0.06	0.02	0.04	0.03	0.07	0.03	0.02	0.03	0.02	0.00	0.03	0.02	0.01	0.07	0.04	0.52
	C	0.18	0.11	0.06	0.09	0.17	0.09	0.14	0.10	0.12	0.10	0.03	0.02	0.01	0.02	0.06	0.21	1.51
	D	0.43	0.33	0.35	0.24	0.22	0.32	0.47	0.31	0.35	0.25	0.22	0.21	0.19	0.23	0.53	0.36	5.01
	E	0.46	0.34	0.28	0.25	0.25	0.30	0.39	0.50	0.63	0.56	0.41	0.41	0.54	0.57	0.50	0.57	6.96
	F	0.26	0.29	0.15	0.15	0.19	0.09	0.23	0.28	0.29	0.35	0.33	0.17	0.20	0.32	0.34	0.32	3.96
	G	0.10	0.11	0.03	0.04	0.07	0.07	0.06	0.10	0.11	0.08	0.09	0.07	0.07	0.06	0.07	0.06	1.19
	Total	**1.59**	**1.35**	**1.00**	**0.91**	**1.02**	**1.11**	**1.43**	**1.40**	**1.60**	**1.45**	**1.10**	**0.93**	**1.06**	**1.23**	**1.66**	**1.73**	**20.57**
2.65	A	0.24	0.14	0.07	0.06	0.08	0.17	0.20	0.17	0.26	0.18	0.11	0.10	0.06	0.10	0.14	0.15	2.23
	B	0.14	0.13	0.16	0.15	0.26	0.30	0.38	0.25	0.25	0.12	0.05	0.03	0.06	0.05	0.10	0.12	2.55
	C	0.26	0.27	0.12	0.16	0.16	0.26	0.25	0.39	0.33	0.22	0.08	0.06	0.03	0.04	0.12	0.33	3.08
	D	0.71	0.38	0.27	0.16	0.24	0.40	0.74	0.72	0.71	0.48	0.20	0.18	0.23	0.31	0.61	0.87	7.21
	E	0.85	0.48	0.33	0.12	0.14	0.26	0.79	0.93	1.24	1.27	0.62	0.53	0.49	0.54	1.10	0.95	10.64
	F	0.66	0.38	0.18	0.07	0.06	0.11	0.50	0.87	0.83	0.70	0.39	0.20	0.18	0.23	0.73	0.58	6.67
	G	0.28	0.17	0.05	0.03	0.02	0.04	0.15	0.15	0.14	0.16	0.20	0.06	0.03	0.11	0.24	0.29	2.12
	Total	**3.14**	**1.95**	**1.18**	**0.75**	**0.96**	**1.54**	**3.01**	**3.48**	**3.76**	**3.13**	**1.65**	**1.16**	**1.08**	**1.38**	**3.04**	**3.29**	**34.50**
4.7	A	0.42	0.35	0.13	0.03	0.04	0.04	0.05	0.12	0.35	0.45	0.17	0.14	0.10	0.09	0.26	0.17	2.91
	B	0.39	0.20	0.07	0.06	0.10	0.08	0.13	0.13	0.42	0.22	0.09	0.05	0.06	0.07	0.04	0.18	2.29
	C	0.26	0.12	0.05	0.04	0.04	0.06	0.17	0.20	0.45	0.36	0.15	0.06	0.07	0.04	0.09	0.13	2.29
	D	0.39	0.14	0.14	0.13	0.07	0.12	0.38	0.39	0.76	0.93	0.48	0.18	0.14	0.21	0.91	0.86	6.23
	E	0.38	0.08	0.13	0.03	0.00	0.01	0.56	1.05	1.06	1.23	0.43	0.31	0.34	0.49	1.58	0.89	8.57
	F	0.29	0.07	0.07	0.00	0.00	0.01	0.35	0.98	0.78	0.58	0.17	0.00	0.02	0.05	0.73	0.68	4.78
	G	0.12	0.08	0.03	0.00	0.00	0.00	0.19	0.44	0.20	0.15	0.03	0.00	0.00	0.01	0.16	0.25	1.66
	Total	**2.25**	**1.04**	**0.62**	**0.29**	**0.25**	**0.32**	**1.83**	**3.31**	**4.02**	**3.92**	**1.52**	**0.74**	**0.73**	**0.96**	**3.77**	**3.16**	**28.73**

Table A–5. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 400 Area (Station 9) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
7.15	A	0.19	0.12	0.03	0.01	0.00	0.03	0.02	0.03	0.16	0.54	0.45	0.18	0.07	0.09	0.12	0.07	2.11
	B	0.08	0.04	0.00	0.01	0.00	0.00	0.01	0.02	0.10	0.33	0.12	0.05	0.03	0.00	0.06	0.03	0.88
	C	0.06	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.10	0.49	0.26	0.05	0.03	0.01	0.06	0.04	1.15
	D	0.09	0.01	0.03	0.01	0.00	0.00	0.05	0.01	0.29	0.86	0.46	0.23	0.16	0.25	0.60	0.21	3.26
	E	0.11	0.02	0.00	0.00	0.00	0.00	0.10	0.11	0.19	0.66	0.55	0.13	0.03	0.34	0.85	0.12	3.21
	F	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.07	0.18	0.31	0.19	0.00	0.00	0.00	0.10	0.06	0.96
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.04	0.06	0.07	0.01	0.00	0.00	0.02	0.05	0.34
	Total	**0.57**	**0.24**	**0.07**	**0.03**	**0.00**	**0.03**	**0.19**	**0.32**	**1.06**	**3.25**	**2.10**	**0.65**	**0.32**	**0.69**	**1.81**	**0.58**	**11.91**
9.8	A	0.00	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.19	0.28	0.14	0.04	0.01	0.04	0.02	0.86
	B	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.04	0.06	0.06	0.01	0.01	0.01	0.32
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.05	0.06	0.04	0.00	0.01	0.01	0.24
	D	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.20	0.14	0.10	0.04	0.39	0.06	1.10
	E	0.00	0.02	0.00	0.00	0.00	0.00	0.05	0.05	0.02	0.23	0.25	0.07	0.00	0.03	0.27	0.01	1.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.07
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.07
	Total	**0.01**	**0.13**	**0.02**	**0.00**	**0.00**	**0.00**	**0.05**	**0.05**	**0.12**	**0.79**	**0.86**	**0.47**	**0.24**	**0.09**	**0.72**	**0.11**	**3.66**
12.7	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.02	0.00	0.00	0.00	0.00	0.12
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.03	0.00	0.01	0.00	0.08
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.03
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.00	0.08	0.00	0.14
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.08	0.00	0.01	0.00	0.03	0.01	0.14
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.07**	**0.22**	**0.05**	**0.04**	**0.00**	**0.13**	**0.01**	**0.53**

Table A–5. Annual Average Joint Frequency During 2016 (as Percent of Time) of Wind Speed, Stability Class, and Direction for the 400 Area (Station 9) at the 10-Meter Level (3 pages)

Wind Speed (m/sec)	Stability Class	Wind Direction Toward:																
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Total
15.6	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.03
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.01**	**0.00**	**0.00**	**0.00**	**0.03**
19	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total	A	0.98	0.80	0.35	0.20	0.21	0.41	0.38	0.41	0.89	1.48	1.10	0.60	0.30	0.31	0.65	0.58	9.65
	B	0.65	0.44	0.26	0.26	0.39	0.45	0.55	0.42	0.82	0.79	0.31	0.23	0.26	0.14	0.29	0.38	6.64
	C	0.76	0.54	0.24	0.29	0.37	0.41	0.56	0.69	1.01	1.25	0.57	0.25	0.18	0.11	0.35	0.72	8.30
	D	1.62	0.88	0.79	0.54	0.53	0.84	1.64	1.43	2.11	2.67	1.60	0.96	0.82	1.04	3.12	2.36	22.95
	E	1.80	0.94	0.74	0.40	0.39	0.57	1.89	2.65	3.14	3.95	2.34	1.47	1.42	1.97	4.33	2.55	30.55
	F	1.25	0.75	0.40	0.22	0.25	0.21	1.08	2.20	2.10	1.98	1.10	0.37	0.40	0.60	1.90	1.64	16.45
	G	0.50	0.36	0.11	0.07	0.09	0.11	0.41	0.77	0.49	0.49	0.43	0.14	0.10	0.18	0.49	0.65	5.39
	Total	**7.56**	**4.71**	**2.89**	**1.98**	**2.23**	**3.00**	**6.51**	**8.57**	**10.56**	**12.61**	**7.45**	**4.02**	**3.48**	**4.35**	**11.13**	**8.88**	**99.93**

Table A–6. Exposure and Consumption Data for the Hanford Site (2 pages)

FOOD SOURCE FOR THE MAXIMALLY EXPOSED INDIVIDUAL
(Fraction of food produced at indicated location)

Food	Local	Regional	Imported
Vegetable	1.000	00	00
Meat	1.000	00	00
Milk	1.000	00	00

VALUES FOR RADIONUCLIDE–INDEPENDENT VARIABLES

HUMAN INHALATION RATE (cm^3/hr) = 5.26E+03

SOIL PARAMETERS
Effective surface density, kg/sq m, dry weight
(assumes 15–cm plow layer) = 2.15E+02

BUILDUP TIMES
For activity in soil (yr) = 5.00E+01
For radionuclides deposited on ground/water (d) = 1.83E+04

DELAY TIMES
Ingestion of pasture grass by animals (hr) = 0E+00
Ingestion of stored feed by animals (hr) = 2.16E+03
Ingestion of leafy vegetables by man (hr) = 3.360E+02
Ingestion of produce by man (hours) = 3.36E+02
Transport time from animal feed–milk–man (d) = 2.00E+00
Time from slaughter to consumption (d) = 2.00E+01

WEATHERING
Removal rate constant for physical loss (per hr) = 2.90E-03

CROP EXPOSURE DURATION
Pasture grass (hr) = 7.20E+02
Crops/leafy vegetables (hr) = 1.44E+03

AGRICULTURAL PRODUCTIVITY
Grass–cow–milk–man pathway (kg/m^2) = 2.80E-01
Produce/leafy veg for human consumption (kg/m^2) = 7.16E-01

FALLOUT INTERCEPTION FRACTIONS
Vegetables = 2.00E-01
Pasture = 5.70E-01

GRAZING PARAMETERS
Fraction of year animals graze on pasture = 4.00E-01
Fraction of daily feed that is pasture grass when animal grazes on pasture = 4.30E-01

Table A–6. Exposure and Consumption Data for the Hanford Site (2 pages)

ANIMAL FEED CONSUMPTION FACTORS
Contaminated feed/forage (kg/day, dry weight) = 1.56E+01

DAIRY PRODUCTIVITY
Milk production of cow (L/day) = 1.10E+01

MEAT ANIMAL SLAUGHTER PARAMETERS
Muscle mass of animal at slaughter (kg) = 2.00E+02
Fraction of herd slaughtered (per day) = 3.81E-03

DECONTAMINATION
Fraction of radioactivity retained after washing
or leafy vegetables and produce = 5.00E-01

FRACTIONS GROWN IN GARDEN OF INTEREST
Produce ingested = 1.00E+0
Leafy vegetables ingested = 1.00E+00

INGESTION RATIOS:
IMMEDIATE SURROUNDING AREA/TOTAL WITHIN AREA
Vegetables = 1.00E+00
Meat = 1.00E+00
Milk = 1.00E+00

MINIMUM INGESTION FRACTIONS FROM OUTSIDE AREA
(Minimum fractions of food types from outside area listed below are actual fixed values.)
Vegetables = 0E+00
Meat = 0E+00
Milk = 0E+00

HUMAN FOOD UTILIZATION FACTORS
Produce ingestion (kg/yr) = 7.62E+01
Milk ingestion (L/yr) = 5.30E+01
Meat ingestion (kg/yr) = 8.40E+01
Leafy vegetable ingestion (kg/yr) = 7.79E+00

SWIMMING PARAMETERS
Fraction of time spent swimming = 0.00E+00
Dilution depth for water (cm) = 1.00E+00

EXTERNAL DOSE
Ground–surface contamination correction factor = 5.00E-01

Table A–7. Hanford Site Meteorological Data — General Site Information

HEIGHT OF LID
LIDAI = 1,000 m

RAINFALL RATE [2016]
RR = 19.4 cm/yr

AVERAGE AIR TEMPERATURE[2016]
A = 13.3 degrees C (55.96 degrees F)

SURFACE ROUGHNESS LENGTH
0 = 0.010 m

VERTICAL TEMPERATURE GRADIENTS: (TG) (K/m)

STABILITY E	0.073
STABILITY F	0.109
STABILITY G	0.146

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APPENDIX B

RADIOACTIVE MATERIALS USED AND/OR POTENTIALLY USED AT THE HANFORD SITE IN 2016

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Table B–1. Radionuclides Used and/or Potentially Used at the Hanford Site in Calendar Year 2016 (2 pages)

Ac-225	Au-195	C-11	Co-58m	F-18	Ho-166	K-42	Nb-92m	Pa-234m
Ac-226	Au-195m	C-14	Co-60	Fe-55	Ho-166m	Kr-81	Nb-93m	Pb-203
Ac-227	Au-196	C-15	Co-60m	Fe-59	I-122	Kr-81m	Nb-94	Pb-204m
Ac-228	Au-196m	Ca-41	Cr-49	Fr-221	I-123	Kr-83m	Nb-94m	Pb-205
Ag-105	Au-198	Ca-45	Cr-51	Fr-222	I-124	Kr-85	Nb-95	Pb-209
Ag-106m	Au-198m	Ca-47	Cr-55	Fr-223	I-125	Kr-85m	Nb-95m	Pb-210
Ag-108	Au-199	Cd-107	Cs-131	Ga-67	I-126	Kr-87	Nb-96	Pb-211
Ag-108m	Ba-131	Cd-109	Cs-132	Ga-68	I-128	Kr-88	Nb-97	Pb-212
Ag-109m	Ba-131m	Cd-111m	Cs-134	Ga-70	I-129	Kr-89	Nb-97m	Pb-214
Ag-110	Ba-133	Cd-113	Cs-134m	Ga-72	I-130	Kr-90	Nb-98	Pd-103
Ag-110m	Ba-133m	Cd-113m	Cs-135	Gd-148	I-130m	La-137	Nb-100	Pd-107
Ag-111	Ba-135m	Cd-115	Cs-135m	Gd-149	I-131	La-138	Nb-101	Pd-109
Ag-111m	Ba-137m	Cd-115m	Cs-136	Gd-150	I-132	La-140	Nb-103	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-7	Ce-143	Cs-141	Ge-69	I-135	Mg-27	Ni-63	Pm-146
Am-242m	Be-10	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-91	Pa-232	Po-218
Au-193m	Br-84m	Co-57	Eu-156	Ho-164	Ir-194	Nb-91m	Pa-233	Pr-142
Au-194	Br-85	Co-58	Eu-157	Ho-164m	K-40	Nb-92	Pa-234	Pr-142m
Pr-143	Ra-227	Rh-105	Sc-46	Sn-125m	Tc-99	Th-234	V-48	Y-92
Pr-144	Ra-228	Rh-105m	Sc-47	Sn-126	Tc-99m	Ti-44	V-49	Y-93
Pr-144m	Rb-81	Rh-106	Sc-48	Sr-82	Tc-101	Ti-45	W-181	Yb-164

Table B–1. Radionuclides Used and/or Potentially Used at the Hanford Site in Calendar Year 2016 (2 pages)

Pt-191	Rb-81m	Rn-218	Se-75	Sr-83	Tc-103	Ti-51	W-185	Yb-165
Pt-193	Rb-82	Rn-219	Se-77m	Sr-85	Tc-106	Tl-200	W-185m	Yb-166
Pt-193m	Rb-82m	Rn-220	Se-79	Sr-85m	Te-121	Tl-201	W-187	Yb-167
Pt-195m	Rb-83	Rn-222	Se-79m	Sr-87m	Te-121m	Tl-202	W-188	Yb-169
Pt-197	Rb-84	Rn-224	Si-31	Sr-89	Te-123	Tl-204	Xe-122	Yb-175
Pt-197m	Rb-84m	Ru-97	Si-32	Sr-90	Te-123m	Tl-206	Xe-123	Yb-177
Pt-199	Rb-86	Ru-103	Sm-145	Sr-91	Te-125m	Tl-206m	Xe-125	Zn-65
Pt-199m	Rb-86m	Ru-105	Sm-146	Sr-92	Te-127	Tl-207	Xe-127	Zn-69
Pu-234	Rb-87	Ru-106	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	-
Ra-226	Rh-104m	Sc-44m	Sn-125	Tc-98	Th-233	U-240	Y-91m	-

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