U.S. DEPARTMENT OF ENERGY

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

PNNL-20919-3

EMP Attachment 3
DOE-SC PNNL Site
Dose Assessment Guidance

SF Snyder

December 2011

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

DISCLAIMER

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

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <http://www.ntis.gov/about/form.aspx>
Online ordering: http://www.ntis.gov


This document was printed on recycled paper.
(8/2010)

PNNL-20919-3

EMP Attachment 3
DOE-SC PNNL Site
Dose Assessment Guidance

SF Snyder

December 2011

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

Pacific Northwest National Laboratory
Richland, Washington 99352

Attachment 3

DOE-SC PNNL Site Dose Assessment Guidance

Summary

This Dose Assessment Guidance (DAG) describes methods to use to determine the maximally exposed individual (MEI) location and estimate dose impact to that individual under the U.S. Department of Energy (DOE) Office of Science (DOE-SC) Pacific Northwest National Laboratory (PNNL) Site Environmental Monitoring Plan (EMP). This guidance applies to public dose from radioactive material releases to the air from DOC-SC PNNL Site operations. This guidance is an attachment to PNNL's EMP (PNNL-20919) and addresses a discrete, vital subject area of the EMP that is subject to revision independent of the main text of the EMP document.

Acronyms and Abbreviations

CAP88-PC v3	*Clean Air Act* Assessment Package 1988 – Personal Computer, version 3
CFR	*Code of Federal Regulations*
CRD	Contract Requirement Document
DOE	U.S. Department of Energy
DOE-SC	DOE Office of Science
EDE	effective dose equivalent
EMP	environmental monitoring plan
EPA	U.S. Environmental Protection Agency
ICRP	International Commission on Radiological Protection
MEI	maximally exposed individual
NESHAP	National Emission Standards for Hazardous Air Pollutants
PNNL	Pacific Northwest National Laboratory
TED	total effective dose
TEDE	total effective dose equivalent
WAC	Washington Administrative Code
WDOH	Washington State Department of Health

Building/Facility Acronyms

BSF	(PNNL leased) Biological Sciences Facility
EMSL	(PNNL Site) Environmental Molecular Science Lab
Energy NW	Energy Northwest, Columbia Generating Station
ISB1 and ISB2	(PNNL leased) Information Sciences Buildings 1 and 2
LIGO	Laser Interferometer Gravitational Wave Observatory, Hanford Observatory
LSL	(Battelle) Life Sciences Lab II
NSB	National Security Building
PSF	(PNNL Site) Physical Sciences Facility (including Buildings: 3410, 3420, 3425, and 3430)
WSU	Washington State University, Tri-Cities campus

Contents

Figures

Tables

1.0 Introduction

This document is an attachment to the Pacific Northwest National Laboratory (PNNL) Environmental Monitoring Plan (EMP) and describes dose assessment guidance for radiological air emissions. The impact of radiological air emissions from the U.S. Department of Energy Office of Science (DOE-SC) PNNL Site is indicated by dose estimates to a maximally exposed member of the public, referred to as the maximally exposed individual (MEI). Reporting requirements associated with dose to members of the public from radiological air emissions are in 40 CFR Part 61.94, WAC 246-247-080, and DOE Order 458.1. The DOE Order and state standards for dose from radioactive air emissions are consistent with U.S. Environmental Protection Agency (EPA) dose standards in 40 CFR 61.92 (i.e., 10 mrem/yr to a MEI). Despite the fact that the current Contract Requirements Document (CRD) for the DOE-SC PNNL Site operations does not include the requirement to meet DOE CRD 458.1, paragraph 2.b, public dose limits, the DOE dose limits would be met when EPA limits are met.

The reporting requirements applicable to environmental air surveillance dose assessment are contained in:

- DOE Order 231.1A,[1] "Environment, Safety, and Health Reporting," and DOE M 231.1-2, "Occurrence Reporting and Processing of Operations Information"
  - Indicates notification, reporting, investigation, and closure requirements for occurrence reporting.
  - Indicates criteria for reporting by categories of DOE operations and of significance. Group 6C(1) and (4) Contamination/Radiation Control / Radiation Exposure are applicable to dose impact determinations and reporting for impacts to a member of the public..
- DOE Order 458.1 Chg 2, "Radiation Protection of the Public and the Environment"[2]
  - Requires reporting when public dose limits of CRD paragraph 2.b are exceeded.
  - Requires reporting actual or potential exposures of the public that could result in either 1) a dose from DOE sources exceeding 10-millirem effective dose equivalent (EDE) in a year, or exceeding any limit or failing to meet any other requirement specified, or any other legal or applicable limits; or 2) a combined dose equal to or greater than 100 millirem EDE in a year from DOE and other man-made sources.
- 40 CFR Part 61.94, NESHAP subpart H "Compliance and Reporting"
  - Requires DOE sites that release airborne radioactive effluents to prepare an annual radionuclide air emissions report (e.g., DOE 2010), including estimated radionuclide emissions to the atmosphere and their maximum dose impact at an offsite school, residence, business, or office.

[1] DOE Order 231.1A, "Environmental, Safety, and Health Reporting," is not specifically listed in the current PNNL Site contract (DE-AC05-76RL01830, see M779 of July 15, 2011). However, the associated Manual (DOE M 231.1-2) is included in the current contract in M412 and contains the reporting requirements and CRD for O 231.1A.

[2] This complete Order is not included in full in the current PNNL Site contract (July 15, 2011). However, application of its requirements herein is done as a good business practice.

- WAC 246-247-080 and PNNL Site Radioactive Air Emissions License (RAEL-05) (WDOH 2010)
  - Adopts by reference the reporting requirements in 40 CFR 61, Subpart H, with some additional information. The report submitted to EPA under that regulation also satisfies WDOH reporting requirements if all information required by the state regulation is included.
  - Requires reporting to the Washington State Department of Health (WDOH) when an air monitoring concentration meets or exceeds the 40 CFR 61 (Appendix E) Table 2 value (see Sampling and Analysis Plan, EMP Attachment 1 Table 3.2) or when detection limits exceed 10% of the values.

1.1 Estimating Dose to a Member of the Public

The radiological dose that an individual member of the public potentially receives during a calendar year from DOE-SC PNNL Site air emissions is calculated using the *Clean Air Act* Assessment Package 1988 – Personal Computer, version 3 (CAP88-PC v3) software (Rosnick 2007). Use of an EPA-approved method, such as the CAP88-PC code, is required for this purpose (40 CFR 61.93(a)). Dose quantities are reported in units of mrem for individuals. In addition, DOE requires a collective dose assessment for the offsite population. Units of person-rem are used for the collective dose received by the total population within an 80-kilometer (km) radius of the DOE-SC PNNL Site. EPA regulations in 40 CFR Part 61, Subpart H specify that estimates of radiological dose to a member of the public be reported in terms of EDE or total effective dose equivalent (TEDE), consistent with an older methodology described in International Commission on Radiological Protection (ICRP) Publication 26 (ICRP 1977) and ICRP Publication 30 (ICRP 1979–1988). DOE has adopted use of the total effective dose (TED) as recommended in the more recent ICRP Publication 60 (ICRP 1991). Doses calculated as TED and TEDE are similar in most cases.

Both TED and TEDE represent the total risk of potential health effects from radiation exposure, including dose from radionuclides taken into the body and dose from sources external to the body. CAP88-PC v3 uses radiation- and tissue-weighting factors consistent with ICRP Publications 60 (ICRP 1991) and 72 (ICRP 1996), and thereby indicates dose in terms of TED. Although the regulations specify that dose be calculated in terms of TEDE, EPA approval of CAP88-PC v3 for use by DOE facilities provides the acceptance of the more recent ICRP (1991, 1996) methods.

1.2 Radiological Release and Transport Modeling

Due to the current, very low emissions rates of radioactive materials, doses to individuals are calculated using computer models rather than direct measurements of radionuclide concentrations at the receptor location. The data needed to perform compliance dose calculations for the DOE-SC PNNL Site include conservatively estimated or measured effluent releases, meteorological data for the year of interest, and conservative assumptions regarding the MEI exposure characteristics. These data are either entered directly into the CAP88-PC v3 code or provided as data files formatted for use with the software.

The transport of radionuclides from the release sources to the points of exposure is predicted by the CAP88-PC v3 models for environmental transport pathways. Those models calculate concentrations of radionuclides in air, water, and food. Radionuclides taken into the body by inhalation or ingestion may be distributed among different organs and retained for various times. In addition, long-lived radionuclides

deposited on the ground can be taken up by agricultural products, may be re-suspended and dispersed by winds, and can be possible contributors to long-term external exposure. Dietary and exposure parameters are used to calculate radionuclide intakes and radiological doses to people. Standardized computer programs are used to perform the calculations. These programs are incorporated into a master code containing internally consistent mathematical models that use site-specific dispersion and uptake parameters. An EPA-approved version of the CAP88-PC software (version 3, Rosnick 2007) is used to demonstrate compliance under 40 CFR Part 61, Subpart H; WAC 246-247; and DOE Order 458.1. Exposure parameters used in compliance calculations for the DOE-SC PNNL Site MEI should be consistent with those used for Hanford Site calculations (DOE 2008; DOE 2010, Appendix A). When they are not, explanations should be provided to indicate why one DOE facility considers a different assumption applicable to its operation.

1.3 Dose Calculations

Radionuclide concentrations in air from DOE-SC PNNL Site effluents are expected to be sufficiently low that detection at offsite locations may not be possible. As in the past, when concentrations of radionuclides in the environment are too low to measure, the DOE specifies that the doses are to be calculated from effluent data using environmental transport and dosimetry models.

The radiological dose calculation takes into account the long-term (50 years) internal exposure from radionuclides taken into the body during the current year. The TED is the sum of individual committed (50 years) organ doses multiplied by weighting factors that represent the proportion of the total health-effect risk that each organ would contribute based on uniform irradiation of the whole body. Internal organs may also be irradiated from external sources. The external exposure received during the current year is added to the committed internal dose to obtain the total TED. The TED is frequently expressed in rem or millirem. The transfer factors used with the CAP88-PC software are documented in Parks (1992) and Rosnick (2007). If required for comparative purposes, transfer factors used for pathway and dose calculations are also documented in GENII Version 1.485 code documentation (Napier et al. 1988), Schreckhise et al. 1993, and Staven et al. 2003; and GENII Version 2.0 code documentation (Napier 2010).

Radiological dose impact to the public from PNNL Site releases considers air pathway sources with the following exposure routes:

- Inhalation
- External Exposure from air submersion
- External Exposure from ground contamination
- Ingestion of local foodstuffs (crops and livestock).

The MEI is a hypothetical member of the public residing or working at a particular location who has a postulated lifestyle conducive to receiving higher radiological doses than other members of the public would be likely to receive. The PNNL Site MEI location may vary from year to year depending on meteorology, as well as the types and quantities of radionuclides released in facility effluents. The defined MEI for the DOE-SC PNNL Site adheres to the EPA definition of the receptor location that is a school, business, office, or residence.

The CAP88-PC code uses the meteorology, radioactive material release rates, and MEI location to calculate a dose estimate. For a given calendar year, annual average meteorology is used to determine the maximally exposed individual location for radionuclide releases from DOE-SC PNNL Site facilities. The meteorology data are formatted for use in the CAP88-PC v3 code. The MEI location is determined by identifying the maximum radionuclide air concentration indicated by the CAP88-PC v3 output for a school, business, office, or residence location. CAP88-PC v3 calculations for MEI dose include the radionuclide emission rates from in-stack sampling or estimation with 40 CFR 61, Appendix D methods. These measurements are made routinely as part of the facility effluent monitoring program.

Important region-specific parameters affecting the movement of radionuclides within potential exposure pathways, such as irrigation rates, growing periods, and holdup periods, are provided in the annual Hanford Site environmental report (e.g., Poston et al. 2010) and in DOE (2008). These same parameter values are directly applicable to DOE-SC PNNL Site pathway evaluations. Certain parameter values are specific to the lifestyles of either "maximally exposed" or "average" individuals. Procedures, models, and parameters previously defined for the Hanford Site to be used to calculate the radiological doses to the public are also documented in DOE (2008) and are specifically applicable to CAP88-PC v3, e.g., DOE (2010) and adapted for the PNNL Site.

Given the current low level of air emissions from the DOE-SC PNNL Site, MEI parameters are applied. If these prove to be too conservative in the future (i.e., dose estimate is overly conservative and the over-estimate approaches a dose limit or constraint), other less conservative individual lifestyle parameters would be considered with justification and approvals, as needed.

1.4 Population Dose

Population dose calculations consider the same pathways as those evaluated for an individual. Regulatory dose limits have not been established for population doses under the DOE, WDOH, or EPA regulations. However, evaluation of the collective doses (expressed in person-rem) to all residents within an 80-km radius of the site is required by DOE Order 458.1 paragraph 4.e(1)(d). The 80-km population dose represents the summed average individual doses for the number of individuals involved for all potential exposure pathways. The pathways assigned to the DOE-SC PNNL Site MEI are also applicable to the offsite population. Average, rather than maximum, intake rates and exposure parameters are typically used to more realistically estimate population dose.

The close proximity of the DOE-SC PNNL Site to the Hanford Site 300 Area allows the 80-km population distribution for the 300 Area to be applied to the DOE-SC PNNL Site collective dose calculations. Geographic distributions of the population residing within an 80-km radius of the four Hanford Site operating areas based on 2000 Bureau of the Census data are documented in Elliot et al. (2004). Data from the 2010 Census were evaluated and published in Hamilton and Snyder (2011). These data influence the population dose by providing estimates of the number of people exposed to radioactive effluents and their proximity to the points of release.

The CAP88-PC formatted population file for 2010 census results is shown in Figure 1, with a total of 432, 117 people within the 80-km (50-mile) radius of the DOE-SC PNNL Site. Use of the data file shown in the figure will provide output that indicates population dose for sectors with midpoint-distances from the emission point origin of 0.8 km, 2.4 km, 4.0 km, 5.6 km, 7.2 km, 12.05 km, 24.15 km, 40.25 km, 56.35 km, and 72.45 km. These correspond to sectors of 0–1 mi, 1–2 mi, 2–3 mi, 3–4 mi, 4–5 mi, 5–10 mi, 10–20 mi, 20–30 mi, 30–40 mi, and 40–50 mi radii.

```
$ Hanford 300 Area T, Long/Lat: -119.286  46.364,    NSEC=16 NRADS=10
    1.6     3.2     4.8     6.4     8.0    16.1    32.2    48.3
   64.4    80.5
        0        0        0        0        0        4      247     1513
     4787     2661        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        2       12     1153     3778        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        1        2
     7646     1360        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        1       40      127      463        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        4      432      161      937
    25767    22823        0        0        0        0        0        0
        0        0        0        0        0        0        0       48
       26      890     5117    13571    14711      102        0        0
        0        0        0        0        0        0        0        0
        0        0        1     1117      136     4325     2321      106
       86      335        0        0        0        0        0        0
        0        0        0        0        0        1        4      215
      133    11526      981       80     4208     4131        0        0
        0        0        0        0        0        0        0        0
        0        1      246     3261     8204    28773    10485      301
    33838     2595        0        0        0        0        0        0
        0        0        0        0        0       22      466     1317
      177    14896    67443       68       65      252        0        0
        0        0        0        0        0        0        0        0
        0       18      112      100       40    15107    50970      956
      965     1819        0        0        0        0        0        0
        0        0        0        0        0       24       39       39
       74      130      656      361      100    23994        0        0
        0        0        0        0        0        0        0        0
        0       29       27       44       98      310      186      682
      185      483        0        0        0        0        0        0
        0        0        0        0        0        9       57      123
       78      414      505       53      278      124        0        0
        0        0        0        0        0        0        0        0
        0        3       32       35       37      325      885     3573
     1624      169        0        0        0        0        0        0
        0        0        0        0        0        0        1        5
       24      236     2020     1667     8135     3655        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0
```

Population within 80 km of the Hanford Site 300 Area, 2010 Census (Hamilton and Snyder 2011, PNNL-20631) Reference location is 300 Area Meteorological Station. Long/Lat: -119.286 46.364. CAP88-PC, 10 sectors, formatted Aug2011 SFS.

Figure 1. 2010 Population Data Formatted for use in CAP88-PC v3

1.5 Use of Environmental Surveillance Data

It is possible to estimate radiological impacts based on measured concentrations of radionuclides in air (i.e., air surveillance sample results), if radionuclide concentrations are sufficiently high to be detectable. However, surveillance data may only be used to demonstrate compliance with radionuclide air emissions standards under specific conditions (40 CFR 61.93(b)5). The CAP88-PC v3 model can also be used with annual meteorological data to estimate the air concentrations, via atmospheric dispersion models, at a specific monitoring station location for comparison with air sampling results. This comparison could substantiate the releases estimated by the Effluent Monitoring Program and confirm the adequacy of facility air emissions control systems. If environmental surveillance data for the DOE-SC PNNL Site is unexpectedly high, environmental transport or dose evaluations could be performed using meteorological data and environmental models to consider the source and potential impacts. The process for evaluating and reporting any identified anomalous results is indicated in the Data Management Plan (see EMP Attachment 2).

2.0 MEI Location Determination

This section provides guidance for determining the retrospective MEI location for the annual Radiological Air Emissions Report (e.g., Snyder et al. 2011). In comparison to the Hanford Site, the potential DOE-SC PNNL Site MEI could be located in closer proximity to DOE-SC PNNL Site emission points. Potential receptor doses from air emissions are determined from the modeled air concentrations of radionuclides at the receptor location. There is higher year-to-year variability in air concentrations at locations close to emission points. Therefore, it is necessary to re-evaluate the MEI location each year using meteorological data applicable to the reporting year. Potential MEI locations, with distance and direction from PSF are provided in Table 1 and Table 2. Locations of interest are sorted by direction from the DOE-SC PNNL Site (Table 1) and by receptor type (Table 2).

To determine the MEI location for a given year, the following approach is detailed. The individual determining the MEI location would generate CAP88-PC atmospheric dispersion results using meteorology for the year of interest for locations from 150 m to at least 1550 m, at 100-m intervals. The sector that provides the highest air concentration values for the 150–1550 m distances would be identified. An evaluation of the distances beyond these is recommended to make sure the highest values are not overlooked. Once the distance and direction for the highest air concentrations are roughly known, review the listings in Table 1, or equivalent, to determine if there is a potential receptor of interest in that location to identify an MEI. The dose calculated using CAP88-PC at the identified maximum location would be used for compliance reporting. In addition, it is recommended that the atmospheric dispersion values be documented for air monitoring station locations (both DOE-SC PNNL Site and nearby Hanford Site locations) and for Hanford Site locations of interest (indicated in tables as “Hanford integration” sites).

Table 1. Distance to 2011 Potential Evaluation Locations Sorted by Direction from the DOE-SC PNNL Site

Distance (m)	Direction	Location Description	Receptor
3820	N	Air monitoring station	ID PNL-2
15217	N	Hanford integration-Resident/MEI	Ringold
11314	NNE	School	Edwin Markham Elementary
915	NE	Fenceline – historic predominant wind direction	NE boundary
2468	NE	Hanford integration-Resident/MEI	Sagemoor
7555	NE	School	Country Haven Academy
1845	ENE	Resident	Resident2 Far (East) side of Columbia River
1493	E	Resident	Resident3 Far (East) side of Columbia River
547	SE	Business	Restaurant
280	SE	Office-Battelle	3430 to ISB1
370	SE	Office-Battelle	3430 to ISB2
972	SE	Resident	Condominium townhouse
480	SSE	Air monitoring station	ID PNL-3, MEI location based on long-term average meteorology
139	SSE	Fenceline – historic predominant wind direction	SSE boundary
4434	SSE	Hanford integration-air monitoring station	Leslie Groves Park
170	SSE	Office-Battelle	3410 to ISB1
280	SSE	Office-Battelle	3410 to ISB2, 3420 to ISB1
380	SSE	Office-Battelle	3420 to ISB2
470	SSE	Office-Battelle	3430 to NSB
2536	SSE	School	WSU Tri-Cities
430	S	Office-Battelle	3410 to NSB
710	S	Office-Battelle	3420 to LSL
510	S	Office-Battelle	3420 to NSB
570	S	Office-Battelle	3430 to LSL
360	S	Onsite	3420 to EMSL
270	S	Onsite	3430 to EMSL
881	S	Resident/Short- and Long-term stay	User Housing Facility
2938	S	School	Hanford High School
3652	S	School	Children's Garden Montessori
640	SSW	Office-Battelle	3410 to LSL
320	SSW	Onsite	3410 to EMSL
1586	SSW	School (Daycare)	Kindercare
530	SW	Office-Battelle	3410 to BSF

Table 1. (contd)

Distance (m)	Direction	Location Description	Receptor
570	SW	Office-Battelle	3420 to BSF
450	SW	Office-Battelle	3430 to BSF
826	NW	Fenceline – historic predominant wind direction	NW boundary
15142	NW	Hanford integration-onsite business	LIGO
4190	NNW	Air monitoring station	ID PNL-1
12327	NNW	Hanford integration-onsite business	Energy NW WNP-2

Table 2. Distance to 2011 Potential Receptor Locations Sorted by Receptor Type

Location Description	Distance (m)	Direction	Receptor
Air monitoring station	480	SSE	ID PNL-3, MEI location based on long-term average meteorology
Air monitoring station	3820	N	ID PNL-2
Air monitoring station	4190	NNW	ID PNL-1
Business	547	SE	Restaurant
Fenceline – historic predominant wind direction	139	SSE	SSE boundary
Fenceline – historic predominant wind direction	826	NW	NW boundary
Fenceline – historic predominant wind direction	915	NE	NE boundary
Hanford integration-air monitoring station	4434	SSE	Leslie Groves Park
Hanford integration-onsite business	12327	NNW	Energy NW WNP-2
Hanford integration-onsite business	15142	NW	LIGO
Hanford integration-Resident/MEI	2468	NE	Sagemoor
Hanford integration-Resident/MEI	15217	N	Ringold
Office-Battelle	530	SW	3410 to BSF
Office-Battelle	170	SSE	3410 to ISB1
Office-Battelle	280	SSE	3410 to ISB2, 3420 to ISB1
Office-Battelle	640	SSW	3410 to LSL
Office-Battelle	430	S	3410 to NSB
Office-Battelle	570	SW	3420 to BSF
Office-Battelle	380	SSE	3420 to ISB2
Office-Battelle	710	S	3420 to LSL
Office-Battelle	510	S	3420 to NSB
Office-Battelle	450	SW	3430 to BSF
Office-Battelle	280	SE	3430 to ISB1
Office-Battelle	370	SE	3430 to ISB2
Office-Battelle	570	S	3430 to LSL
Office-Battelle	470	SSE	3430 to NSB
Onsite	320	SSW	3410 to EMSL
Onsite	360	S	3420 to EMSL

Table 2. (contd)

Location Description	Distance (m)	Direction	Receptor
Onsite	270	S	3430 to EMSL
Resident	972	SE	Condominium townhouse
Resident	1493	E	Resident3 Far (East) side of Columbia River
Resident	1845	ENE	Resident2 Far (East) side of Columbia River
Resident/Short- and Long-term stay	881	S	User Housing Facility
School	2536	SSE	WSU Tri-Cities
School	2938	S	Hanford High School
School	3652	S	Children's Garden Montessori
School	7555	NE	Country Haven Academy
School	11314	NNE	Edwin Markham Elementary
School (Daycare)	1586	SSW	Kindercare

Distances are indicated in Table 1 and Table 2 with a resolution of approximately 10 m, as determined by measurements from electronic and printed resources. Types of receptors of potential interest when evaluating air impacts are:

- Onsite. Receptor at EMSL.
- DOE-SC PNNL Site air monitoring station locations.
- Fenceline. DOE-SC PNNL Site fenceline locations in the predominant wind direction. See Table 3 for fenceline distances for 16 compass directions.
- Offsite businesses. If the business is a Battelle facility, these are indicated specifically. Other businesses in the predominant wind direction are also indicated.
- Hanford integration. Locations of historic interest to the Hanford Site are indicated. These include Hanford Site MEI locations, air monitoring station locations, and onsite locations of non-DOE employees.
- Resident. Includes short-term stay residents, nearest residents, and nearest residents with the potential to raise subsistence amounts of crops and livestock.
- School. Locations of nearest schools and daycare facilities.

Given current radiological operations in the 300 Area, no receptor locations in the Hanford Site 300 Area are evaluated for impacts from DOE-SC PNNL Site emissions. See Figure 2 as a reference for geographic locations with radii of approximately 5 km, 10 km, and 15 km from the DOE-SC PNNL Site radiological emission units.

As an additional ready reference, Table 3 indicates the distances from the 3410 Building emission point to the DOE-SC PNNL Site Boundary. Accuracy is within approximately 10 m. See Figure 3 for a map of the DOE-SC PNNL Site.

Table 3. Distance from 3410 Building to DOE-SC PNNL Site Fenceline

Direction from 3410 Building	Distance to Boundary/Fenceline (m)	Distance to Boundary/Fenceline (ft)
N	900	2950
NNE	980	3210
NE	915	3000
ENE	754	2475
E	723	2370
ESE	201	660
SE	181	595
SSE	139	455
S	128	420
SSW	706	2315
SW	421	1380
WSW	340	1115
W	581	1905
WNW	630	2065
NW	826	2710
NNW	968	3175

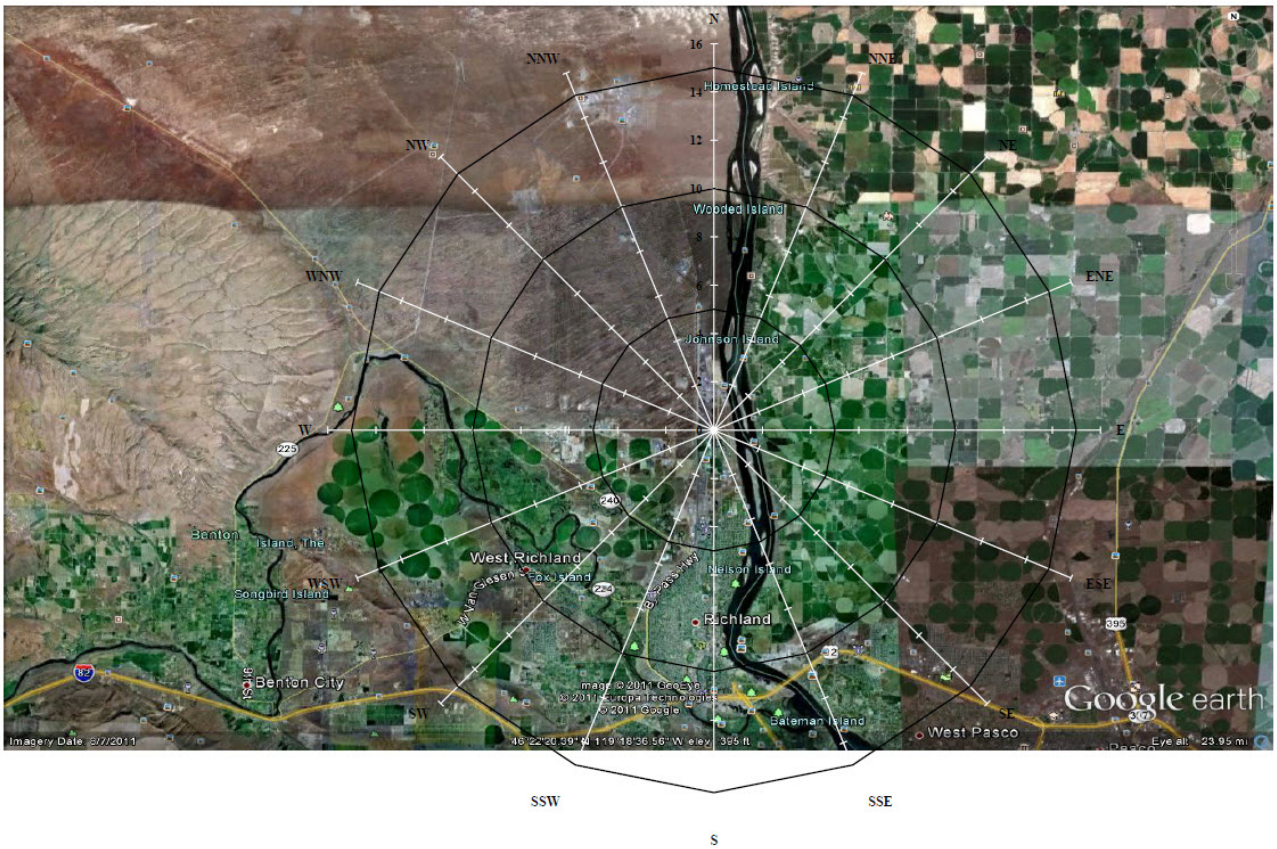

Figure 2. DOE-SC PNNL Site Region with Reference Radii at About 5-km, 10-km, and 15-km

Figure 3. DOE-SC PNNL Site

3.0 References

40 CFR 61. "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 61, Appendix D. 2011. "National Emission Standards for Hazardous Air Pollutants." Appendix D, "Methods for Estimating Radionuclide Emissions." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 61, Appendix E, Table 2. 2011. "National Emission Standards for Hazardous Air Pollutants." Appendix E, "Compliance Procedures Methods for Determining Compliance with Subpart I; Concentrations Levels for Environmental Compliance." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

40 CFR 61, Subpart H. 2002. "National Emission Standards for Hazardous Air Pollutants." Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." *Code of Federal Regulations*, U.S. Environmental Protection Agency.

DOE Manual 231.1-2. 2003. "Occurrence Reporting and Processing of Operations Information." Office of Environment, Safety and Health, U.S. Department of Energy, Washington, D.C.

DOE Order 231.1A. 2003. "Environmental, Safety, and Health Reporting." U.S. Department of Energy, Washington, D.C.

DOE Order 458.1 Chg 2. 2011. "Radiation Protection of the Public and the Environment." U.S. Department of Energy, Washington, D.C.

DOE – U.S. Department of Energy. 2008. *Methods for Calculating Doses to Demonstrate Compliance with Air Pathway Radiation Dose Standards at the Hanford Site*. DOE/RL-2007-53, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE – U.S. Department of Energy. 2010. *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2009*. DOE/RL-2010-17, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Elliott DB, EJ Antonio, and K Rhoads. 2004. *Hanford Area 2000 Population*. PNNL-14428, Pacific Northwest National Laboratory, Richland, Washington.

Hamilton EL and SF Snyder. 2011. *Hanford Site Regional Population – 2010 Census*. PNNL-20631, Pacific Northwest National Laboratory, Richland, Washington.

International Commission on Radiological Protection (ICRP). 1977. "Recommendations of the International Commission on Radiological Protection." ICRP Publication 26, *Annals of the ICRP*, Vol. 1, No. 3, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1979–1988. "Limits for Intakes of Radionuclides by Workers." ICRP Publication 30, Parts 1–4 (and supplements), *Annals of the ICRP*, Vol. 2 (No. 3/4), Vol. 4 (No. 3/4), Vol. 6 (No. 2/3), Vol. 8 (No. 4), and Vol. 19 (No. 4), Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1991. "ICRP Publication 60, 1990 Recommendations of the International Commission on Radiological Protection." *Annals of the ICRP* 21:1-3, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1996. "Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5. Compilation of Ingestion and inhalation Dose Coefficients." ICRP Publication 72, *Annals of the ICRP*, Vol. 26(1), Pergamon Press, Oxford.

Napier BA, RA Peloquin, DL Strenge, and JV Ramsdell. 1988. *GENII - The Hanford Environmental Radiation Dosimetry Software System*. PNL-6584, 3 volumes, Pacific Northwest Laboratory, Richland, Washington.

Napier BA. 2010. *GENII Version 2 Users' Guide*. PNNL-14583, Rev 3a, Pacific Northwest National Laboratory, Richland, Washington.

Parks BS. 1992. *User's Guide for CAP88-PC. Version 1.0*. 402-B-92-001, Office of Radiation Programs, U.S. Environmental Protection Agency, Las Vegas, Nevada.

Poston TM, JP Duncan, and RL Dirkes (eds.). 2010. *Hanford Site Environmental Report for Calendar Year 2009*. PNNL-19455, Pacific Northwest National Laboratory, Richland, Washington.

Rosnick RJ. 2007. *CAP88-PC Version 3.0 User Guide*. Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington D.C.

Schreckhise RG, K Rhoads, JS Davis, BA Napier, and JV Ramsdell. 1993. *Recommended Environmental Dose Calculation Methods and Hanford-Specific Parameters*. PNL-3777, Rev. 2, Pacific Northwest Laboratory, Richland Washington.

Snyder SF, JM Barnett, K Rhoads, and LE Bisping. 2011. *Pacific Northwest National Laboratory Site Radionuclide Air Emissions Report for Calendar Year 2010*. PNNL-20436-1, Pacific Northwest Laboratory, Richland Washington.

Staven LH, BA Napier, K Rhoads, and DL Strenge. 2003. *A Compendium of Transfer Factors for Agricultural and Animal Products*. PNNL-13421, Pacific Northwest National Laboratory, Richland, Washington.

Washington Administrative Code. 2005. *Radiation Protection – Air Emissions*. WAC 246-247, Statute Law Committee, Washington State, Olympia, Washington.

WDOH – Washington State Department of Health). 2010. *Operation of the Physical Science Facility – RAEL-05*. AIR 10-603. Letter from P. John Martell, WDOH to Michael J. Weis, PNSO, dated June 24, 2010. Radioactive Air Emissions Section, Richland, Washington.

Pacific Northwest
NATIONAL LABORATORY

U.S. DEPARTMENT OF
ENERGY

Proudly Operated by Battelle *Since 1965*

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)
www.pnl.gov