ECF-HANFORD-20-0059
Revision 0

Preliminary Risk Calculations for 200-CP-1 Operable Unit Waste Sites

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

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Preliminary Risk Calculations for 200-CP-1 Operable Unit Waste Sites

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APPROVED
By Sarah Harrison at 11:57 am, Aug 31, 2020

Release Approval | Date

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ENVIRONMENTAL CALCULATION COVER PAGE

SECTION 1 - Completed by the Responsible Manager

Project:
200-CP-1 Operable Unit RI/FS Work Plan

Date: 08/20/2020

Calculation Title and Description:
Preliminary Risk Calculations for 200-CP-1 Operable Unit Waste Sites

RELEASE / ISSUE

Qualifications Summary

ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

Preparer(s):

Name: Kimberly Ralston-Hooper

Degree, Major, Institution, Year:
PhD, Forestry and Natural Resources (Aquatic Toxicology Emphasis), Purdue University, 2009
MS, Agronomy, Purdue University, 2002
BA, Chemistry, Hanover College, 1995

Professional Licenses:

Brief Narrative of Experience: Dr. Ralston-Hooper is an ecotoxicologist with over 7 years of experience in the field of environmental risk assessment. Kimberly has extensive knowledge in the areas of exposure and dose assessment, statistical data analysis, developing novel approaches in determination of toxicological effects in aquatic and terrestrial species, predictive toxicology, and experimental design. She also has experience with RESRAD biota in determining radiological effects in ecologically relevant species. Kimberly has received training on the WRPS procedures for preparation and issue of environmental modeling calculations. This extensive and relevant experience qualifies Kimberly for her role as a preparer of this ECF.

Name: Donna Morgans

Degree, Major, Institution, Year:
MS, Environmental Toxicology, Oregon State University, 2003
BS, Microbiology, Oregon State University, 1986

Professional Licenses:

Brief Narrative of Experience: Donna Morgans' professional experience has focused on assessing the potential for adverse human health effects associated with exposure to radiological and nonradiological contaminants in air, soil, water, and animal and plant tissues. In support of restoration efforts to address contamination in a variety of environmental media, she has managed and performed complex risk assessment and data compilation efforts to address a host of federal, state, and local regulations that include Comprehensive Environmental Response, Compensation, and Liability Act lifecycle decisions. Donna is also proficient in the application of aspects related to CERCLA including the development and review of work plans, remedial investigations, feasibility studies, and proposed plans. She has applied this knowledge to a variety of environmental projects and programs for private industry clients and federal government agencies. She has experience in developing risk assessment products and incorporating the appropriate federal and state regulatory requirements on projects throughout the US. Donna also has experience in the statistical evaluation of analytical data to determine population distributions using ProUCL and modeling the effects from exposure to radiological contaminants in soil using RESRAD

ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

Checker(s):

Name: Mahmud Rahman

Degree, Major, Institution, Year: PhD, Environmental Science, Oklahoma State University, 2000
MS, Environmental Science, Oklahoma State University, 1997
BS, Mechanical Engineering, Bangladesh University of Engineering and Technology, 1992

Professional Licenses:

Brief Narrative of Experience: Dr. Rahman has 20 years of environmental consulting experience for performing baseline human health risk assessments, screening level ecological risk assessments, radiological dose assessment, statistical data analysis, evaluating site characterization results, and deriving cleanup criteria and media-specific background concentrations for both radiological and chemical contaminants. He has received training on the CHPRC procedures for this environmental model work. This extensive and relevant experience qualifies Dr. Rahman as a checker for calculations used in this ECF.

Senior Reviewer(s):

Name: Sue Robinson

Degree, Major, Institution, Year: MS, Environmental Toxicology, Western Washington University, 1985
BS, Biology (Marine Emphasis), Western Washington University, 1982

Professional Licenses:

Brief Narrative of Experience: Sue Robinson is an Environmental Toxicologist with 35 years of experience, specializing in evaluating the fate, effects and impact of chemicals and physical stressors on ecological and human health. The fate and effects of metals associated with mining / refining operation impacts (sediment, surface water, soil, biota) have been a focus over the past 22 years. Ms. Robinson’s work includes legacy and operating site impacts to the environment, regulatory compliance strategies, ecological and human health toxicology and conducting environmental risk assessments. Of particular note, Sue's technical expertise includes designing, managing and participating with field and laboratory studies designed to assess chemical- and site-specific toxicity, mobility, and bioavailability given the key role of these factors in the assessment of risk and in developing site-specific remediation levels. Over the course of her career Sue has managed a number of high profile risk and impact-based investigations and assessments in both upland and aquatic environments to support regulatory compliance and remedial strategy development. She currently leads the Hanford Risk Assessment Group in Richland. Sue is an active member and on the Board of Directors of the North American geographic unit of the Society of Environmental Toxicology and Chemistry. She is also a member of the Society of Toxicolgy and the American Mining Association.

SECTION 2 - Completed by Preparer

Calculation Number: ECF-HANFORD-20-0059	Revision Number: 0

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SECTION 3 - Completed by the Responsible Manager

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SECTION 4 - Document Review and Approval

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SECTION 5 - Applicable if Calculation is a Risk Assessment or Uses an Environmental Model

Prior to Initiating Modeling:

Required training for modelers completed:
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William Nichols	Per Electronic Approval (attached)	08/24/2020

Safety Software Approved:
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William Nichols	Per Electronic Approval (attached)	08/24/2020

Calculation Approved:
Risk/Modeling Integration Manager:

Print First and Last Name	Signature	Date
Alaa Aly	Per Electronic Approval (attached)	08/24/2020

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Terms

CDI	chronic daily intake
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
ECF	environmental calculation file
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
OU	operable unit
PEF	particulate emission factor
PRG	preliminary remediation goal
RESRAD	RESidual RADioactivity
HHRA	human health risk assessment
SF	slope factor
PUREX	plutonium-uranium extraction

1 Purpose

The purpose of this environmental calculation file (ECF) is to describe the assumptions and methodologies used to calculate a preliminary (screening level) human health risk assessment (HHRA) for the Plutonium Uranium Extraction (PUREX) Canyon Building 202A and storage tunnels within the 200-CP-1 Operable Unit (OU). Waste streams from 202A Canyon include both radiological and chemical contaminants; however, this ECF focuses on radiological contaminants of potential concern (COPCs) because inventory estimates for portions of the Canyon are published in CP-14977, *Plutonium Uranium Extraction Facility Documented Safety Analysis*, in addition to process knowledge, facility surveys, and tunnel disposal records. The results of the preliminary HHRA presented in this ECF inform questions of interest regarding additional data needs to refine outdoor worker (or ecological) risk in these areas and a basis for remedial action for the PUREX Canyon and tunnels. Only portions of the 202A Canyon can currently be accessed by U.S. Department of Energy (DOE) site workers (currently having a surveillance path); however, it is assumed for exposure calculation purposes that the entire Canyon area could be accessible in the future to an outdoor worker.

High levels of radiological contamination are present at the 202A Canyon and storage tunnels, which provides the basis for the preliminary HHRA without having sample data. The HHRA was performed using soil preliminary remediation goals (PRGs), the U.S. Environmental Protection Agency (EPA) linear low-dose risk equation, and the EPA one-hit high risk equation (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A) Interim Final*) to evaluate risk for the outdoor worker exposed to nonsoil, surface contamination of 202A Canyon and storage tunnels. This preliminary HHRA approach is extremely conservative as it compares soil PRGs to fixed surface contamination (i.e., assumes fixed surface concentrations on structures are equivalent to the same concentration in soil with similar soil exposure pathways[1]) and assumes an outdoor worker could trespass inside of a structure to which they would not have physical access. This conservative (nonstandard) screening risk assessment approach was used to evaluate whether sufficient information is available to establish a basis for remedial action for the 202A Canyon and storage tunnels.

2 Background

The PUREX facility was designed and operated to recover plutonium, uranium, and neptunium from irradiated fuel elements received from the 100-N Reactor and the single-pass reactors on the Hanford Site. The facility consists of many areas that are outlined below.

2.1 202A and Associated Components

202A consists of the following four main structural components:

- A thick-walled, heavily shielded concrete portion called the Canyon, which contains the former processing equipment
- A section composed of three gallery levels parallel to and isolated from the Canyon

[1] Surface fixed contamination and soil contamination are not equivalent for evaluating risk for a number of reasons including bioavailability differences (i.e., depth of contamination within the static surface can vary affecting external exposure), and more importantly the manner in which worker contact exposure differs between exposure to contaminated soil (multiple exposure pathways) and exposure to contamination that is fixed on static surfaces (external contact only).

- A steel and transite annex to the north of the gallery section that houses offices, the laboratory, and a number of building service areas (not included in this evaluation)
- Storage tunnels that house railcars of contaminated equipment; both tunnels are covered with earth fill to provide for radiation shielding

For the purpose of evaluating potentially complete human and ecological exposure pathways, even though portions of the PUREX complex can currently be accessed, it is assumed the entire Canyon area could be accessible to an outdoor worker in the future.

2.1.1 Inaccessible Areas

Inaccessible portions of the canyon are subdivided into a single row of 12 process cells paralleled on the south side by a hot (radioactive) pipe trench with an air tunnel connected to the cells running underneath the pipe trench. The height of the process cells including the cover blocks is 21.1 m (39.5 ft), of which approximately 9.14 m (30 ft) is belowground surface. East of the Canyon, a railroad spur enters the plant belowgrade through a tunnel. At the east end of the Canyon is an inactive fuel storage basin. All fuel was removed, and the floor of the basin was stabilized during deactivation. Currently, cover blocks are in place over each of the process cells, which can only be removed by crane. A specific HHRA for described inaccessible areas is not included in this ECF but is considered as part of the Canyon area HHRA.

2.1.2 Accessible Areas

Areas that are accessible for surveillance and maintenance activities include the east crane maintenance platform, the crane way, three gallery levels including the pipe and operating gallery, the sample gallery, and the west end of the storage gallery. The west end of the storage gallery includes a separate area that was used for the neptunium purification and loadout facility (in Q Cell), the plutonium product removal room, and the plutonium oxide production facility (in N Cell). A specific HHRA for the described accessible areas is not included in this ECF but is considered as part of the Canyon area HHRA.

2.1.3 PUREX Storage Tunnels 1 and 2

Both PUREX Storage Tunnels 1 and 2 were stabilized with engineering grout, which significantly reduces the possibility of subsequent releases. The tunnels are entirely covered with earth fill to provide a minimum cover of 2.4 m (8 ft) for radiation shielding. The top of the tallest waste package in Storage Tunnel 1 is approximately 4.16 m (13.67 ft) and the top of the tallest waste package in Storage Tunnel 2 is 4.48 m (14.7 ft). With the exception of the tallest waste packages, the vast majority of waste in the storage tunnels is below 4.6 m (15 ft) of cover. As a result of the cover, direct contact exposure is likely to be incomplete and therefore the potential for risk is highly unlikely.

2.2 Scope of Preliminary Risk Estimate

In this ECF, the preliminary HHRA is performed for the Canyon area only.

3 Methodology

A standard risk characterization for human health direct contact or ecological risk is not presented in this ECF due to the heterogeneous and highly radioactive nature of the waste inside the process cells and associated areas. Rather, the risk characterization described in this chapter for outdoor workers identifies the presence of complete exposure pathways for the Canyon area that potentially poses risk if an outdoor worker were to enter the Canyon (as also discussed later, a focus on the cancer risk to an outdoor worker is also protective of ecological receptors).

Excess lifetime cancer risk (ELCR) for radiological COPCs under the outdoor worker scenario were calculated using the following three methods:

- RESidual RADioactivity (RESRAD) model PRGs to determine ELCR
- Linear low-dose carcinogenic risk equation to determine ELCR
- One-hit high carcinogenic risk equation (EPA/540/1-89/002) to determine ELCR

Both RESRAD PRGs and linear low-dose equations assume low intake and that the dose-response relationship is linear in the low-dose portion of the multistage model dose response curve. Based on this assumption, the slope factor (SF) is a constant and risk is directly related to intake. However, this assumption is only valid when estimated risk is below 0.01 (1×10^{-2}: a probability of one excess cancer in every 100 exposed people). When this assumption is not met, an alternative equation for calculating cancer risk, such as the one-hit high risk equation, should be used. Due to the high radiological contamination and cancer risk associated with the exposures evaluated at the 202A Canyon, results for all three approaches are presented.

Using a simplified (nonstandard) assumption to calculate preliminary human health risk for the outdoor worker, it was assumed that exposure to fixed surface contamination on buildings and equipment is equivalent to the exposure received from an equivalent degree of soil contamination. This conservative assumption was made because PRGs for fixed surface contamination such as concrete or equipment are not available. Based on this assumption, preliminary risks for human health were estimated for the 202A Canyon as described in the following sections.

3.1 Calculation of Preliminary ELCRs for Each Area

Radionuclides are carcinogens in nature, hence, carcinogenic risk. ELCR for radiological COPCs under the outdoor worker scenario were calculated in two steps: calculation of a radionuclide-specific ELCR and calculation of an area-specific ELCR. A COPC-specific ELCR is calculated using three different methods for each area as described below.

1. **Radionuclide-Specific ELCR Calculation using RESRAD PRG values** – The ELCR for each radionuclide is calculated using the following equation:

$$ELCR_{Rad} = \frac{Source\_Conc_{Rad}}{PRG_{Rad}} \times TR$$

where:

$ELCR_{Rad}$	=	radionuclide-specific ELCR (unitless)
$Source\_Conc_{Rad}$	=	radionuclide-specific soil concentration (pCi/g)
PRG_{Rad}	=	radionuclide-specific PRG (pCi/g)
TR	=	target cancer risk, 10^{-4}.

2. **Radionuclide-Specific Calculation using Linear Low-Dose Carcinogenic Risk Equation** – The individual radionuclide ELCR for soil ingestion, inhalation, and external gamma exposure scenarios were calculated using the following equation:

$$ELCR_{Rad} = CDI\ x\ SF$$

where:

$ELCR_{Rad}$ = radionuclide-specific ELCR (unitless)

CDI = chronic daily intake average over 70 years (pCi or pCi-yr/g)

SF = slope factor (pCi or pCi-yr/g)$^{-1}$.

3. **Radionuclide-Specific Calculation Using One-Hit High Carcinogenic Risk Equation** – The individual radionuclide ELCR for soil ingestion, inhalation, and external gamma exposure scenarios were calculated using the following equation:

$$ELCR_{Rad} = 1 - \exp(-CDI\ x\ SF)$$

where:

$ELCR_{Rad}$ = radionuclide-specific ELCR (unitless)

CDI = chronic daily intake average over 70 years (pCi or pCi-yr/g)

SF = slope factor (pCi or pCi-yr/g)$^{-1}$.

The total area-specific ELCR from each method used is calculated by summing the radionuclide-specific ELCRs by using the following equation:

$$ELCR_{Area} = \sum_{1}^{N} ELCR_{Radi}$$

where:

$ELCR_{Area}$ = total area-specific ELCR

$ELCR_{Radi}$ = radionuclide-specific ELCR for the i^{th} COPCs

N = number of radionuclides.

3.1.1 Determination of Source Concentration

The remaining radioactive material within the 202A Canyon is based on the inventory estimates from CP-14977, which are considered conservative (bounding estimates) based on process knowledge, professional judgement, and experience. Only the transuranic isotopes and the dominant fission products, strontium-90 and cesium-137, are included. The inventories were decay-corrected to January 2018 based on the most recent version of CP-14977. Table 1 summarizes the PUREX Canyon inventory from CP-14977.

The inventories of the radionuclides presented in Table 1 were utilized to calculate their corresponding soil concentrations using the following equation:

$$Soil\ Concentration\ \left(\frac{pCi}{g}\right) = \frac{Release\ Inventory\ (Ci) \times 1E-12\ \frac{pCi}{Ci}}{Volume\ of\ Contamination\ (m^3)\ \times\ 10^6\ cm3/m3} \times \frac{1}{Soil\ Bulk\ Density\ \left(\frac{g}{cm^3}\right)}$$

Input assumptions related to the parameters are presented in Chapter 4. Table 2 presents the soil concentrations for radionuclides in the Canyon area.

Table 1. 202A and Filter Inventory Decayed to January 2018

Radionuclide	Inaccessible Areas											Accessible Areas		
	A Cell (Ci)	B Cell (Ci)	C Cell (Ci)	D Cell (Ci)	E Cell (exclude skip) (Ci)	E Cell Skip (Ci)	H Cell (Ci)	J Cell (35A) (Ci)	J Cell (Ci)	L Cell (Ci)	Deep Bed Filters (Ci)	White Room (Ci)	N Cell (Ci)	PR Room (Ci)
Cs-137	1.14E+03	1.14E+03	1.14E+03	1.92E+03	1.28E+03	0.00E+00	6.41E+02	0.00E+00	0.00E+00	0.00E+00	6.41E+02	0.00E+00	0.00E+00	0.00E+00
Sr-90	9.11E+02	9.11E+02	9.11E+02	1.54E+03	1.05E+03	0.00E+00	5.12E+02	0.00E+00	0.00E+00	0.00E+00	5.12E+02	0.00E+00	0.00E+00	0.00E+00
Pu-238	8.00E+00	8.00E+00	8.00E+00	1.30E+01	9.00E+00	5.00E+00	4.00E+00	1.00E+00	2.00E+00	5.00E+01	4.00E+00	5.00E+00	2.10E+01	1.50E+01
Pu-239	3.70E+01	3.70E+01	3.70E+01	6.40E+01	4.30E+01	2.50E+01	2.10E+01	5.00E+00	1.10E+01	2.40E+02	2.10E+01	2.70E+01	1.00E+02	7.50E+01
Pu-240	2.10E+01	2.10E+01	2.10E+01	3.70E+01	2.40E+01	1.40E+01	1.20E+01	3.00E+00	6.00E+00	1.40E+02	1.20E+01	1.50E+01	5.90E+01	4.30E+01
Pu-241	1.67E+02	1.67E+02	1.67E+02	2.90E+02	1.92E+02	1.13E+02	9.80E+01	2.40E+01	4.80E+01	1.08E+03	9.80E+01	1.18E+02	4.57E+02	3.34E+02
Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Am-241	6.10E+01	6.10E+01	6.10E+01	1.02E+02	7.10E+01	4.10E+01	3.50E+01	9.00E+00	1.70E+01	3.99E+02	3.50E+01	4.40E+01	1.64E+02	1.23E+02

Source: Table C-6 in CP-14977, *Plutonium Uranium Extraction Facility Documented Safety Analysis.*

Note: Activities decayed to January 2018.

Table 2. Source-Term Soil Concentration for 202A Canyon Areas

Radionuclide	Canyon Areas												
	A Cell (Ci)	B Cell (Ci)	C Cell (Ci)	D Cell (Ci)	E Cell (exclude skip) (Ci)	E Cell Skip (Ci)	H Cell (Ci)	J Cell (35A) (Ci)	J Cell (Ci)	L Cell (Ci)	Total Activity (Ci)	Amount of Soil* (g)	Source Concentration (pCi/g)
Cs-137	1.14E+03	1.14E+03	1.14E+03	1.92E+03	1.28E+03	0.00E+00	6.41E+02	0.00E+00	0.00E+00	0.00E+00	7.26E+03	1.84E+09	3.95E+06
Sr-90	9.11E+02	9.11E+02	9.11E+02	1.54E+03	1.05E+03	0.00E+00	5.12E+02	0.00E+00	0.00E+00	0.00E+00	5.84E+03		3.18E+06
Pu-238	8.00E+00	8.00E+00	8.00E+00	1.30E+01	9.00E+00	5.00E+00	4.00E+00	1.00E+00	2.00E+00	5.00E+01	1.08E+02		5.88E+04
Pu-239	3.70E+01	3.70E+01	3.70E+01	6.40E+01	4.30E+01	2.50E+01	2.10E+01	5.00E+00	1.10E+01	2.40E+02	5.20E+02		2.83E+05
Pu-240	2.10E+01	2.10E+01	2.10E+01	3.70E+01	2.40E+01	1.40E+01	1.20E+01	3.00E+00	6.00E+00	1.40E+02	2.99E+02		1.63E+05
Pu-241	1.67E+02	1.67E+02	1.67E+02	2.90E+02	1.92E+02	1.13E+02	9.80E+01	2.40E+01	4.80E+01	1.08E+03	2.35E+03		1.28E+06
Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00
Am-241	6.10E+01	6.10E+01	6.10E+01	1.02E+02	7.10E+01	4.10E+01	3.50E+01	9.00E+00	1.70E+01	3.99E+02	8.57E+02		4.67E+05

*Amount of soil (g) is based on building dimensions (247.8 m [813 ft] length by 4.26 m [14 ft] width by 12 m [39.5 ft] height by 0.15 m (0.5 ft) thickness of contamination) and soil density of 1.5 g/cm^3.

The process cells have an overall length of 247.8 m (813 ft), each cell is 4.26 m (14 ft) wide, and 12 m (39.5 ft) in height. For simplicity in calculating the overall volume, only the exterior walls are included in the volume calculation. For estimating preliminary outdoor worker risk, the thickness of contamination is assumed to be 0.15 m (0.5 ft) deep and uniformly mixed in soil[2] with a soil bulk density of 1.5 g/cm^3.

3.1.2 Determination of PRGs for Radionuclides

PRGs for radionuclides based on outdoor worker scenario were utilized in the preliminary risk calculations and were based on the RESRAD model. ECF-HANFORD-16-0133, *Calculation of Soil Radiological Preliminary Remedial Goals for the Outdoor Worker Scenario* presents radiological soil PRGs for an outdoor worker exposure scenario with a target cancer risk of 1×10^{-4} for use in the remedial investigation/feasibility study reports for the Inner Area Source OUs located within the Central Plateau of the Hanford Site. The RESRAD computer code Version 7.0 (ANL, 2014) was used to calculate the soil PRGs for radiological contaminants based on the outdoor worker exposure scenario. The outdoor worker PRGs and their underlying SFs are presented in Tables 3 and 4.

Table 3. Outdoor Worker PRGs for Radionuclides based on RESRAD Model

Radionuclide	PRG (pCi/g) (RESRAD Model)
Cs-137	1.08E+01
Sr-90	1.19E+03
Pu-238	3.44E+03
Pu-239	2.97E+03
Pu-240	2.97E+03
Pu-241	2.03E+04
Pu-242	--
Am-241	6.13E+02

PRG = preliminary remediation goal
RESRAD = RESidual RADioactivty

Table 4. Slope Factors used to Calculate Inhalation, Soil Ingestion, and External Exposure ELCRs for the Outdoor Worker Scenario

Radionuclide	Slope Factors for External Gamma (g/pCi-year)	Slope Factors for Inhalation (Based on Absorption Type) (per pCi)	Recommended Lung Absorption Type	Slope Factors for Ingestion (per pCi)
Cs-137	0.00000254	1.19E-11	F	3.18E-11
Sr-90	1.95E-08	1.05E-10	M	5.88E-11
Pu-238	6.92E-11	3.36E-08	M	1.17E-10

[2] Inventory is likely a coating on the cement inside the process cells. A depth of 0.3 m (1 ft) is used to estimate this assumption.

Table 4. Slope Factors used to Calculate Inhalation, Soil Ingestion, and External Exposure ELCRs for the Outdoor Worker Scenario

Radionuclide	Slope Factors for External Gamma (g/pCi-year)	Slope Factors for Inhalation (Based on Absorption Type) (per pCi)	Recommended Lung Absorption Type	Slope Factors for Ingestion (per pCi)
Pu-239	2.09E-10	5.55E-08	M	1.21E-10
Pu-240	7.13E-11	3.33E-08	M	1.21E-10
Pu-241	4.07E-12	3.33E-10	M	1.73E-12
Pu-242	4.36E-10	3.13E-08	M	1.15E-10
Am-241	2.77E-08	2.81E-08	M	9.1E-11

ELCR = excess lifetime cancer risk
F = fast
M = moderate

3.1.2.1 CDI Calculation for Soil Inhalation

The CDI for soil inhalation was calculated using the source concentration or the estimate of the total remaining radioactive material within the area of interest (as described in Section 3.1.1) and EPA default parameters for soil inhalation rate, exposure frequency, and exposure duration of an outdoor worker. In addition, the Hanford Site-specific particulate emission factor (PEF) was used (Chapter 4 provides details on the PEF value).

$$CDI\,(pCi) = \frac{Conc\,\left(\frac{pCi}{g}\right) \times IR_{Inh}\,\left(\frac{m3}{day}\right) \times EF_{ow}\left(\frac{days}{yr}\right) \times ED_{ow}\,(yrs) \times TF_{ow}\,(unitless) \times CF(1000\,\frac{g}{kg})}{PEF\,(\frac{m3}{kg})}$$

where:

Conc = source concentration of radionuclide and area of interest

IR_{Inh} = inhalation rate of outdoor worker (60 m^3/d)

EF_{ow} = exposure frequency of outdoor worker (225 d/yr)

ED_{ow} = exposure duration of outdoor worker (25 yr)

TF_{ow} = outdoor time fraction (= 8 hr/24 hr = 0.33)

PEF = soil particulate emission factor (73,000,000,000 m^3/kg)

CF = conversion factor (kg to g).

3.1.2.2 CDI Calculation for Soil External Gamma Exposure

The CDI for external gamma exposure was calculated using the source concentration or the estimate of the total remaining radioactive material within the area of interest (as described in Section 3.1.1) and EPA default parameters for exposure frequency and exposure duration of an outdoor worker.

$$CDI\ (pCi-year/g) = Conc\left(\frac{pCi}{g}\right) \times ED_{ow}\ (yrs) \times Outdoor\_Time\_Fraction \times GSF$$

where:

Conc	=	source concentration of radionuclide and area of interest
ED_{ow}	=	exposure duration of outdoor worker (25 yr)
Outdoor Time Fraction	=	0.21 [(225 d/yr*8 hr/d)/(24 hr/d*365 d/yr)]
GSF	=	gamma shielding factor (1 for outdoor exposure).

3.1.3 Slope Factors

Morbidity risk coefficients, or SFs, for soil ingestion, inhalation, and external exposure to radionuclides were used to calculate ELCRs (Table 4). The values are consistent with those published in Tables 2.4, 2.5, and 2.6 in ORNL/TM-2013-00, *Calculation of Slope Factors and Dose Coefficients*. For each radionuclide listed, SFs correspond to the risks per unit intake or exposure for that radionuclide only, except when marked with a "+D" to indicate that the risks from associated short-lived radioactive daughter products (i.e., those daughter products with radioactive half-lives less than or equal to 6 months) are also included. The intention of this designation is to make realistic risk estimates by including the contributions from their short-lived daughter products, assuming equal activity concentrations (i.e., secular equilibrium) with the principal or parent nuclide in the environment.

4 Assumptions and Inputs

Under current conditions, entry to 202A is under health and safety controls (e g., access limitations, shielding, and exposure monitoring) resulting in an incomplete exposure pathway to the current outdoor worker. Similarly, access controls, fenced areas, lack of vegetation, and ongoing surveillance and monitoring programs restrict or prevent access by ecological receptors. Future exposure of an outdoor worker also is based on key assumptions: a complete loss of all health and safety controls, complete unfettered access to all areas of the facility (both accessible and inaccessible), and outdoor workers having no knowledge of the facility's history.

The following assumptions underlie the RESRAD code for PRG calculations, and the linear low-dose and one-hit high risk equations used for calculating cancer risk for an outdoor worker exposure scenario:

- The reasonably anticipated future land use is industrial.
- Drinking water will be obtained from an offsite source and water beneath the Central Plateau will not be used for irrigation purposes.
- An outdoor worker is potentially exposed for a 25-year duration.
- The potentially complete exposure routes considered are incidental soil ingestion, inhalation of dust, and direct (external gamma) exposure.
- Parameter values used to estimate inhalation rates and incidental ingestion of soil are consistent with the values used for the outdoor worker scenario and are 60 m^3/d and 0.1 g/d, respectively.

- The fraction of time spent inside the Canyon[3] is 0.21 (based on 8 hr/d × 1 d/24 h × 225 days/year × 1 yr/365 d).

The RESRAD model also assumes the following:

- Direct exposure of an outdoor worker to radionuclides in soil to a depth of 4.6 m (15 ft) may occur. For this ECF, it is assumed that the outdoor worker is inside the canyon and all portions of the process cells are accessible.

The linear low-dose and one-hit high risk equations also assume the following:

- The soil PEF is 7.3×10^{10} m^3/kg. The methodology and calculation of the Hanford Site-specific PEF is documented in ECF-HANFORD-11-0033, *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study*.

5 Software Applications

5.1 Approved Software

All supporting calculations are performed on electronic spreadsheets using Microsoft® Excel®.

6 Calculation

The following section presents information about the file associated with the original risk estimates and data evaluation. Both calculations were verified independently by utilizing the methodology, assumptions, and inputs described in Chapters 3 and 4.

6.1 Original Risk Estimate

The ELCR calculations were performed with electronic spreadsheets using the methodology described in Chapter 3 and the assumptions and inputs identified in Chapter 4. Results of the calculations are presented in Chapter 7.

6.2 Calculation Review and Quality Check

A quality control review was performed independently to verify the results of the original calculations. As a part of the quality control review, ELCR calculations were performed by using the methodologies presented in Chapter 3 for each area. The results of the risk calculations were compared against independently calculated ELCRs to ensure the formulas used during the calculations of risk for each area were not corrupted and correct formulas were used. The results of the review did not identify any error associated with the formulae used during the calculation of cancer risks.

[3] As discussed in Section 2.2.1, the overall height of the process cells is 12 m (39.5 ft) with 9.1 (30 ft) of the process cells below ground surface.

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7 Results/Conclusions

Table 5 presents the results of preliminary human health risk estimates for the Canyon area. The preliminary radionuclide ELCR estimates using the outdoor worker scenario PRGs were calculated based on the RESRAD model, the linear low-dose cancer risk equation, and the one-hit equation for high carcinogenic risk levels. The ELCRs for each radionuclide are compared to the acceptable target risk range of 1×10^{-4}.

The preliminary risk estimates for the Canyon area are substantially greater than the acceptable target risk threshold of 1 in 10,000 (1×10^{-4}). The magnitude of the preliminary total outdoor worker cancer risks estimated for 202A in this ECF support evaluating remedial alternatives in the feasibility study[4] and illustrates that additional analytical data will not result in meaningful refinements of human health (or ecological) risk estimates for the Canyon complex.

Table 5. Preliminary Risk Estimates for Canyon Area

Radionuclides	Source Concentration (pCi/g)	Outdoor Worker PRG (pCi/g) based on Target Risk of 10^{-4}	ELCR Outdoor Worker		
		RESRAD	RESRAD	Linear Low-Dose Risk	One-Hit High Risk
Cs-137	3.95E+06	1.08E+01	>1.00E-02	>1.00E-02	>1.00E-02
Sr-90	3.18E+06	1.19E+03	>1.00E-02	>1.00E-02	>1.00E-02
Pu-238	5.88E+04	3.44E+03	1.71E-03	3.89E-03	3.89E-03
Pu-239	2.83E+05	2.97E+03	9.53E-03	>1.00E-02	>1.00E-02
Pu-240	1.63E+05	2.97E+03	5.48E-03	>1.00E-02	>1.00E-02
Pu-241	1.28E+06	2.03E+04	6.29E-03	1.27E-03	1.27E-03
Pu-242	0.00E+00	--	--	0.00E+00	0.00E+00
Am-241	4.67E+05	6.13E+02	>1.00E-02	>1.00E-02	>1.00E-02
		Cumulative ELCR	>1.00E-02	>1.00E-02	>1.00E-02

ELCR = excess lifetime cancer risk
PRG = preliminary remediation goal
RESRAD = RESidual RADioactivity

8 References

ANL, 2014, RESRAD for Windows, Version 7.0, Argonne National Laboratory, Environmental Assessment Division, Argonne, Illinois.

CP-14977, 2019, *Plutonium Uranium Extraction Facility Documented Safety Analysis*, Rev. 11, CH2M HILL Plateau Remediation Company, Richland, Washington.

[4] The preliminary human health total cancer risk estimates are significantly higher than the acceptable target cancer risk level of 10^{-4}. Accordingly, remedial alternatives identified to protect outdoor workers will also be protective of ecological receptors.

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