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Air Pathway Dose Modeling for the E-Area Low-Level Waste Facility

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EXECUTIVE SUMMARY

Dose-release factors (DRFs) were calculated for potential atmospheric releases of several radionuclides from the E-Area Low-Level Waste Facility (ELLWF). The ELLWF receives solid low-level radioactive waste from across the Savannah River Site (SRS) and offsite for disposal. These factors represent the maximum dose a receptor would receive if standing at either 100 m or 11,408 m (Site Boundary) from the edge of an ELLWF disposal unit which are points of assessment (POA) for Department of Energy (DOE) Order 435.1 performance assessments (PA). The DRFs were calculated for 1 Ci of the specified radionuclide being released from the ground surface to the atmosphere (mrem per curie released). The calculation conservatively represented the ELLWF as a point source, and conservatively assumed the receptor was positioned at the center of the contaminant plume and continuously exposed for a period of one year. These DRFs can be refined to take into consideration disposal unit size, proximity, and timing of peak dose to establish less conservative radionuclide specific disposal limits.

DRFs were calculated for H-3 and C-14 in Revision 0 of this report. H-3 as HTO and C-14 as CO_2 were identified as volatile radionuclides of potential concern in earlier radionuclide screening studies. In Revision 1, DRFs were calculated for eight additional radionuclides identified by an updated screening analysis as potentially important volatile radionuclides. These include Ar-37, Ar-39, Ar-42, Hg-194, Hg-203, Kr-81, Kr-85, and Xe-127. In Revision 2, following a revised screening analysis of volatile radionuclides of potential concern, updated DRFs were calculated for five radionuclides H-3 (HTO vapor), C-14 (CO_2 gas), Hg-194 (vapor), Kr-81 (gas), and Kr-85 (gas). The updated DRFs are based on 1) the current SRS 5-year meteorological dataset (2014-2018) and 2) the current version of the US Environmental Protection Agency's (EPA) dose model CAP88-PC Version 4.1. The short-lived progeny of Hg-194 (Au-194) is in secular equilibrium with its parent and is included in the DRF for Hg-194. Therefore, Au-194 is not assessed separately. For Revision 3, updated DRFs were calculated for Ar-37 (gas), Ar-39 (gas), Kr-83m (gas), and Hg-206 using the same methods as used in Revision 2.

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LIST OF ABBREVIATIONS

DC_PAK	Dose Coefficient File Package
DOE	Department of Energy
DRF	Dose-Release Factors
EDE	Effective Dose Equivalent
ELLWF	E-Area Low-Level Waste Facility
FGR	Federal Guidance Report
IBM	International Business Machine
LLW	Low-Level Waste
MEI	Maximally Exposed Individual
NRC	Nuclear Regulatory Commission
PA	Performance Assessment
PC	Personal Computer
POA	Point of Assessment
SA	Special Analysis
SRS	Savannah River Site
TED	Total Effective Dose

1.0 Introduction

The US Department of Energy (DOE) Order 435.1 performance assessment (PA) process (USDOE 1999) prescribes a performance objective (10 mrem y^{-1}) for evaluating atmospheric releases of radionuclides from DOE low-level waste (LLW) disposal facilities. The potential dose to an individual from exposure to radionuclides released into the atmosphere from LLW disposals can be estimated by application of radionuclide-specific dose-release factors (DRFs) (mrem Ci^{-1}) to estimated flux rates (Ci y^{-1}) at a particular time and location. In Revision 0 of this report, Lee (2006) calculated DRFs for potential atmospheric releases of 15 volatile radionuclides from seven ELLWF disposal units in support of the 2008 ELLWF PA (WSRC 2008). The mainframe version of the US Environmental Protection Agency's (EPA) dose model CAP88 was used in the Revision 0 assessment. In Revision 1 of this report (Dixon and Minter 2017), the site-specific Savannah River National Laboratory (SRNL) atmospheric dose models MAXDOSE-SR version 2013 (Stone and Jannik 2013a) and MAXINE version 2017 (Bell 2017) were used to calculate DRFs for ten radionuclides. Revision 2 provided updated DRFs using the current version of the US Environmental Protection Agency's (EPA) dose model CAP88-PC Version 4.1. After Revision 2 was finalized, DRFs were requested for Ar-37, Ar-39, Kr-83m, and Hg-206. Revision 3 provides the additional DRFs calculated using the same methods as used in Revision 2 of this document. The method for estimating new DRFs for the ELLWF disposal units is described in this report.

1.1 Prior Air Pathway Screening

The air pathway screening analysis (Crapse and Cook 2006) for the 2008 PA evaluated the list of elements comprising 816 radionuclides to identify those elements or elemental species with a potential to form a vapor phase under disposal conditions. The resulting list of 15 volatile radionuclides considered for further analysis included: C-14, Cl-36, H-3, I-129, S-35, Sb-124, Sb-125, Se-75, Se-79, Sn-113, Sn-119m, Sn-121, Sn-121m, Sn-123, and Sn-126 as having the potential for atmospheric release from ELLWF disposal units (Figure 1-1) and present in the inventory at levels above calculated trigger values. Air pathway disposal limits were subsequently developed for these 15 radionuclides in the 2008 PA. In a 2011 special analysis (SA) (Hiergesell and Taylor 2011), this list of 15 radionuclides was reevaluated to assess the potential for plume overlap in the air pathway. This analysis reduced the list of radionuclides requiring disposal limits to H-3 and C-14 by incorporating a mechanism to partition volatile contaminants across the water-air interface within the partially saturated pore space of the engineered and natural materials through which vapor phase transport occurs. The other 13 radionuclides produced a zero flux at the land surface and were removed from the list of air pathway disposal limits. Subsequent to Revision 0 of this report, DRFs were requested for eight additional radionuclides based on an updated screening methodology described by Dyer (2017). These include Ar-37, Ar-39, Ar-42, Hg-194, Hg-203, Kr-81, Kr-85, and Xe-127. Revision 1 of this report addressed these radionuclides and associated DRFs. In Dyer (2021), a revised screening analysis of volatile radionuclides of potential concern was performed and only five radionuclides remained above the PA screening criteria: H-3 (HTO vapor), C-14 (CO_2 gas), Hg-194 (vapor), Kr-81 (gas), and Kr-85 (gas). DRFs were calculated for these five radionuclides in Revision 2 of this report. For Revision 3, DRFs were calculated for Ar-37, Ar-39, Kr-83m, and Hg-206. Should updated vapor phase transport calculations result in other radionuclides of interest (i.e., volatile radionuclides producing a flux at land surface above the waste zone), DRFs can be developed for these as well.

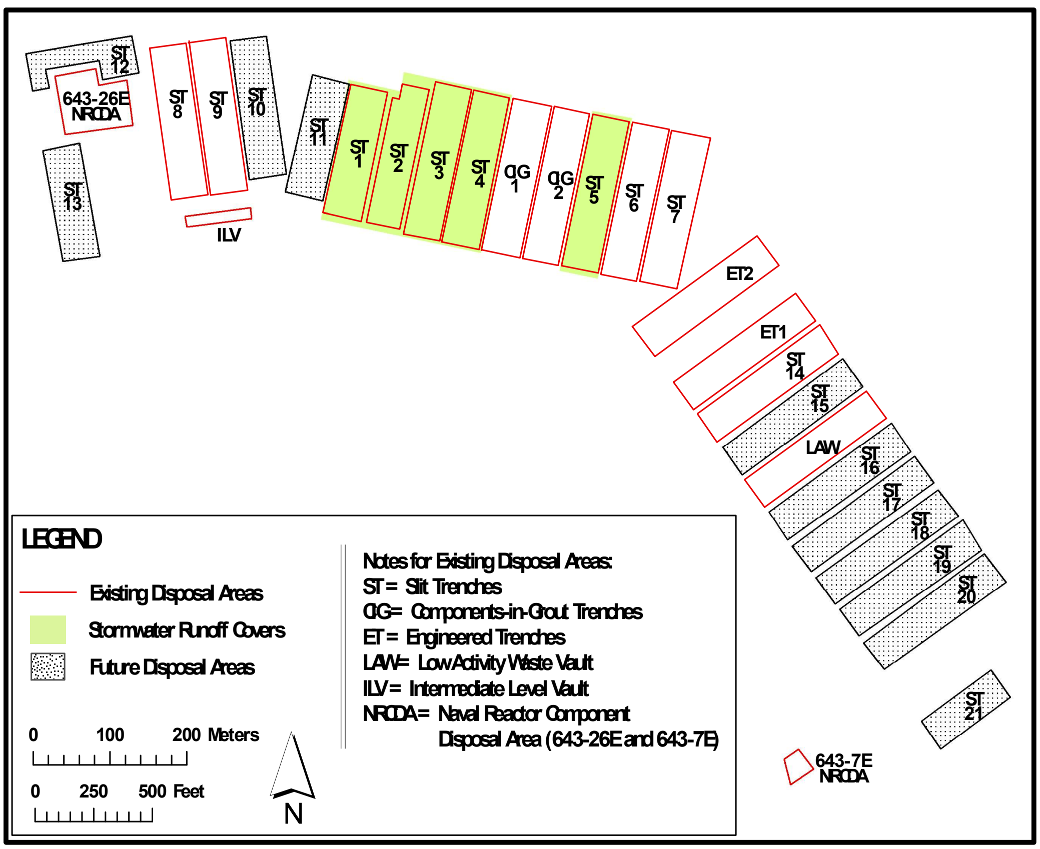
1.2 Points of Assessment and ELLWF Disposal Unit Considerations

For the purposes of this calculation, the terrain and grade elevation of E-Area were specified for the atmospheric release of radionuclides from ELLWF disposal units (Jannik 2014). Figure 1-1 shows the layout of disposal units within the 100-acre facility. As can be seen, many disposal units share a common sized footprint. However, other disposal units, such as the Naval Reactor Component Disposal Areas, Intermediate Level Vault, and some trench units, have unique sizes and shapes. Irrespective of these differences, disposal units can reasonably be treated as a *point source* in atmospheric modeling when the point of assessment (POA) is defined as the SRS boundary, 7.09 miles (11,408 m) from the ELLWF. This is because of the large plume travel distance relative to the size of disposal units. This POA is adopted during the 100 years of institutional control when site access will be controlled.

Following the end of institutional control, unrestricted site access is assumed and the POA moves to the 100-m ELLWF disposal unit boundary (prescribed by the DOE Order). Here disposal unit size and dimensions can have an impact on the atmospheric pathway dose received by this now close-by receptor when using *area sources*. Notably, as the size of the disposal unit footprint increases the dose impact to the 100-m receptor decreases for a unit curie inventory uniformly distributed within the disposal unit.

For this evaluation, including Revisions 2 and 3, disposal units will be treated as point sources for both the 100-m and Site boundary POA's to produce conservative DRFs. This approach along with other conservatisms described in this report will produce a reasonably bounding estimate to ensure no member of the public will receive, via the air pathway, more than 10 mrem per year, excluding the dose from radon and its progeny (USDOE 1999). Additional modeling can be performed taking into consideration disposal unit size (area sources), proximity (plume overlap) and timing of peak doses (temporal plume separation) if less conservative DRFs are needed.

Figure 1-1. E-Area Low Level Waste Facility Conceptual Layout.

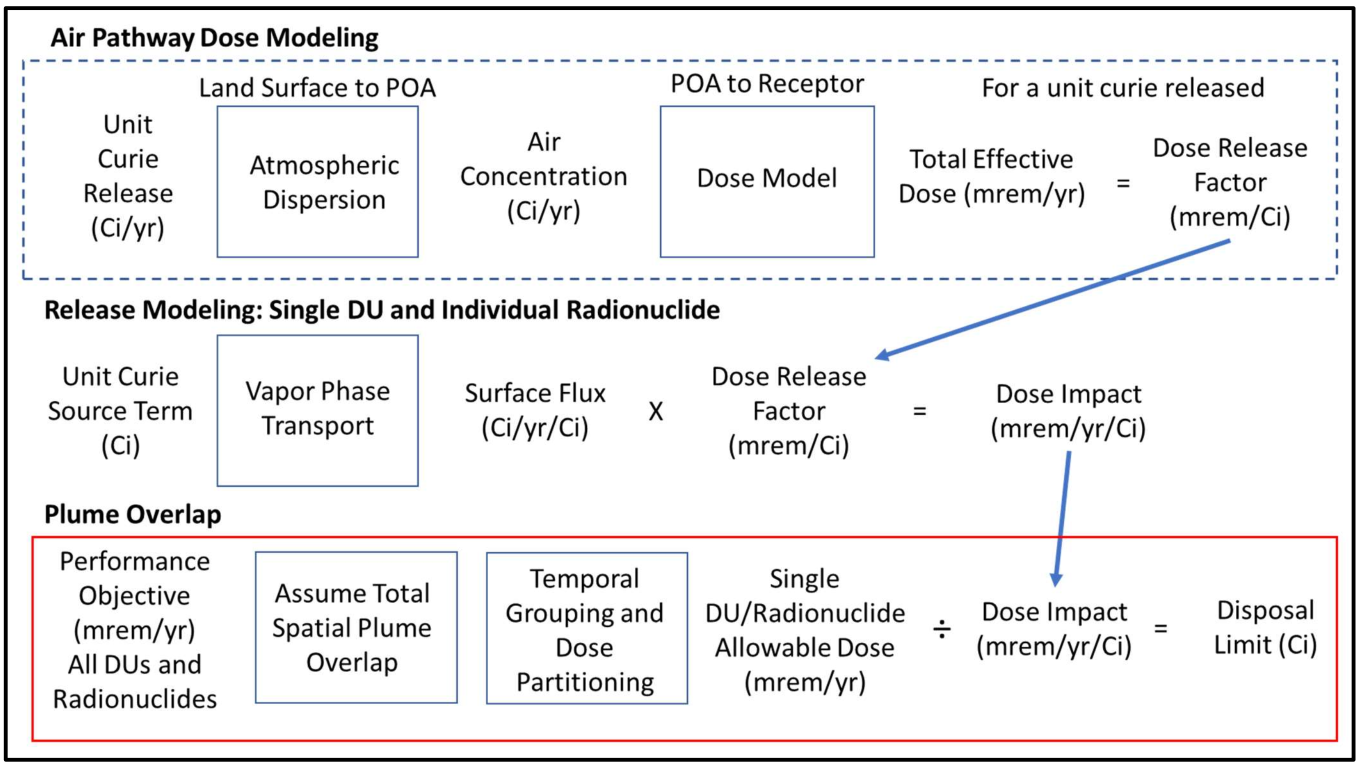


2.0 Air Pathway Dose Modeling

2.1 PA Analysis

Air pathway dose modeling includes both a Gaussian plume atmospheric model for calculating dispersion of the contaminant release to each POA, and a dose model to calculate a dose impact per curie *released*, or dose-release factor, to the receptor from various exposure pathways related to atmospheric transport. The DRF is applied to the peak flux of a volatile radionuclide from the disposal unit to obtain a dose impact per curie *disposed*. The peak flux is obtained by modeling vapor phase transport from the waste zone to the land surface. The dose impact per curie *disposed* is in turn used to produce air-pathway based radionuclide disposal limits. Figure 2-1 is a schematic of the overall air pathway PA analysis.

Figure 2-1. Air Pathway PA Schematic



Those aspects of the PA analysis covered by this report are shown within the dashed box in Figure 2-1. Dose-release factors (mrem Ci^{-1}) are estimated by first modeling atmospheric dispersion to the POA and then calculating the total effective dose (TED) (mrem yr^{-1}) assuming an annual atmospheric release of the associated radionuclide unit source term (Ci yr^{-1}). The DRFs are simply the ratio of the TED to the annual release activity. Because these DRFs are determined using a unit-curie annual release, the TED (mrem yr^{-1}) = DRF (mrem Ci^{-1}). The DRFs were calculated using a point source model to produce the most conservative TED and DRF for the ELLWF.

In compliance with DOE Order 458.1, dose may be calculated to the maximally exposed individual (MEI) or to a representative person. In Revision 1 of this report (Dixon and Minter 2016), the representative person concept was used to determine the DRFs using the SRS site-specific dose models MAXDOSE-SR_E-area Version 2014 (Dixon 2016, Stone and Jannik 2013a) and MAXINE (Bell 2017). For Revision 2 of this E-Area assessment, the DRFs were determined for the MEI using the latest version of EPA's National Emission Standards for Hazardous Air Pollutants; Radionuclides (NESHAPs) required dosimetry code: CAP88-PC Version 4.1 (released March 2020; https://www.epa.gov/radiation/cap-88-pc). This change in dose assessment codes was necessary in order to assess one of the volatile contaminants of concern, Hg-194, as a vapor.

2.2 CAP88 PC

CAP88-PC (v4.1) is a personal computer (PC) version of the original mainframe CAP88 version. CAP88-PC models the TED to a receptor at specified locations in 16 compass point directions by first estimating the relative average air concentration (χ/Q) of the released radionuclides and then applying the appropriate exposure parameters and dose coefficients to estimate pathway-specific doses. To estimate the χ/Qs, CAP88-PC accesses a site-specific five-year meteorological database that includes wind speed, wind direction, temperature, dew point, and horizontal and vertical turbulence intensities. The resultant relative air concentrations are used to estimate TED for ingestion, inhalation, plume shine (air immersion), and ground shine exposure pathways for the MEI. For the vapors and gases assessed in this report, the ground shine pathway is negligible due to CAP88-PC model assumption that ground deposition does not occur for vapors and gases. The MEI is assumed to live at the specified locations the entire year and to eat vegetables, meat, and milk produced at that location.

For the E-Area LLWF disposal units, 1 Ci of each of the volatile radionuclides of concern were assumed to be released from ground level over a one-year period. The 2014-2018 meteorological database for the closest meteorological tower, H Area (Bell 2020), was used to disperse the releases to the MEI at the site boundary and an additional receptor is assumed to be 100-m from the potential release locations. For E-Area, the MEI at the site boundary POA is located at a distance of 11,408 meters to the north. Site- and pathway- specific parameters used in the CAP88-PC model to estimate the resultant DRFs are taken from Stagich (2021).

CAP88-PC uses the DC_PAK 3.02 release of FGR13 for dose conversion factors which does not provide an air submersion dose conversion factor for Ar-37 (USEPA, 2020). Therefore, the program calculates a TED of zero for 1 Ci of Ar-37. The most recent dose conversion factor for Ar-37 is provided by the DOE Derived Concentration Technical Standard (USDOE, 2011). The air submersion dose conversion factor from USDOE (2011) and the air concentration (χ) from CAP88-PC were used to calculate the DRF for Ar-37 with the following equation.

$$DRF = \chi * DF * SF * CF$$

where,

χ	atmospheric concentration, pCi/m^3
SF	shielding factor accounting for the fraction of time spent indoors (1.0 in CAP88-PC)
DF	nuclide specific plume-shine dose factor, mrem cm^3/yr μCi (USDOE, 2011)
CF	unit conversion factor (1E-06 μCi/pCi * 1E-06 m^3/cm^3)

3.0 Key Inputs and Assumptions

The following key inputs and assumptions were employed in the calculation of DRFs. Listed beside each input or assumption is a determination of whether it represents a conservative, best estimated or non-conservative factor.

Key inputs

- Down selected nine (9) volatile radionuclides of potential concern based on an updated screening analysis (Dyer 2021). This screening analysis was used to down select volatile elements based on atomic and molecular properties from the periodic table, radionuclide half-life considerations, and volatility of the most probable gas-phase species (conservative).
- Used the current 2014-2018 meteorological database for the closest meteorological tower, H-tower (Bell 2020) to disperse the releases to the 100 m facility and SRS Site boundaries (best estimate)
- Employed the MEI concept for dose calculations using the latest version of EPA's CAP88-PC dose model. (conservative).

Key Assumptions

- Represented disposal units as a point source (conservative),
- Adopted ground level release of radionuclide above the disposal unit (best estimate)
- Assumed radionuclide release over a period of one year which is standard methodology for dose calculations (potentially non conservative)
- Receptor standing in the plume centerline and receiving continuous exposure over the entire year which is standard methodology for dose calculations (conservative)

Based on the methodology, inputs, and assumptions employed in the atmospheric dispersion and dose models, the calculated DRFs are considered conservative-tending values. Potential atmospheric plume overlap between disposal units (non-conservative) and temporal aspects of plume separation (conservative) may need to be addressed in the overall PA air analysis but are not considered in this work.

4.0 Results and Discussion

4.1 Dose Release Factors

Revisions 2 and 3 updated DRFs for the individual receptor located at the Site boundary and 100 m from ELLWF disposal units are listed in Table 4-1 and are compared to the equivalent values from Revision 1 of this report (Dixon and Minter 2016).

Table 4-1. Comparison of Dose Release Factors (DRF) for Five Volatile Radionuclides from E-Area Low Level Waste Facility (mrem Ci^{-1})

	Dixon and Moore 2016	Dixon and Jannik 2021	Percent Change
Radionuclide	100 m[a]	100 m[d]	(2021-2016)/2016
H-3	1.6E-02	7.8E-03	-51%
C-14	6.9E+00	1.2E+00	-83%
Hg-194	8.4E+00	2.7E+00	-68%
Hg-206	-	2.3E-03	-
Kr-81	2.7E-05	1.5E-05	-44%
Kr-83m	-	4.3E-07	-

Kr-85	1.7E-04	9.4E-05	-45%
Ar-37	4.3E-07	2.4E-07	-44%
Ar-39	8.0E-05	4.5E-05	-44%
	Site Boundary[b,c]	**Site Boundary[c,d]**	
H-3	4.8E-06	2.6E-06	-46%
C-14	2.2E-03	4.1E-04	-81%
Hg-194	2.0E-03	9.3E-04	-54%
Hg-206	-	1.0E-08	-
Kr-81	8.5E-09	5.0E-09	-41%
Kr-83m	-	1.0E-10	-
Kr-85	5.4E-08	3.2E-08	-41%
Ar-37	1.4E-10	8.0E-11	-43%
Ar-39	2.6E-08	1.5E-08	-42%

[a]χ/Q values derived from MAXDOSE-SR E-area were used for input in MAXINE to estimate TED at 100 m
[b]TED to the SRS Representative Person is estimated by MAXDOSE-SR_E-area
[c]Site Boundary is 11,408 m due North of E-Area
[d]TED to MEI is estimated by CAP-88-PC

As shown in Table 4-1, all new DRFs decreased over those calculated in Revision 1 (Dixon and Minter 2016). The decrease in the DRFs is mainly due to changing to using CAP88-PC (MEI) from using MAXDOSE-SR_E-area (representative person) to calculate the DRFs. The larger decrease for C-14 is because both CAP88-PC and MAXDOSE-SR_E-area use computational methods unique to each model for calculating dose due to C-14. Differences in these computational methods contribute in part to the decrease in DRF for C-14. The larger decrease for Hg-194 is due to assessing mercury as a vapor in the CAP88-PC model.

In addition to the change in models, there have been updates to 5-year meteorological dataset and there are differences in the various input parameters used in each model, such as decay factors, dose coefficients, human usage factors, and other radionuclide independent parameters that have contributed to the decreases in the DRFs.

5.0 Conclusion

An air pathway screening analysis for the 2021 ELLWF PA (Dyer 2021) evaluated the list of elements comprising 816 radionuclides to identify those elements or elemental species with a potential to form a vapor phase under disposal conditions. This analysis produced a list of nine (9) volatile radionuclides: H-3 (HTO vapor), C-14 (CO_2 gas), Hg-194 (vapor), Hg-206, Kr-81 (gas), Kr-83m (gas), Kr-85 (gas), Ar-37 (gas), and Ar-39 (gas). The updated DRFs for these radionuclides are based on 1) the current SRS 5-year meteorological dataset (2014-2018) and 2) the current version of the US Environmental Protection Agency's (EPA) dose model CAP88-PC Version 4.1. The short-lived progeny of Hg-194 (Au-194) is in secular equilibrium with its parent and is included in the DRF for Hg-194. Therefore, Au-194 was not assessed separately.

In this analysis, the ELLWF disposal units were represented as point sources rather than area sources at the 100-m POA to produce a conservative DRF for the post-institutional control period. Additional modeling can be performed taking into consideration disposal unit size (area sources), proximity (plume overlap) and timing of peak doses (temporal plume separation) if less conservative DRFs are needed. Generally best-estimate and conservative inputs and assumptions were used in the calculation of DRFs.

DRFs for the receptor located at the site boundary and 100-m from the E-Area disposal units are listed in Table 5-1.

Table 5-1. Dose Release Factor (DRF) for the E-Area Low Level Waste Facility (mrem Ci^{-1})

Radionuclide	100 m	Site Boundary[a]
H-3	7.8E-03	2.6E-06
C-14	1.2E+00	4.1E-04
Hg-194	2.7E+00	9.3E-04
Hg-206	2.3E-03	1.0E-08
Kr-81	1.5E-05	5.0E-09
Kr-83m	4.3E-07	1.0E-10
Kr-85	9.4E-05	3.2E-08
Ar-37	2.4E-07	8.0E-11
Ar-39	4.5E-05	1.5E-08

[c]Site Boundary is 11,408 m due North of E-Area

6.0 References

Bell, E.S. 2017. Maxine Version 2017. SRNL-L3200-2017-00066. Savannah River National Laboratory. Aiken, SC 29808.

Bell, E.S. 2020. Creation of CAP88 and MAXDOSE Meteorological Datasets (2014-2018) for Regulatory Dose Assessment. SRNL-STI-2020-00259, Revision 0. July, 2020. Savannah River National Laboratory, Aiken, SC.

Beres, D.A. 1990, The Clean Air Act Assessment Package-1988 (CAP-88) A Dose and Risk Assessment Methodology for Radionuclide Emissions to Air, U.S. Environmental Protection Agency Contract No. 68-D9-0170, Washington, D.C.

Crapse, K.P. and J.R. Cook, 2006. Atmospheric Pathway Screening Analysis for the E-Area Low Level Waste Facility, WSRC-STI-2006-00159, Washington Savannah River Company, Aiken, SC 29808. 09/05/2006.

Dixon, K.L. and K.R. Moore. 2016. Air Pathway Dose Modeling for the E-Area Low-Level Waste Facility, Rev. 0. SRNL-STI-2016-00512. Savannah River National Laboratory. Aiken, SC 29808.

Dixon, K. L. 2014. MAXDOSE-SR and POPDOSE-SR Version 2014. SRNL-L3200-2013-00051, Rev. 1. Savannah River National Laboratory. Aiken, SC 29808.

Dixon, K.L. 2016. MAXDOSE-SR Version 2014 Modified for E-Area Dose Release Factor Calculations. SRNL-L3200-2016-00096. Savannah River National Laboratory. Aiken, SC 29808.

Dyer, J.A. 2017. Air and Radon Pathways Screening Methodologies for the Next Revision of the E-Area PA, SRNL-STI-2017-00568, Revision 0. Savannah River National Laboratory. Aiken, SC 29808.

Dyer, J.A. 2021. Air and Radon Pathways Screening Methodologies for the Next Revision of the E-Area PA, SRNL-STI-2017-00568, Revision 1. Savannah River National Laboratory. Aiken, SC 29808.

Hiergesell, R.A. and G.A. Taylor. 2011. Special Analysis Air Pathway Modeling of E-Area Low-Level Waste Facility. SRNL-STI-2011-00327. Savannah River National Laboratory. Aiken, SC 29808. August 2011.

Jannik, G.T. 2014. Facility Area Coordinates and Grade Elevations for the Savannah River Site (U). SRNL-L4310-2014-00027. Savannah River National Laboratory. Aiken, SC 29808. 21August 2014.

Lee, P.L. 2006. Air Pathway Dose Modeling for the E-Area Low Level Waste Facility. WSRC-STI-2006-00252, Washington Savannah River Company, Aiken, SC 29808. 10/31/2006.

Stagich, B.H. 2021. Radiological Impact of 2020 Operations at the Savannah River Site. SRNL-STI-202-00284, Savannah River National Laboratory. Aiken, SC 29808. June 2021.

Stone, D. and G.T. Jannik. 2013a MAXDOSE-SR and POPDOSE-SR Version 2013: 2013a. Routine-Release Atmospheric Dose Models used at SRS. SRNL-STI-2013-00722. Savannah River National Laboratory. Aiken, SC 29808. December 2013.

Stone, D. and G.T. Jannik. 2013b. Site Specific Reference Person Parameters and Derived Concentration Standards for the Savannah River Site. SRNL-STI-2013-00115. Savannah River National Laboratory. Aiken, SC 29808. March 2013.

U. S. Department of Energy (DOE). 2011. Derived Concentration Technical Standard. DOE-STD-1196-2011. US Department of Energy. April 2011.

U. S. Department of Energy (DOE). 1999. Implementation Guide for Use with DOE M 435.1-1. DOE G 431.1-1. US Department of Energy. July 1999.

U.S. Environmental Protection Agency, 2020. CAP88-PC Version 4.1 User Guide. Washington, D.C.

U.S. Environmental Protection Agency, 2002. National Emission Standards for Hazardous Air Pollutants; Radionuclides, Title 40 Code of Federal Regulations, Part 61, Subpart H, Washington, D.C.

U. S. Nuclear Regulatory Commission (NRC). 1977a. Calculation of Annual Dose to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50 Appendix I. Regulatory Guide 1.109, Rev. 1. Washington, DC. October 1977a.

U. S. Nuclear Regulatory Commission (NRC). 1977b. Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors. Regulatory Guide 1.111. Washington, D.C. 1977b.

Washington Savannah River Company (WSRC). 2008. E-Area Low-Level Waste Facility DOE 435.1 Performance Assessment. WSRC-STI-2007-00306, Rev. 0. Washington Savannah River Company, Aiken, SC 29808. July 2008.

Appendix A. Hand Calculation of Dose Release Factor for Ar-37

CAP88-PC uses the DC_PAK 3.02 release of FGR13 for dose conversion factors which does not provide an air submersion dose conversion factor for Ar-37 (USEPA, 2020). Thus, the program calculates a total effective dose of zero for 1 Ci of Ar-37. Since the mode of exposure for noble gas radionuclides is air submersion, dose conversion factors for other exposure pathways (i.e., inhalation, ingestion, etc.) are also zero.

The most recent dose conversion factor for Ar-37 is provided by the DOE Derived Concentration Technical Standard (USDOE, 2011). The air submersion dose conversion factor from USDOE (2011) and the air concentration (χ) from CAP88-PC were used to calculate the DRF for Ar-37 with the following equation.

$$DRF = \chi * DF * SF * CF$$

where,

χ	atmospheric concentration, pCi/m^3
SF	shielding factor accounting for the fraction of time spent indoors (1.0 in CAP88-PC)
DF	nuclide specific plume-shine dose factor, mrem-cm^3/yr-µCi (USDOE, 2011)
CF	unit conversion factor (1E-06 µCi/pCi * 1E-06 m^3/cm^3)

This calculation was performed for both the site boundary (11,408 m) and the 100 m points of assessment.

Input values for the site boundary point of assessment, AR-37:

χ	1.12E-03 pCi/m^3 at 11,408 m, from CAPP88 simulation
DF	7.15E+04 mrem-cm3/yr-µCi, from DOE-STD-1196-2011
SF	1.0, from CAP88 simulation
CF	1.0E-12 µCi-m^3/pCi-cm^3

$$DRF = 1.12\text{E-}03\ \frac{pCi}{m^3} * 7.15\text{E+}04\ \frac{mrem \cdot cm^3}{yr \cdot \mu\text{Ci}} * 1.0 * 1.0\text{E-}12\ \frac{\mu\text{Ci} \cdot m^3}{pCi \cdot cm^3}$$

$$\boldsymbol{Site\ Boundary\ \ DRF = 8.0\text{E-}11\ \frac{mrem}{Ci}}$$

Input values for the 100 m point of assessment, Ar-37:

χ	3.35E+00 pCi/m^3 at 100 m, from CAP88 simulation
DF	7.15E+04 mrem-cm3/yr-μCi, from DOE-STD-1196-2011
SF	1.0, from CAP88 simulation
CF	1.0E-12 μCi-m^3/pCi-cm^3

$$DRF = 3.35\text{E+00}\ \frac{pCi}{m^3} * 7.15\text{E+04}\ \frac{mrem \cdot cm^3}{yr \cdot \mu\text{Ci}} * 1.0 * 1.0\text{E-12}\ \frac{\mu\text{Ci} \cdot m^3}{pCi \cdot cm^3}$$

$$\mathbf{100\ \boldsymbol{m}\ \boldsymbol{DRF} = 2.4\text{E-07}}\ \ \boldsymbol{\frac{mrem}{Ci}}$$

Distribution:

T. L. Danielson, 703-41A
K. L. Dixon, 773-42A
J. A. Dyer, 703-41A
L. L. Hamm, 735-A
T. Hang, 773-42A
J. J. Mayer, 999-W
I. J. Stewart, 704-58E
M. Cofer II, 773-42A
Records Administration (EDWS)