DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC (WRPS)
Contractor For U.S. Department of Energy, Office of River Protection

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Potential Groundwater Impacts and Inadvertent Intruder Doses from Tank 241-AX-103 Using Post-Retrieval Inventories

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RPP-ENV-58813	01	Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington
RPP-RPT-58693	00	Engineered System Data Package for Waste Management Area A-AX
RPP-RPT-60885	01	Model Package Report System Model for the WMA A-AX Performance Assessment
RPP-RPT-63817	00	Laser Scanning Waste Volume Estimate for Tank 241-AX-103
RPP-RPT-63929	00	Practicability Evaluation Request Forego a Third Retrieval Technology for Tank 241-AX-103
RPP-RPT-64056	00	Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment

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Watson, David (Dj) J	CLOSURE & INTERIM MEASURES

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APPROVED
By Sarah Harrison at 12:57 pm, Sep 11, 2023

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RPP-CALC-65649
Revision 0

Potential Groundwater Impacts and Inadvertent Intruder Doses from Tank 241-AX-103 Residuals Using Post-Retrieval Inventories

Prepared by:

D. J. Watson
Washington River Protection Solutions, LLC

Date Published
June 2022

Prepared for the U.S. Department of Energy
Office of River Protection

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ENVIRONMENTAL MODEL CALCULATION COVER PAGE

SECTION 1 - COMPLETED BY RESPONSIBLE MANGER DESIGNEE

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Project:
A and AX farm Retrieval

Date: 6/15/2023

Calculation Title and Description:
Potential Groundwater Impacts and Inadvertent Intruder Doses from Tank 241-AX-103 Using Post-Retrieval Inventories

SECTION 2 - COMPLETED BY PREPARER

Calculation Number: RPP-CALC-65649 **Revision Number:** 0

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Revision Number	Description	Date	Affected Pages
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3. Does document contain controlled-use information? ☐ Yes ☒ No

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EXECUTIVE SUMMARY

Single-shell tank 241-AX-103 has undergone waste retrieval under the terms of the Consent Decree in *State of Washington v. Dept. of Energy*, Case No. 2:08-cv-05085-FVS (E.D. WA October 25, 2010)[1]. Tank 241-AX-103 has been retrieved to the limits of technology using two retrieval technologies established in the Tank Waste Retrieval Work Plan (RPP-RPT-58934, *241-AX-103 Tank Waste Retrieval Work Plan*), approved by the Washington State Department of Ecology. A residual volume of 785 ft^3 (~5,875 gal) was obtained using modified sluicing and high-pressure water technologies deployed by Extended Reach Sluicing Systems. The residual volume consists of 687 ft^3 (5,139 gal) on the tank bottom based on laser scan measurements and 98 ft^3 (736 gal) on walls, rings and equipment based on estimated waste thicknesses from video observations (RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*).

Radiological doses, cancer risks, and non-cancer hazards to a receptor using groundwater at the Waste Management Area A-AX fenceline under the U.S. Environmental Protection Agency's residential tap water scenario were calculated using the Waste Management Area A-AX GoldSim®[2] model. Potential doses to an inadvertent intruder into residual waste in tank 241-AX-103 under the acute Well Driller and chronic Suburban Garden, Rural Pasture and Commercial Farm scenarios were also calculated using the same model. Two different waste inventories were considered: An average inventory estimate and a 95% upper confidence limit inventory (RPP-RPT-64056). The following conclusions are based on the results from these model runs.

- Estimated groundwater concentrations at the Waste Management Area A-AX fenceline for the selected radiological analytes (^{99}Tc, ^{126}Sn, and ^{129}I) indicate that the impacts from residual waste left in tank 241-AX-103 are 2 to 3 orders of magnitude below the Federal maximum contaminant levels. The beta/photon dose rate equivalents from these radionuclides are 2 to 3 orders of magnitude below the 4 millirem/year (mrem/yr) groundwater regulatory standard. The peak total beta/photon dose rate equivalent is 2 orders of magnitude below the regulatory standard, even when using upper-bound inventories with non-detects at one-half the detection limit. The peak total groundwater pathway dose rate to an all-pathways representative person using the average inventory without non-detects is over 3 orders of magnitude lower than the regulatory standard of 25 mrem/yr. The primary contributors to this dose rate are ^{99}Tc, ^{129}I and ^{126}Sn. When using the upper-bound inventories with non-detects evaluated at half the detection limit, the groundwater pathway dose rate is still 3 orders of magnitude below the regulatory standard. With these inventories, ^{79}Se becomes a greater contributor to total dose rate than ^{126}Sn.

[1] The "Consent Decree" collectively refers to the Consent Decree in Case No. 2:08-cv-05085-FVS (October 25, 2010), the Amended Consent Decree, Case No. 2:08-cv-05085-RMP (March 11, 2016), the Second Amended Consent Decree, Case No. 2:08-cv-05085-RMP (April 12, 2016), the Third Amended Consent Decree, Case No. 2:08-cv-05085-RMP (October 12, 2018), the Fourth Amended Consent Decree, Case No. 2:08-cv-05085-RMP (December 10, 2020) and the Fifth Amended Consent Decree, Case No. 2:08-cv-05085-RMP (July 18, 2022).

[2] GoldSim® simulation software is a registered trademark of GoldSim Technology Group LLC of Seattle, Washington (see http://www.goldsim.com).

- The groundwater concentration for hexavalent chromium is 5 orders of magnitude below the Washington State *Model Toxics Control Act* (*Revised Code of Washington* 70A.305, "Hazardous Waste Cleanup—Model Toxics Control Act") Method B cleanup level and 4 orders of magnitude below the WAC 173-201A-240, "Toxic Substances," ambient water quality criteria. The hazard quotient for hexavalent chromium is 5 orders of magnitude below the regulatory standard of 1 and the peak cancer risk at the fenceline is about 50 times below the regulatory standard of 1×10^{-6}.

- Trivalent chromium's peak fenceline groundwater concentration results in a hazard quotient that is more than 8 orders of magnitude below the regulatory standard of 1.0.

- The groundwater concentration for nitrate is over 4 orders of magnitude below the Federal maximum contaminant level and 5 orders of magnitude below the Washington State *Model Toxics Control Act* Method B cleanup levels. The groundwater concentration for nitrite is about 4 orders of magnitude below the Federal maximum contaminant level and the Washington State *Model Toxics Control Act* Method B cleanup limit. Additionally, the hazard quotient for nitrate is 5 orders of magnitude below the regulatory standard of 1.0, and about 4 orders of magnitude below for nitrite.

- The peak fenceline groundwater concentration for fluoride is 4 orders of magnitude below the Federal maximum contaminant level and 3 orders of magnitude below the Washington State *Model Toxics Control Act* Method B cleanup limit. Additionally, the hazard quotient of fluoride is 3 orders of magnitude below the regulatory standard of 1.0.

- The peak fenceline groundwater concentration for cyanide is 5 orders of magnitude below the Federal maximum contaminant level and 3 orders of magnitude below the Washington State *Model Toxics Control Act* Method B cleanup limit. Additionally, the hazard quotient of cyanide is about 3 orders of magnitude below the regulatory standard of 1.0.

- A maximum exposure dose of 4.5 mrem from an acute Well Driller inadvertent intrusion scenario is estimated at 500 years post-closure, using average residual inventories with non-detect values set to zero. Using the 95% upper confidence limit inventories with non-detect values set to zero results in a maximum dose of 7.3 mrem in the acute Well Driller inadvertent intrusion scenario. Both of these doses are well below the 500 mrem regulatory standard for acute exposure. If non-detect values are evaluated at one-half the detection limit in both the average and upper-bound inventories, the resulting doses are still below the regulatory standard at the time of peak exposure.

- The maximum chronic exposure dose rate of 1.1 mrem/yr from a Suburban Garden inadvertent intrusion scenario is estimated at 500 years post-closure, using average residual inventories with non-detect values set to zero. Using the 95% upper confidence limit inventories with non-detect values set to zero results in a maximum dose rate of 1.8 mrem/yr. Both of these dose rates are well below the regulatory standard for chronic exposure of 100 mrem/yr. If non-detect values are evaluated at one-half the detection limit in both the average and upper-bound inventories, the resulting dose rates are still below the regulatory standard at the time of peak exposure.

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LIST OF TERMS, ACRONYMS, AND ABBREVIATIONS

AERMIC	American Meteorological Society/U.S. Environmental Protection Agency Regulatory Model Improvement Committee
AMS	American Meteorological Society
BBI	Best-Basis Inventory
CFR	*Code of Federal Regulations*
COPC	constituent of potential concern
CLARC	Cleanup Levels and Risk Calculation
DCAL	Dose and Risk Calculation
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EMCF	Environmental Model Calculation File
EMMA	Environmental Model Management Archive
EPA	U.S. Environmental Protection Agency
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HI	Hazard Index
HQ	Hazard Quotient
ICRP	International Commission for Radiation Protection
IMBA	Integrated Modules for Bioassay Assessment
K_d	distribution coefficient
MCL	maximum contaminant level
MTCA	*Model Toxics Control Act*
PA	Performance Assessment
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzofuran
POC	point of calculation
PUREX	Plutonium Uranium Extraction (Plant)
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	*Revised Code of Washington*
RESRAD	RESidual RADioactive
RfDo	oral reference dose
RT	Radionuclide Transport (Module)
SST	Single-Shell Tank
STOMP	Subsurface Transport Over Multiple Phases
TWRWP	Tank Waste Retrieval Work Plan
UCL	Upper Confidence Level
WAC	*Washington Administrative Code*
WMA	Waste Management Area
WMCL	Washington State Maximum Contaminant Level
WRPS	Washington River Protection Solutions, LLC

1.0 PURPOSE

The purpose of this environmental model calculation file (EMCF) is to document the analysis of hazardous chemical and dangerous waste constituent impacts from tank waste residuals left in tank 241-AX-103 (AX-103) and the dose impacts to a hypothetical inadvertent intruder into tank AX-103 tank waste residuals. This document supports the development of a Retrieval Data Document for tank AX-103, which is required by the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) Milestone M-045-86M (Ecology et al., 1989).

1.1 OBJECTIVE

The objective of the modeling described in this EMCF is to estimate the risk and hazard impacts from tank AX-103 residuals and to evaluate the dose from exposure in hypothetical scenarios of inadvertent intrusion into tank AX-103 residuals. The groundwater impact metrics are cancer risk and non-cancer health effects to a receptor at the Waste Management Area (WMA) fenceline. To evaluate non-cancer hazards, chemical concentrations in groundwater at the WMA A-AX fenceline are compared to the Federal and State drinking water limits, as well as the Washington State *Model Toxics Control Act* (MTCA) (*Revised Code of Washington* 70A.305, "Hazardous Waste Cleanup—Model Toxics Control Act") Method A or B groundwater cleanup levels from the Washington State Department of Ecology (Ecology) (Cleanup Levels and Risk Calculation [CLARC], Queried 05/08/2023, [CLARC data tables and other technical information], https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables), which are based on equations and exposure assumptions presented in MTCA *Washington Administrative Code* (WAC) 173-340-720, "Groundwater Cleanup Standards." The inadvertent intruder metrics are the dose or dose rate to the intruder from intrusion.

These calculations are performed using a system model of WMA A-AX, implemented using GoldSim®[3] software (GoldSim Contaminant Transport Module User's Guide [GoldSim Technology Group 2017a]; GoldSim Probabilistic Simulation Environment User's Guide [GoldSim Technology Group 2017b]).

1.2 SUPPORTING DOCUMENTS

The calculations described in this EMCF use conceptual models and mathematical models that are appropriate for the intended use as documented in a series of data package reports, model package reports, other environmental calculation reports, and/or other technical literature.

1.2.1 Data Package Reports

Data package reports have been developed to provide a technical basis for the environmental model used in these EMCF calculations. Data package reports supporting these calculations

[3] GoldSim® simulation software is a registered trademark of GoldSim Technology Group LLC of Seattle, Washington (see http://www.goldsim.com).

provide the basis for the mathematical model selection, key assumptions, and model parameterization.

The data package reports that support this calculation are:

RPP-ENV-58813, Rev. 1	*Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*
RPP-RPT-58693, Rev. 0	*Engineered System Data Package for Waste Management Area A-AX*.

1.2.2 Model Package Reports

Model package reports describe the conceptual and mathematical models used in the calculation. The model package report supporting this calculation supports model implementation and is:

RPP-RPT-60885, Rev. 1	*Model Package Report System Model for the WMA A-AX Performance Assessment*.

1.2.3 Other Environmental Model Calculation Files

The EMCFs supporting this calculation support parameterization and are:

RPP-CALC-61254, Rev. 3	*Inadvertent Intruder Dose Calculation Update for the Integrated Disposal Facility Performance Assessment* (provides multiplication factors for dose conversion factors to correct for the effects of short-lived progeny at the time of consumption [RPP-RPT-60885])
RPP-RPT-63634, Rev. 0	*Model Package Report System Model for Tank Farms Inadvertent Intruder Scenarios* (describes equations for inadvertent intruder scenarios).

1.2.4 Other Technical Reports

RPP-ENV-58806, Rev. 1A	*Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area C at the Hanford Site, Southeast Washington*
DOE/RL-2016-67, Rev. 0	*Hanford Site Groundwater Monitoring Report for 2016* (provides site-specific depth to groundwater)
RPP-RPT-63817, Rev. 0	*Laser Scanning Waste Volume Estimate for Tank 241-AX-103*

RPP-RPT-64056, Rev. 0	*Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*
RPP-RPT-63929, Rev. 0	*Practicability Evaluation Request to Forego a Third Retrieval Technology for Tank 241-AX-103*.

1.3 DOCUMENT STRUCTURE

The structure of this EMCF follows the required structure of an EMCF:

- Section 2.0 provides supplemental background information for these calculations
- Section 3.0 describes calculation methodology
- Section 4.0 describes the key assumptions and inputs
- Section 5.0 describes the computational software used in these calculations
- Section 6.0 describes the output(s) from the environmental model
- Section 7.0 provides the calculation results and conclusions
- Section 8.0 is a list of references cited in this calculation report.

Attachment 1 contains the software installation and checkout forms for the GoldSim® simulation software.

Attachment 2 contains the tank residual inventories and volumes used in the model for the risk and hazard impact calculations.

Attachment 3 contains the parameter inputs used for the residential tap water scenario evaluated in this document.

Attachment 4 contains contaminant-specific inputs used for each of the exposure pathways of the residential tap water scenario evaluated in this document.

Attachment 5 contains the parameter inputs used for the all-pathways representative person scenario.

Attachment 6 contains the parameter inputs used for the inadvertent intruder scenarios evaluated in this document.

Attachment 7 contains the dose conversion factors used in the model for the inadvertent intruder calculations.

Attachment 8 contains the bioconcentration factors used in the model for the inadvertent intruder calculations.

Attachment 9 contains the radionuclide-specific shielding factors used in the model for the inadvertent intruder calculations.

Attachment 10 contains derived concentrations of beta and photon emitters in drinking water yielding a dose of 4 millirem/year (mrem/yr) to the total body or to any critical organ in the WMA A-AX system model.

Attachment 11 contains the inventory screening analysis.

Attachment 12 contains the checking information.

2.0 BACKGROUND

Details of the development of the system model used in the calculations described in this EMCF are provided in RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*. RPP-RPT-63634, *Model Package Report System Model for Tank Farms Inadvertent Intruder Scenarios* corrects errors in the inadvertent intruder section of RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, and therefore correctly describes the inadvertent intruder scenarios.

2.1 HISTORY

WMA A-AX comprises the 241-A and 241-AX Tank Farms and is located within the 200 East Area of the Central Plateau of the Hanford Site. The 241-A Tank Farm (A Farm) and 241-AX Tank Farm (AX Farm) were constructed between 1953 and 1955 and between 1963 and 1965, respectively. The WMA A-AX tank farms are surrounded by several other double-shell tank farms within the A Complex,[4] and single-shell tank (SST) Farm 241-C (C Farm) is located nearby to the northwest (Figure 2-1). WMA A-AX includes catch tanks, diversion boxes, valve pits, pipelines, French drains, and unplanned release sites. Numerous liquid discharge facilities used at various times (cribs, trenches, ditches, septic systems, etc.) surround the WMA.

The tanks in both A Farm and AX Farm were designed for the storage of boiling waste generated from irradiated fuel reprocessing at the 202-A Plutonium Uranium Extraction (PUREX) Plant. A Farm contains six 75-ft diameter nominally 1,000,000-gal capacity SSTs that consist of a carbon steel liner inside a concrete tank. AX Farm contains four such SSTs of a later design. A Farm and AX Farm were placed in service in 1955 and 1965, respectively, and both were used to store and transfer waste until mid-1980.

The waste in tank AX-103 was retrieved as described in the Tank Waste Retrieval Work Plan (TWRWP; RPP-RPT-58934, *241-AX-103 Tank Waste Retrieval Work Plan*) that was approved in accordance with Section IV-B of the Consent Decree in *State of Washington v. Dept. of Energy*, Case No. 2:08-cv-05085-FVS (E.D. WA October 25, 2010) (hereinafter, "Consent Decree"[5]). The U.S. Department of Energy (DOE) will assert that the retrieval technologies selected in the above-referenced TWRWP have reached their limits of technology, in compliance with the Consent Decree Section IV.B.5 requirements. The Consent Decree defines "limits of technology" as follows:

> *The "limits of technology" means that the recovery rate of that retrieval technology for that tank is, or has become, limited to such an extent that it extends*

[4] The A Complex consists of Tank Farms 241-A, 241-AN, 241-AP, 241-AW, 241-AX, 241-AY, and 241-AZ.

[5] The "Consent Decree" collectively refers to the Consent Decree in Case No. 2:08-cv-05085-FVS (October 25, 2010); the Amended Consent Decree, Case No. 2:08-cv-05085-RMP (March 11, 2016); the Second Amended Consent Decree, Case No. 2:08-cv-05085-RMP (April 12, 2016); and the Third Amended Consent Decree, Case No. 2:08-cv-05085-RMP (October 12, 2018), the Fourth Amended Consent Decree, Case No. 2:08-cv-05085-RMP (December 10, 2020), and the Fifth Amended Consent Decree, Case No. 2:08-cv-05085-RMP (July 18, 2022).

> *the retrieval duration to the point at which continued operation of the retrieval technology is not practicable, with the consideration of practicability to include matters such as risk reduction, facilitating tank closures, costs, the potential for exacerbating leaks, worker safety, and the overall impact on the tank waste retrieval and treatment mission.*

Appendix C, Part 1 of the Consent Decree states that:

> *If the waste residual goal of 360 cubic feet is not achieved using the established two technologies, an additional retrieval technology established in a revised TWRWP shall be deployed to the "limits of technology;" provided that DOE may request that the State agree that DOE may forego implementing a third retrieval technology if DOE believes implementing such technology is not practicable under the criteria set forth above.*

Using the retrieval technologies established in the above-mentioned TWRWP (RPP-RPT-58934), DOE has retrieved tank AX-103 to a residual volume of 5,875 gal (785 ft^3) (RPP-RPT-63817, *Laser Scanning Waste Volume Estimate for Tank 241-AX-103*).

Figure 2-2 illustrates the closure concept for WMA A-AX following tank waste retrieval. Surface facilities will be removed, and retrieved SSTs and accessible ancillary equipment with significant void spaces will be filled with grout. Waste transfer pipelines are also expected to be left in place. An engineered surface cover system will be placed over the tank farm and groundwater underneath the covered area will be monitored using existing wells.

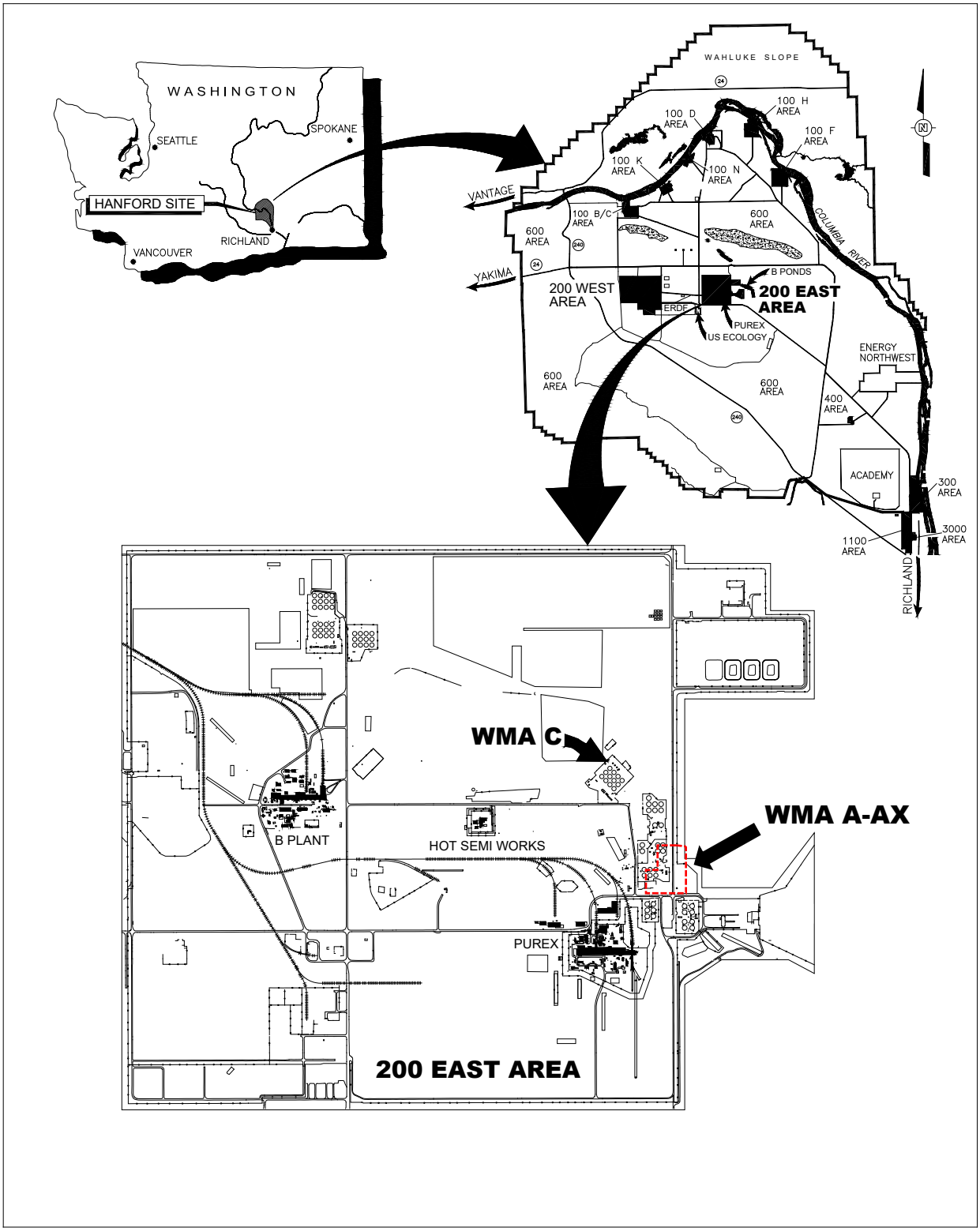
A Farm and AX Farm closure plans call for retrieval of wastes remaining in the SSTs (mostly sludge and saltcake solids) to the maximum extent practicable, grouting the residual wastes and interior volume of the SSTs, and constructing a surface barrier over the tank farms. This analysis uses numerical models to evaluate the potential risk and hazard impacts from hazardous chemical and dangerous waste constituent impacts from tank waste residuals left in tank AX-103.

2.2 JUSTIFICATION OF METHODOLOGY

2.2.1 Groundwater Impacts

The establishment of the groundwater pathway system model is described in RPP-RPT-60885. This work builds on the model developed for the WMA A-AX performance assessment (PA) (RPP-ENV-61497, *Preliminary Performance Assessment of Waste Management Area A-AX, Hanford Site, Washington*), the justification for which has been established in the EMCFs written to support that effort.

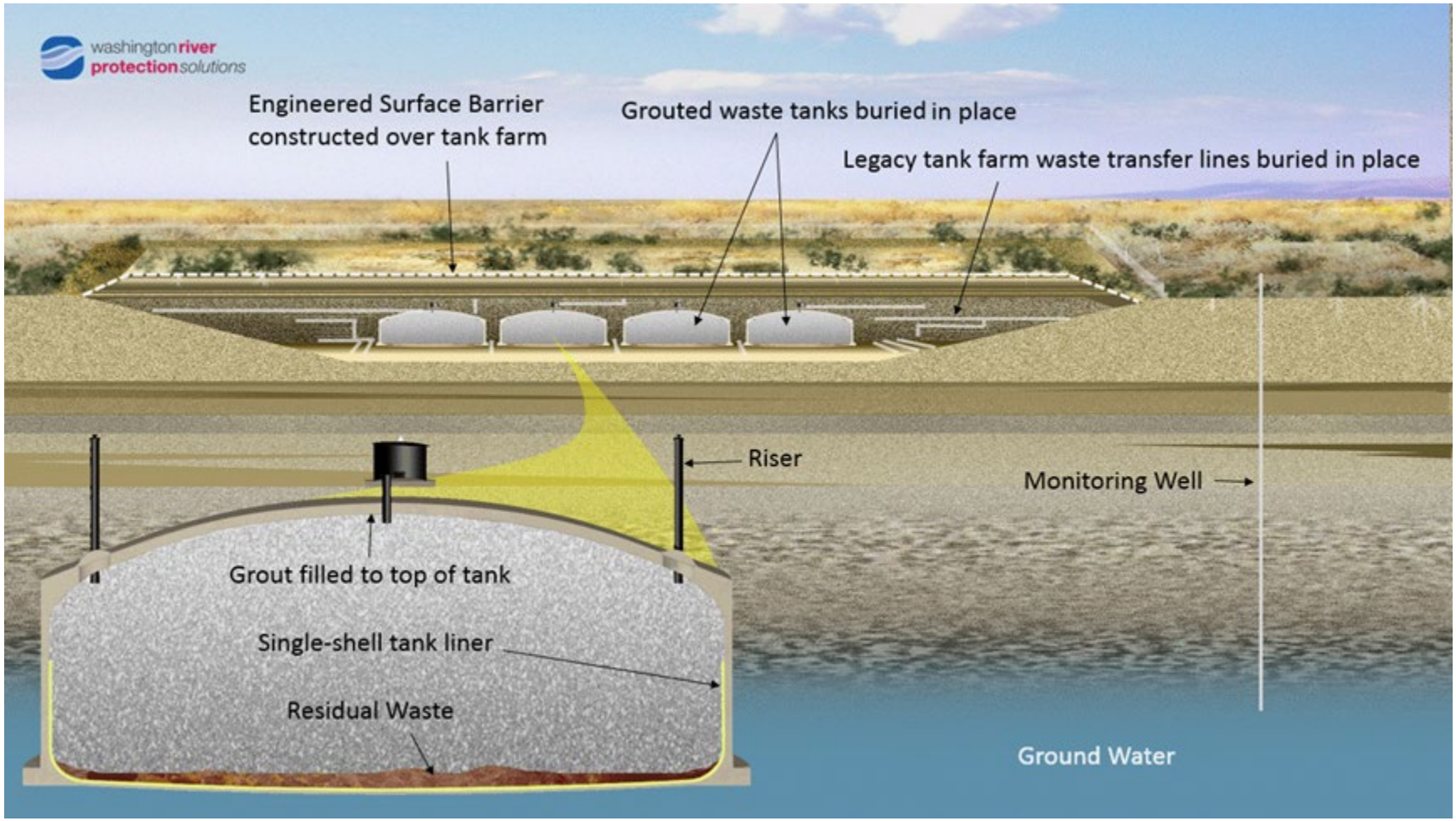
Figure 2-1. Location of Waste Management Area A-AX in Relation to Hanford Site.



H:\CHG\241-C TF\2E-WMA-C1A

PUREX = Plutonium Uranium Extraction (Plant) WMA = Waste Management Area

Figure 2-2. Conceptual Model of Closure of Waste Management Area A-AX.



The system model used in this EMCF evaluates releases from residual wastes left in tank AX-103 after closure. Evaluation of the released constituents of potential concern (COPCs) in the vadose zone depends on the inventory, tank structure, transport of the contaminants through the vadose zone, and transport in the saturated zone to the point of calculation (POC) directly below the WMA fenceline. Fenceline concentrations are used for subsequent estimation of concentrations of COPCs and related cancer risks and non-cancer hazards to humans from the potential use of the contaminated water at the POC. The system model was developed by abstracting process modeling results and capturing key features, events, and processes related to key safety functions, while maintaining computational efficiency.

The results obtained from the system model related to the groundwater pathway include COPC concentrations in the saturated zone directly below the WMA fenceline from which both cancer risks from chemicals and non-cancer hazards can be calculated using the U.S. Environmental Protection Agency (EPA)'s residential tap water scenario. These concentrations are also used to demonstrate compliance with MTCA by comparing them to groundwater cleanup levels specified in the January 2023 edition of CLARC. Radionuclide groundwater concentrations are used to evaluate compliance with the regulatory standard for a beta/photon-emitter dose of 4 mrem/yr using the derived concentrations from EPA 816-F-00-002, *Implementation Guidance for Radionuclides*, Appendix I. Details of the development of the system model are provided in RPP-RPT-60885.

The system model for the WMA A-AX PA was developed by connecting the subsystem PA models of WMA A-AX using the GoldSim® computer code. GoldSim® is designed to simulate transport of COPCs accompanied with solubility-limit and sorption within modules, allowing each waste source to be represented by a discrete element within the model.

2.2.2 Inadvertent Intruder Doses

While calculating intruder doses over time from a radionuclide without progeny can be done using a spreadsheet application, the calculation complexity increases as the number of radionuclides and waste sources increase. This can substantially increase the potential for data entry or calculation error. Radionuclides with progeny require the use of first-order radionuclide decay and decay product growth equations, further complicating the calculation. The Radionuclide Transport (RT) Module in the GoldSim® simulation software is a tool that can specifically and easily evaluate decay and ingrowth of radionuclides. The GoldSim Contaminant Transport Module User's Guide (GoldSim Technology Group 2017a) states:

> *The RT Module allows decay chains (daughter products) to be simulated (one species can be specified to transform into one or more others). To support modeling of radioactive decay chains, the RT Module also allows you to link to an extensive database of radionuclide decay data (based on a standard reference provided by the Inte[r]national Commission for Radiation Protection). … The data is based on the International Commission for Radiation Protection (ICRP)'s Publication 107. The feature allows you to view over 1300 radionuclides (along with their corresponding stable elements) and to selectively include some of these radionuclides in your simulation.*

Furthermore, GoldSim® is designed to calculate decay and ingrowth, as well as transport and exposure parameters, within modules, allowing each waste source to be represented by a discrete element within the model.

Using a tool specifically developed to support radionuclide fate and transport calculations facilitates the verification of the calculations and enhances reproducibility and transparency of the calculations. Furthermore, by using the embedded database of radionuclide properties in GoldSim®, less chance exists that a data entry error affecting the radionuclide decay chain calculations can occur.

3.0 METHODOLOGY

The system-level model is implemented using GoldSim® software (GoldSim Technology Group 2017a). The detailed methodology for various calculations performed with the system-level model is discussed in RPP-RPT-60885, and the chemical hazards calculations are detailed in RPP-ENV-62206, *Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington*.

3.1 SELECTION OF TECHNICAL STAFF

3.1.1 Responsible Manager

The responsible manager or a delegate selects the technical staff that develops the conceptual and mathematical approach, performs and documents the calculations, checks the work, and reviews the calculation for technical accuracy and completeness. For the calculations described in this EMCF, as delegated by the responsible manager, the Washington River Protection Solutions, LLC (WRPS) Technical Lead (see Section 3.1.3) has selected the technical staff.

Marcel P. Bergeron, WRPS
M.A., Geology, Indiana University
B.A., Geology, University of Vermont

Mr. Bergeron has more than 40 years of experience in a wide variety of subsurface investigations and studies at radioactive and hazardous waste facilities and contaminated sites. He is experienced in planning and implementation of environmental characterization and risk assessment investigations in various roles, including as a technical contributor, a project and task manager, and a line manager. He has performed quantitative analysis of subsurface systems using analytical and numerical models and visualization tools. He has significant technical project experience in managing technical teams, schedules, and budgets for multidisciplinary projects and communication of project results with clients, regulators, and stakeholders.

3.1.2 Originator

The originator or preparer of the environmental model calculation develops the methodology; gains early concurrence with the senior reviewers; identifies project conditions, assumptions, and inputs; and prepares the calculation and associated calculation report.

David J. (DJ) Watson, WRPS
M.S., Environmental Science, Washington State University
B.S., Geology, Washington State University

Mr. Watson has over 16 years of human health risk assessment and PA experience. He has over 13 years of environmental modeling experience, including subsurface contaminant transport

using STOMP,[6] PFLOTRAN,[7] and TOUGH2[8]; air dispersion with AERMOD[9]; internal and external radiological dosimetry using IMBA®,[10] DCAL,[11] OLINDA,[12] and RESRAD[13]; and system modeling using GoldSim®. He has worked in the areas of underground tank waste retrieval and tank closure, radiation dosimetry of both internally-deposited radionuclides and external exposure, nuclear fuel fabrication and transport, and geologic carbon dioxide (CO_2) sequestration. His work has supported DOE, the U.S. Nuclear Regulatory Commission, International Atomic Energy Agency, Joint Global Change Research Institute, and other industrial and research organizations.

3.1.3 Checker

The checker reviews the environmental model calculation to verify that it is clearly developed, and that the calculation was performed as described and without error. Checking includes ensuring that all the inputs are consistent with the original referenced material. The checker documents the review of the calculation on an appropriate Checker Log.

Kearn P. (Pat) Lee, Washington River Protection Solutions, LLC
M.CE., Civil and Environmental Engineering, University of Delaware
B.ChE., Chemical Engineering, University of Delaware

Mr. Lee has more than 15 years of PA development and analysis experience and has been supporting DOE nuclear waste programs for 20 years. He supported the development of the post-closure PA for the license application to dispose high-level waste at Yucca Mountain in Nevada. Following completion of the license application, Mr. Lee transitioned into developing and testing different technologies to retrieve radioactive waste from underground tanks on the Hanford Site in Washington. Combining experience from both endeavors, Mr. Lee brings experience in model development and analysis and project management to the Technical Lead

[6] Subsurface Transport Over Multiple Phases (STOMP) is developed and distributed by Battelle Memorial Institute.

[7] PFLOTRAN is open-source software and can be redistributed and/or modified under the terms of the GNU Lesser General Public License as published by the Free Software Foundation.

[8] TOUGH2 software was developed by Lawrence Berkeley National Laboratory, University of California, Berkeley, California with support from the Office of Science, Office of Basic Energy Sciences, Materials Sciences and Engineering Division of the U.S. Department of Energy.

[9] AERMOD atmospheric dispersion modeling system was developed by the AERMIC (American Meteorological Society [AMS]/EPA Regulatory Model Improvement Committee), a collaborative working group of scientists from the AMS and the EPA.

[10] Integrated Modules for Bioassay Assessment (IMBA)® is a registered trademark of Public Health England, London, United Kingdom; IMBA Expert™ DOE-Edition is a trademark of ACJ & Associates, Richland, Washington, and U.K. Health Protection Agency, Oxfordshire, United Kingdom.

[11] DCAL (Dose and Risk Calculation) software was developed by the Dosimetry Research Group (now the Biosystems Modeling Team in the Advanced Biomedical Science and Technology Group) at Oak Ridge National Laboratory under the sponsorship of the EPA.

[12] OLINDA code was written by Michael Stabin, Ph.D., CHP, Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, Tennessee.

[13] The RESRAD (RESidual RADioactive) family of codes is developed at Argonne National Laboratory, Lemont, Illinois, managed by UChicago Argonne, LLC, for DOE's Office of Science.

role for the DOE O 435.1, *Radioactive Waste Management* PAs for the Hanford Integrated Disposal Facility and WMA A-AX.

3.1.4 Senior Reviewer

The senior reviewer reviews the calculation methodology, assumptions, and criteria and verifies that they are appropriate for the intended use and that the calculation was developed correctly.

Marcel P. Bergeron, WRPS
M.A., Geology, Indiana University
B.A., Geology, University of Vermont

See Section 3.1.1 for a description of Mr. Bergeron's experience and qualifications.

3.2 CONCEPTUAL MODEL

The conceptual model of the source term, release mechanisms, vadose zone transport, and saturated zone transport are fully described in RPP-RPT-60885. To fulfill requirements set forth in the HFFACO (Ecology et al. 1989) Action Plan, Appendix I, this calculation analyzes impacts from radionuclides and hazardous chemical and dangerous waste constituents that remain in tank AX-103.

To meet requirements of *Resource Conservation and Recovery Act of 1976* (RCRA), risk-based calculations are performed using the residential tap water scenario. This scenario is used to estimate exposure to hazardous chemical and dangerous waste constituents to a resident receptor who uses the contaminated water from the well located at the POC for domestic purposes. This assumes that a well is drilled at the WMA fenceline and that water from this well is used for domestic purposes. The exposure assumptions in this scenario reflect reasonable maximum exposure. Exposure parameters and toxicity values that are used in the equations are obtained from EPA guidance.

In the residential tap water scenario, the receptor is assumed to be exposed to hazardous chemical and dangerous waste constituents in groundwater from the following exposure routes:

- Ingestion of tap water
- Inhalation of volatile or aerosolized chemicals while showering and other domestic purposes
- Dermal contact with skin while showering and using groundwater for other domestic purposes (such as washing dishes).

Excess lifetime cancer risks for carcinogens and non-cancer hazards for noncarcinogens are calculated. Estimation of intake is based on age-specific ingestion, inhalation, and dermal contact rates for children and adults, assuming 6-year exposure duration for children and 20-year

exposure duration for adults. Figure 3-1 provides the conceptual exposure model for the residential tap water scenario and shows all of the elements of a complete exposure pathway.

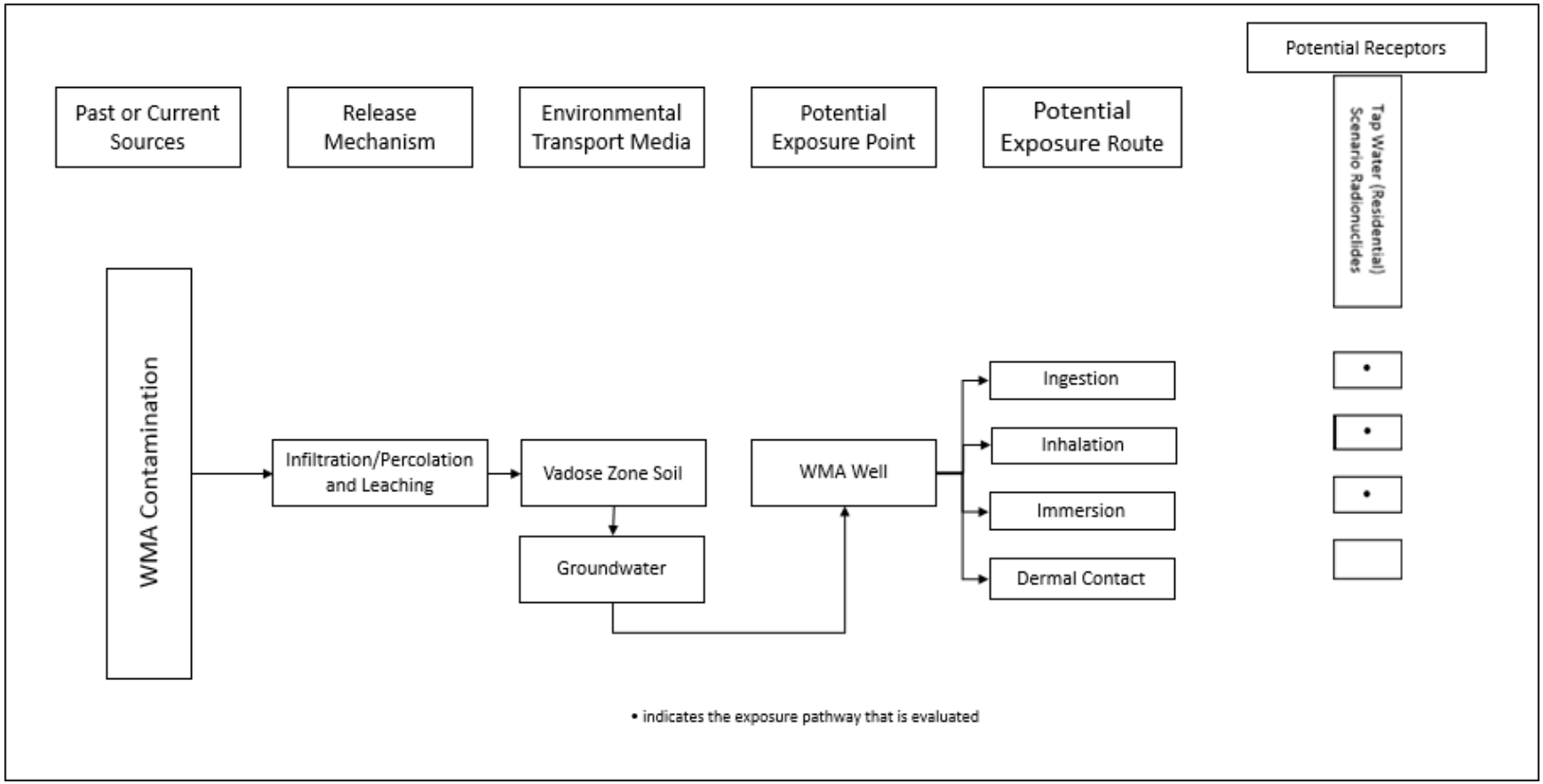
Inhalation of aerosolized COPCs while showering is included in the analysis using the mass-balance model from EPA/600/R-15/271, *Incorporating a Capability for Estimating Inhalation Doses in TEVA-SPOT*, as recommended by Ecology in their comments on RPP-ENV-62206.

To evaluate non-cancer hazards, this analysis also compares calculated groundwater concentrations to groundwater cleanup levels from CLARC (January 2023 edition), which are based on equations and exposure assumptions presented in MTCA WAC 173-340-720.

Human health risks are calculated using equations and exposure assumptions presented in RPP-ENV-58813, with a target risk level of 1×10^{-6} and a cumulative risk level of 1×10^{-5} for carcinogens or a Hazard Quotient (HQ) of 1 and Hazard Index (HI) of 1 for noncarcinogens.

The acute Well Driller exposure scenario for the Hanford Site assumes that, after a loss of institutional control and societal memory about the Hanford Site, a well is drilled through the tank to the water table and the driller is exposed to radiation from the drill cuttings brought to the surface. The well driller's exposure to drill cuttings is assumed for a total of five days (8 hours per day for a total of 40 hours). The dose is calculated by assuming that the cuttings are uniformly spread across the drill pad and are not diluted by mixing with clean soil. The chronic exposure scenarios for the Hanford Site evaluate the long-term exposure of three different receptors assuming that a well is drilled through the tank at a future date, bringing drill cuttings containing contaminated material to the surface. The drill cuttings are uniformly spread and tilled onto three different land areas or target fields, thereby allowing an individual to become chronically exposed over a lifetime. In the Suburban Garden Scenario, the cuttings are distributed on the soil surface of a garden. The garden is used to provide 25% of the daily vegetable diet for a family of four living in the home. In addition to exposure from fruit and vegetable consumption, the resident is exposed by incidental soil ingestion, inhalation of the soil particulates, and external exposure. In the Rural Pasture exposure scenario, the cuttings are distributed on the soil surface of a pasture used for milk production from dairy cows. The receptor also uses the target field as a residence. The target field is used to raise dairy cattle that eat fodder grown from the pasture, and the resident subsequently drinks the pasture cows' milk. In addition to exposure from milk consumption, the resident is exposed by incidental soil ingestion and inhalation of the soil particulates. In the Commercial Farm exposure scenario, the cuttings are distributed on the soil surface of a commercial farm. This scenario represents an individual who works on the commercial farm and grows and tends to the crops but does not consume what is produced. The commercial farm worker is exposed by incidental soil ingestion, inhalation of soil particulates, and external exposure. The conceptual model for the inadvertent intruder scenarios is described in detail in Section 3.3 of RPP-RPT-63634.

Figure 3-1. Conceptual Exposure Model for the Residential Tap Water Scenario.



WMA = Waste Management Area

3.3 MATHEMATICAL MODEL

3.3.1 Groundwater Pathway Impacts

The mathematical model used to calculate cancer and non-cancer risks from exposure to hazardous chemicals from tank AX-103 residuals is detailed in Section 3.3 of RPP-CALC-63600, *Calculation of Groundwater Impacts from Hazardous Chemicals in Residual Wastes Left in Tanks and Ancillary Equipment at Waste Management Area A-AX*. A summary of the exposure assumptions used for each of the exposure pathways is provided in Attachment 3, whereas Attachment 4 lists the chemical-specific parameters used for cancer risks and non-cancer hazards.

3.3.1.1 Equation to Calculate the Beta/Photon Dose. The system model used in this EMCF also evaluates the radiological dose from beta/photon-emitting radionuclides for comparison against the regulatory standard for a beta/photon-emitter dose of 4 mrem/yr. The following equation is used to calculate the dose from beta/photon emitters:

$$D_\beta = \sum_i \left(\frac{C_{w,i}}{C_{wd,i}} \times 4mrem \right) \quad (3\text{-}1)$$

Where:

D_β = beta/photon dose (mrem)
$C_{w,i}$ = groundwater concentration of beta/photon emitter *i* (pCi/L)
$C_{wd,i}$ = derived concentration of beta/photon emitter *i* (pCi/L) (EPA 816-F-00-002).

3.3.2 Inadvertent Intruder Dose Calculation

The system model used in this EMCF also evaluates the radiological doses and dose rates from hypothetical inadvertent intrusion scenarios for an acute Well Driller scenario and chronic Suburban Garden, Rural Pasture and Commercial Farm scenarios. Section 7.1.2 compares the results of these analyses against the regulatory standard for acute inadvertent intrusion dose of 500 mrem and chronic inadvertent intrusion dose rate of 100 mrem/yr. Section 7.1.2 presents detailed results for these scenarios, including contributions of exposure pathways and contributing radionuclides. Of all the inadvertent intruder scenarios, the acute Well Driller scenario has among the fewest sources of uncertainty because of the absence of environmental transport and partitioning mechanisms, such as crop uptake or fodder uptake, that are found in the chronic scenarios.

The equations used in the model for the inadvertent intruder scenario are described in detail in Section 4.2 of RPP-RPT-63634.

3.4 CALCULATION PROCEDURE

The WMA A-AX residential tap water scenario and the inadvertent intruder scenario submodels are both part of the WMA A-AX system model, which was constructed in GoldSim® Version 12.1.3 (RPP-RPT-60885).

The simulation is performed for 10,000 years post-closure, which is assumed to begin in 2050. The model uses 1-year timesteps for the first 1,000 years of the simulation and then applied 10-year timesteps for the remainder of the simulation. Values for selected elements are saved using time history result elements and final value elements that report values at 100 years, 500 years, and at the end of the simulation.

The following procedure is used to perform the analysis.

1. Perform screening analysis (Attachment 11) on constituents that are not included in the WMA A-AX PA model.

2. Enter average and upper-bounding inventories from source data into a spreadsheet. Use the spreadsheet to re-order the constituents and their inventories into the order used by the GoldSim® inventory decay model. Create two sets of inventories: one with non-detect values replaced by 0, and one where they are replaced by one-half the detection limit.

3. Enter the two sets of inventories from step 2 into the GoldSim® decay model ("AX-103_Inventory_Decay.gsm") using the scenario manager. For the live model, enter the average inventory with non-detects zeroed out into the **Average_Inventory** element and enter the upper-bound inventory with non-detects zeroed out into the **UCF95_Inventory** element. For the "**Half_Detection_Limit**" scenarios, enter the average inventory with non-detects entered as one-half the detection limit into the **Average_Inventory** element and enter the upper-bound inventory with non-detects entered as one-half the detection limit into the **UCF95_Inventory** element.

4. Run the decay model for all four scenarios. Copy the results from the **Average_Inventory_2050** and **UCF95_Inventory_2050** elements into the Excel®[14] spreadsheet.

5. Open the system model ("AX-103_RDR.20230508.gsm") and add a new version through the version manager.

6. Using the scenario manager add four scenarios:

    a. "Average_Inventory_Detects_Only" for the average inventory with non-detects zeroed out

[14] Excel® is a registered trademark of Microsoft Corporation in the U.S. and other countries.

b. "_95%_UCL_Inventory_Detects_Only" for the upper-bound inventory with non-detects zeroed out

c. "Average_Inventory_Half_Detection" for the average inventory with non-detects entered as one-half the detection limit

d. "_95%_UCL_Inventory_Half_Detection" for the upper-bound inventory with non-detects entered as one-half the detection limit.

7. Using the scenario manager, copy the results from the **Average_Inventory_2050** and **UCF95_Inventory_2050** elements of the decay model into the system model: Radionuclide inventories added to the **Initial_Rad_Inventory** element and chemical inventories added to the **Initial_Chem_No_Cr3** element. Ensure that the data are entered into the correct scenario.

8. Add the residual waste volume into the **Res_Waste_Vol_Source** element.

9. Run each scenario in the system model and export the following results to different sheets in an Excel® workbook.

   a. **\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_GW_Conc** and **\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_GW_Conc_Year**.

   b. **\Transport_Abstraction_Model\SZ_Fence_Conc\ Peak_GW_Chem_Conc_fence** and **\Transport_Abstraction_Model\ SZ_Fence_Conc\Peak_GW_Chem_Conc_year_fence**.

   c. **\Exposure_Scenarios\ Drinking_Water_StandardsB_PhotonB_Photon_Dose_by_Analyte**.

   d. **\Exposure_Scenarios\Residential_Tap_Water_Scenario\ Risk_Calculation_Results\AX_NonRad_HQ_Peak_by_Analyte**.

   e. **\Exposure_Scenarios\Residential_Tap_Water_Scenario\ Risk_Calculation_Results\AX_NonRad_Risk_Peak_by_Analyte**.

   f. **\Exposure_Scenarios\DOE_Exposure_Scenarios\Intruder_Dose_Calc\ Intruder_Results\Scenario_Doses_by_Tank**.

   g. **\Exposure_Scenarios\DOE_Exposure_Scenarios\Intruder_Dose_Calc\ Intruder_Results\AX103_ByAnalyte\Relative_Fraction_of_Pathways**, and the following from **\Exposure_Scenarios\DOE_Exposure_Scenarios\Intruder_Dose_Calc\ Intruder_Calculations** (only for "Average_Inventory_Detects_Only" scenario): **Acute_Exp_Well_Driller\Soil_Ingestion_Dose_WD**, **Acute_Exp_Well_Driller\Inhalation_Dose_WD**,

Acute_Exp_Well_Driller\External_Exposure_Dose_WD,
Acute_Exp_Well_Driller\WellDriller_Sum,
Chronic_Exp_Commercial_Farm\Soil_Ingestion_Dose_CF,
Chronic_Exp_Commercial_Farm\Inhalation_Dose_CF,
Chronic_Exp_Commercial_Farm\External_Exposure_Dose_CF,
Chronic_Exp_Commercial_Farm\CommercialFarm_Sum,
Chronic_Exp_Rural_Pasture\Soil_Ingestion_Dose_RP,
Chronic_Exp_Rural_Pasture\Inhalation_Dose_RP,
Chronic_Exp_Rural_Pasture\External_Exposure_Dose_RP,
Chronic_Exp_Rural_Pasture\Milk_Ingestion_Dose_RP,
Chronic_Exp_Rural_Pasture\RuralPasture_Sum,
Chronic_Exp_Suburban_Garden\Soil_Ingestion_Dose_SG,
Chronic_Exp_Suburban_Garden\Inhalation_Dose_SG,
Chronic_Exp_Suburban_Garden\External_Exposure_Dose_SG,
Chronic_Exp_Suburban_Garden\Veg_Ingestion_Dose_SG,
Chronic_Exp_Suburban_Garden\SuburbanGarden_Sum.

h. **\Inventory\Initial_Chem_Inventory** and **\Inventory\Initial_Rad_Inventory**.

10. Create a sheet in the Excel® workbook that creates the tables for the EMCF by using lookup functions referring to the data sheets in the workbook.

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4.0 ASSUMPTIONS AND INPUTS

RPP-RPT-60885 lists assumptions and inputs for the groundwater pathway calculations as well as the inadvertent intruder scenarios. The assumptions related to the residential tap water scenario, the acute Well Driller inadvertent intrusion scenario and the chronic Suburban Garden, Commercial Farm and Rural Pasture inadvertent intrusion scenarios are also detailed in RPP-ENV-58813.

4.1 KEY ASSUMPTIONS

Key general assumptions used in the system model are detailed in RPP-RPT-60885 and are as follows:

- The landfill closure of WMA A-AX is assumed to occur at year 2050
- It is assumed that institutional control and societal memory is retained for the first 100 years after the year of closure, but for the purposes of the hypothetical inadvertent intruder calculations, the grouted tank provides intruder protections (an intruder drilling through intact grout recognizes the non-native material) for 500 years
- Tank AX-103 is assumed to be retrieved and filled with grout
- Residual waste inventories derived from post-retrieval sampling are representative of the waste left in the tank
- For sensitivity studies evaluating the 95% upper confidence level (UCL) concentrations, there is no concentration constraint that limits the derived 95% UCL concentration to the detection limit when the concentration in the sample is below the detection limit
- The Modified RCRA Subtitle C Barrier functions according to its design specifications for 500 years
- The inadvertent intruder dose calculations are based on the residual radionuclide inventory after retrieval in tank AX-103 (considering radioactive decay and ingrowth) but ignoring any depletion due to transport of radionuclides from the waste site.

4.1.1 Groundwater Pathway Evaluation

Key groundwater transport and recharge assumptions used in the analysis and taken from RPP-RPT-60885 are as follows.

- During the construction and operations period, the following covers are assumed:
    - The undisturbed zone around the facility characterized by a native vegetation cover

  - The disturbed zone around the facility that has scant deep-rooted vegetation but extensive grass cover, combined with the resurfaced zone around the facility that has no vegetation cover

  - The tank farm zone where gravel backfill is kept free of vegetation.

- During the early post-closure period, the following covers are assumed:

  - Tank AX-103 lies beneath the extent of the A Complex surface barrier that is designed to minimize infiltration of meteoric waters

  - The disturbed/resurfaced zone, outside the surface barrier, characterized by an artificially-introduced vegetation cover attempting to reclaim the surface with native vegetation species.

- The impact of the closure barrier on moisture flow is approximated by an assumed recharge rate into the facility.

- Net infiltration through the thick, heterogeneous vadose zone in the 200 Areas dampens the effect of discrete events, and therefore episodic precipitation events can be replaced by an average annual recharge rate.

- The porous media continuum assumption (an extended form of Darcy's law for vadose zone applications) and the soil relative permeability/saturation/capillary pressure relations provide the basis for vadose zone flow and transport modeling.

- The vadose zone is modeled as an aqueous-gas porous media system where flow and transport through the gas phase are assumed to be negligible.

- Hydraulic property heterogeneity is assumed to be insignificant within geologic units. Hence, each geologic unit within the vadose zone is assigned upscaled, effective hydraulic properties.

The POC used in the calculation of the groundwater concentrations corresponds to a downgradient position directly below the current location of the WMA fenceline.

Assumptions about the characteristics of residual waste in tank AX-103 at closure are detailed in RPP-RPT-60885. The key residual waste assumption used in the system model is that the unretrieved wastes are conservatively assumed to be distributed uniformly throughout the bottom area of the waste source for leaching calculations. Post-retrieval estimates indicate that 88% of the residual waste volume is distributed along the bottom of the tank.

Key assumptions about the closed waste form taken from RPP-RPT-60885 include the following.

- The chemical effect of the grout is represented by contaminant-specific distributions of distribution coefficients (K_ds), which have been developed from international literature on sorption of radionuclides on cementitious materials. These values are generally consistent with, or lower than, comparable values used for the facility-specific grout at the Savannah River F and H tank farm PAs [WSRC-STI-2007-00369, *Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure*, and WSRC-STI-2007-00607, *Chemical Degradation Assessment of Cementitious Materials for the HLW Tank Closure Project (U)*].

- Because the closed tank is in the unsaturated zone, conditions are expected to be moderately oxidizing. When data are available to differentiate between oxidizing and reducing conditions, oxidizing conditions are assumed. This approach leads to selecting lower K_d values in the model.

- The selected K_d values are based on the assumption of $Ca(OH)_2$-saturated waters contacting the waste.

- Grout is likely to provide a significant barrier to infiltrating water, thus limiting any water flow through the tank and thereby restricting the release of COPCs from the residual waste to be diffusion-controlled.

- The presence of continuous water connections is assumed across the grout and concrete at the base of the tank for the diffusive transport to occur in the aqueous phase through the tank base mat.

- It is assumed that the steel liner inside the closed tanks is impervious to flow and diffusion until closure, then no credit is taken for the performance of the steel liner or its corrosion products to limit releases from the tanks.

Exposure pathways evaluated for the residential tap water exposure scenario are ingestion, inhalation, and dermal absorption. Assumptions specific to the residential tap water scenario are detailed in RPP-ENV-58813 and RPP-CALC-65265, *Potential Groundwater Impacts and Inadvertent Intruder Doses from Tank 241-AX-103 Residuals Under Various Retrieval Scenarios*, Attachment 10. For domestic use of groundwater as a drinking water supply, EPA considers the inhalation pathway potentially complete only for volatile contaminants, because there is no mechanism for release of nonvolatile chemicals into the air in significant concentrations [EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals) Interim*], except from aerosols while showering. For the residential tap water exposure pathway, inhalation intake is quantified only for volatile contaminants, as defined by EPA (EPA Regional Screening Levels (RSLs) – Generic Tables, Queried 08/15/2022, [Regional Screening Levels (RSLs) – Generic Tables], https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables) and for aerosols while showering.

4.1.2 Inadvertent Intrusion Dose Evaluations

Assumptions specific to the hypothetical inadvertent intruder scenarios evaluated in the EMCF are also detailed in RPP-ENV-58813 and are as follows.

- The tank and infill grout represent very significant and robust barriers to intrusion, and therefore the intrusion calculation is conducted beginning at 500 years.

- Radionuclide concentration in water for chronic inadvertent intruder dose calculations is assumed to be zero.

- The acute Well Driller scenario assumes exposure to drill cuttings for a total of five days (8 hours per day for a total of 40 hours). The scenario also assumes that the cuttings are uniformly spread across the drill pad, and the pad is small enough that concentrations are not diluted by mixing with clean soil.

- In the resident with a Suburban Garden, resident with a Rural Pasture and worker at a Commercial Farm scenarios, contaminated drill cuttings are assumed to be spread evenly over the receptor's land to a tillage depth of 15 cm.

- The chronic Suburban Garden scenario assumes a well diameter of 16.51 cm (6.5 in.) and that drill cuttings are spread over a pasture area of 2,500 m^2. The home garden size is assumed to be 100 m^2.

- The chronic Rural Pasture scenario assumes a well diameter of 26.67 cm (10.5 in.) and that drill cuttings are spread over a pasture area of 5,000 m^2.

- The chronic Commercial Farm scenario assumes a well diameter of 41.91 cm (16.5 in.) and that drill cuttings are spread over a farm area of 647,000 m^2 (160 acres). This scenario represents an individual that works on the commercial farm who grows and tends to the crops but does not consume what is produced.

- For calculating the dose from external exposure, the thickness and lateral extent of the contaminated layer is assumed to be infinite as a conservatism when applied to exposures from relatively small contamination sources.

4.2 INPUTS

Calculation inputs include residual waste inventories, residential tap water scenario parameters, and contaminant-specific factors related to residential tap water scenario exposure pathways.

The post-retrieval residual waste volume estimate was performed using a method described in RPP-RPT-63817. The total measured volume of residual waste in tank AX-103 was the sum of volumes remaining in the tank dish, on the tank walls, in equipment, and on the stiffener rings. The final residual waste volume estimate is 785 ft^3 (5,875 gal), with a 95% UCL volume of

1,045 ft^3 (7,817 gal). The residual waste volume used for all calculations in this EMCF is the actual measured volume reported in RPP-RPT-63817, 785 ft^3 (5,875 gal).

This EMCF uses residual inventory estimates based on tank residual waste samples laboratory analysis results and the residual waste volumes estimated by the Residual Volume Measurement System (laser scanning) and in-tank video (RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*). The residual waste inventories were calculated in accordance with the Best-Basis Inventory (BBI) process as described in RPP-7625, *Guidelines for Updating Best-Basis Inventory*. Two inventories were calculated: an average inventory based on mean concentrations, density, and volume and an upper bounding inventory that is an estimate of inventory parameters (e.g., concentration, density, and volume) at the 95% UCL.

Table 4-1 lists the inputs, sources, and the attachments to this document that list their values.

Table 4-1. Inputs Used in the U.S. Environmental Protection Agency Residential Tap Water and Inadvertent Intruder Scenarios.

Input	Reference	Attachment
Inventory	RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*	2
Volume	RPP-RPT-63817, *Laser Scanning Waste Volume Estimate for Tank 241-AX-103*	2
Residential tap water scenario general parameters	RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*	3
Residential tap water scenario contaminant-specific parameters	RPP-ENV-58806, *Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area C at the Hanford Site, Southeast Washington*	4
Inadvertent intruder scenario parameters	RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*.	5
Groundwater pathway dose conversion factors	RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*.	6
Inadvertent intruder dose conversion factor multipliers	RPP-CALC-61254, *Inadvertent Intruder Dose Calculation Update for the Integrated Disposal Facility Performance Assessment*	6
Bioconcentration factors	RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*.	7
Radionuclide-specific shielding factors	RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*.	8
Derived concentrations of beta and photon emitters	EPA 816-F-00-002, *Implementation Guidance for Radionuclides*	9

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5.0 SOFTWARE APPLICATIONS

The software used to perform this calculation is consistent with the software that is used for other environmental models for WRPS.

5.1 SOFTWARE IDENTIFICATION

Software is registered on the Hanford Information System Inventory and is identified as approved for use. The identification for the software package used in the calculation is as follows:

- GoldSim® Pro
- Version 12.1.3
- Hanford Information System Inventory Identification Number: 5195
- Workstation type and property number: Dell™ Optiplex™[15] 7060MT (WF42946).

Microsoft Excel® is used for post-processing model output, as well as simple calculations and lookup functions (Attachment 11). Spreadsheets created for these purposes are single-use utility spreadsheets. Electronic versions of all spreadsheets are provided to the checker and archived in the Environmental Model Management Archive (EMMA).

5.2 SOFTWARE QUALITY ASSURANCE

All calculations are performed using GoldSim® Pro simulator software, Version 12.1.3. GoldSim® Pro simulator is approved for use by WRPS consistent with TFC-PLN-155, "General Project Plan for Environmental Modeling." The installed GoldSim® Pro simulator software was tested in accordance with the procedure per RPP-PLAN-65454, *Software Management Plan for Grade B Acquired Software GoldSim with Radionuclide Transport*, as documented in RPP-RPT-64104, *Software Test Results Report for GoldSim with Radionuclide Transport*.

5.3 SOFTWARE INSTALLATION AND CHECKOUT

The software installation and checkout form for GoldSim® is provided in Attachment 1 to this EMCF.

[15] Dell™ and Optiplex™ are trademarks of Dell Inc., Round Rock, Texas.

5.4 STATEMENT OF VALID SOFTWARE APPLICATION

The following verifies that GoldSim® is a valid software application and was applied in this EMCF within its range of intended uses for which it was tested and approved.

- GoldSim® Pro was used for DOE to assist in performing simulation of radioactive mass conservation (including decay and ingrowth) and contamination mass transport in a subsurface environment and to perform human health risk assessment for the Hanford Site.

- GoldSim® Pro as it is used in this EMCF has been implemented within the range of its limitations.

6.0 CALCULATIONS

The calculations are performed with GoldSim® using the "AX-103_RDR.20230508.gsm" model file. This model file is reviewed and checked and will be archived in the EMMA along with this EMCF and other supporting files.

6.1 DESCRIPTION OF MODEL CHANGES

This model uses the model described in RPP-RPT-60885 as its basis. This model file was created from the version-controlled "AX-104_RDR.20221102.gsm" model file by performing the following.

- Added Hexavalent Chromium (as "Cr6") and Trivalent Chromium (as "Cr3") to Species vector.
- Added Trivalent Chromium (as "Cr3") to Chemical vector.
- Removed **\Transport_Abstraction_Model\SZ_Fence_Conc\Cr6_Switch**.
- Changed **\Transport_Abstraction_Model\SZ_Fence_Conc\ Chem_Conc_Fenceline_Data** and **\Transport_Abstraction_Model\SZ_100m_Conc\ Chem_Conc_Fenceline_Data** to remove reference to **Cr6_Switch**.
- Update the following to added values for Cr3 and Cr6:
  - **\Input_Parameters\Uncertainty_Inputs\Inventory_Uncertainty\ Initial_Inventory_Uncert**
  - **\Input_Parameters\Uncertainty_Inputs\Sorption_Uncertainty\Kd_Silt_Max**
  - **\Input_Parameters\Uncertainty_Inputs\Sorption_Uncertainty\ Kd_Sand_Max**
  - **\Material\Grout_Material**
  - **\Material\Solubilities**
  - **\Exposure_Scenarios\Residential_Tap_Water_Scenario\ GW_Concentration_Data**
  - **\Exposure_Scenarios\Residential_Tap_Water_Scenario\ Species_specific_parameters\GIABS_CHEM**
  - **\Exposure_Scenarios\Residential_Tap_Water_Scenario\ Species_specific_parameters\Kp**

  - **\Exposure_Scenarios\Residential_Tap_Water_Scenario\ Species_specific_parameters\RfCi**
  - **\Exposure_Scenarios\Residential_Tap_Water_Scenario\ Species_specific_parameters\RfDo**
  - **\Input_Parameters\Uncertainty_Inputs\Inventory_Uncertainty\Chemicals\ Chemical_Inv_Unc_Mult**
  - **\Transport_Abstraction_Model\SZ_Fence_Conc\ Peak_GW_Chem_Conc_year_fence**.

- Added the following elements to **\Input_Parameters\Uncertainty_Inputs\ Source_Term_Uncertainty**:
  - **Cr3_Diss_Conc_Limit_Determ**
  - **Diss_Conc_Limit_Cr3_Source**
  - **Cr3_Diss_Conc_Limit_Uncert**
  - **pore_water_density**
  - **Cr6_Diss_Conc_Limit_Determ**
  - **Diss_Conc_Limit_Cr6_Source**
  - **Cr6_Diss_Conc_Limit_Uncert**.

- Added **\Inventory\Initial_Chem_No_Cr3** to hold the BBI inventory. **\Inventory\Initial_Chem_Inventory** was changed to subtract the Cr6 inventory from the Total Cr inventory to obtain the Cr3 inventory.

- Added inventories (Attachment 2) to the **Inventory** container.

- Added waste volume (Attachment 2) to **\Input_Parameters\Eng_Sys_Transport_Param\Res_Waste_Vol_Source**.

- Changed references from AX-104 to AX-103 in the following elements: **\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_GW_Conc**, **\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_GW_Chem_Conc_fence**.

This model file uses the "scenario" feature in GoldSim® to add different retrieval inventories and evaluate their impacts on the groundwater human health metrics and the intruder doses. The four scenarios used for this analysis are:

- **Average_Inventory_Half_Detection**
- **_95%_UCL_Inventory_Half_Detection**
- **Average_Inventory_Detects_Only**
- **_95%_UCL_Inventory_Detects_Only**.

Some GoldSim® element types do not display calculated values when the model is run using the scenario manager, including the following.

- The following time series elements in **\Exposure_Scenarios\DOE_Exposure_Scenarios\Intruder_Dose_Calc\Intruder_Results\AX103_ByAnalyte**:
  - **WD_By_Pathway_cht**
  - **CF_By_Pathway_cht**
  - **RP_By_Pathway_cht**
  - **SG_By_Pathway_cht**.
- **\Exposure_Scenarios\Drinking_Water_Standards\Beta_Photon\Beta_Photon_Dose_by_Analyte**.
- **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\AX_NonRad_HQ_Peak_by_Analyte**.
- **\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_GW_Chem_Conc_fence**.
- **\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_GW_Conc**.

6.1.1 Model Configuration Control

All inputs and outputs for the development of the WMA A-AX PA GoldSim®-based system model are archived to the EMMA to maintain and preserve models, input files, and select output files under configuration management. Inputs include the input files used in the GoldSim® simulations and the input parameters. Basis information (that is, information collected to form the basis for model input parameterization) is also stored in the EMMA for traceability purposes.

6.1.2 Model Checking

The WMA A-AX GoldSim® system model is checked using the procedure found in Section 4.2.2 of TFC-ESHQ-ENV_FS-C-05, "Preparation and Issuance of Model Package Reports and Environmental Model Calculation Files." The model checker was provided with:

- The versioned copy of the GoldSim® model file ("AX-103_RDR.20230508.gsm")
- A copy of the files used to develop the updated inventories
- A copy of the model package report (RPP-RPT-60885)
- A draft copy of this EMCF.

The checker made comments, and all comments were resolved as indicated by a signed checker's log.

6.2 DESCRIPTION OF CALCULATED OUTPUT

Peak groundwater concentration results for radionuclides and chemicals are contained in extrema elements in the container **\Transport_Abstraction_Model\SZ_Fence_Conc**. Chemical groundwater peak concentrations are contained in an extrema vector of chemicals called **Peak_GW_Chem_Conc_fence**, while radionuclide groundwater peak concentrations are in an extrema vector of GoldSim® type "Rads" called **Peak_GW_Conc**. Peak concentrations are compared to Federal Maximum Contaminant Levels (MCLs), Washington State Maximum Contaminant Levels (WMCLs), and MTCA Method B non-cancer cleanup levels. They are used in subsequent HQ and cancer risk calculations.

Groundwater concentrations are also used to screen out constituents that are not included in the model, but have residual tank inventories. The screening analysis first models surrogate constituents in the model with K_d values of 0 mL/g using the missing constituents' inventories. Any constituent with groundwater concentrations exceeding its MCL or WMCL is then modeled using a surrogate in the model. The model is configured to simulate transport of contaminants with four different vadose and saturated zone K_d values: 0 mL/g, 0.1 mL/g, 0.2 mL/g and 1 mL/g. Therefore, if a remaining constituent's actual K_d value is between 0 mL/g and 0.2 mL/g, it is rounded to the nearest tenth to obtain the surrogate K_d value. If a remaining constituent's actual K_d value is between 0.2 mL/g and 1 mL/g, it is assigned a surrogate value of 0.2 mL/g in the model. Grout K_d values for these surrogates are all set to 0 mL/g. Constituents with groundwater concentrations below their MCLs or WMCLs after the second round of modeling are not reported in this EMCF.

For non-time-series results (such as maxima), the results are captured at 100 years post-closure, 500 years post-closure, and at the end of the 10,000-year simulation.

Chemical HQ results are contained in the extrema vector of chemicals **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\AX_NonRad_HQ_Peak_by_Analyte**. Chemical cancer risk results are contained in the extrema vector of chemicals **\Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\AX_NonRad_Risk_Peak_by_Analyte**.

Beta/photon dose and inadvertent intruder dose results are extracted from time series charts. The inadvertent intruder dose results are from the following elements in **\Exposure_Scenarios\DOE_Exposure_Scenarios\Intruder_Dose_Calc\Intruder_Results\AX103_ByAnalyte\:**

- **WD_By_Pathway_cht**
- **CF_By_Pathway_cht**
- **RP_By_Pathway_cht**
- **SG_By_Pathway_cht**.

The beta photon dose results are from **\Exposure_Scenarios\Drinking_Water_Standards\Beta_Photon\Beta_Photon_Dose_by_Analyte**.

7.0 RESULTS AND CONCLUSIONS

This section presents the results of modeling groundwater transport at WMA A-AX in terms of contaminant concentrations, along with the results of the cancer risk and non-cancer hazard calculations for the closed tank AX-103 using the residential tap water scenario. For carcinogens, the target risk level is 1×10^{-6}, with a target cumulative risk level of 1×10^{-5}. For noncarcinogens, the target is an HQ of 1 and an HI of 1. Results are presented for two time periods: the 0- to 1,000-year time period (2050 to 3050) and 1,000- to 10,000-year period post-closure. Results are evaluated using simulated groundwater concentrations directly below the WMA A-AX fenceline.

For the average and 95% UCL inventory, two analyses were performed: one using only constituents detected in the residual waste, and one using both detected and non-detect contaminant results. Analytes flagged as non-detect were evaluated at one-half the detection limit in accordance with EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) Interim Final*.

It is possible to have impacts from chemicals that have not been considered in this analysis. These impacts cannot be assessed without characterization data from the tank waste. However, as described in Attachment 10, persistent chemicals left in the residual waste at closure that have a soil-water partition coefficient greater than 1 mL/g will not impact the groundwater within 10,000 years because the post-closure transport time to groundwater for these chemicals exceeds 10,000 years.

Hexavalent chromium is a potent oral and inhalation carcinogen, and tank AX-103 is the first AX Farm tank to have a bounding inventory for hexavalent chromium calculated from post-retrieval sampling (RPP-RPT-64056, Appendix D). The resulting inventory was then subtracted from that of total chromium to obtain an inventory for trivalent chromium. The inventories used in this analysis include the 95% UCL inventory, which tends to be an overestimation and, as such, would provide a nearly upper bound to the results. In addition, hexavalent chromium's potency as an inhalation carcinogen is addressed through the adoption of an EPA mass-balance model for inhalation while showering (EPA/600/R-15/271).

Ecology has raised concerns about the potential presence of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in residual tank waste based on detections in the groundwater near WMA A-AX. PCDDs and PCDFs that may be present in residual waste, such as 2,3,7,8 tetrachloro dibenzo-p-dioxin, cannot be evaluated for impacts on groundwater because there is no characterization data for these chemicals in the BBI or post-retrieval samples. Using the organic carbon-water partition coefficients (K_{oc}) for PCDDs and PCDFs found in EPA's Superfund Chemical Data Matrix (EPA Superfund, Queried 10/11/2022, [Superfund Chemical Data Matrix Query], https://www.epa.gov/superfund/superfund-chemical-data-matrix-scdm-query), and the organic carbon fraction of Hanford sediments for various 200 East Area and 200 West Area wells (PNNL-30443, *Sediment Mineralogy Data Review for the Hanford Central Plateau*), the lowest K_d that can be calculated with these data is 14 mL/g. The WMA A-AX PA (RPP-ENV-61497) showed that contaminants in residual waste in an intact, retrieved tank with a K_d greater than 0.6 mL/g did not reach the groundwater within

10,000 years. Furthermore, RPP-RPT-59197, *Analysis of Impacts of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington* identified chemicals that are not sufficiently mobile to reach groundwater within 10,000 years after tank closure. WMA C is near WMA A-AX and has similar hydrostratigraphic units, making it a suitable analogue for this analysis. The screening in RPP-RPT-59197 used hydraulic properties that yielded maximum transport rates and used net infiltration rates that were greater than those used in RPP-RPT-61497. The screening analysis in RPP-RPT-59197 showed that chemicals with K_d values greater than 2 mL/g would not reach groundwater within 10,000 years post-closure. Since the lowest estimated K_d calculated for PCDDs and PCDFs is 14 mL/g, it is reasonable to assume that PCDDs and PCDFs would not impact groundwater within 10,000 years post-closure, using the increased net recharge of the WMA C screening analysis. Since AX-103 is an intact tank, there is no chance that PCDD and PCDF detections in groundwater could have originated from it.

Hypothetical intruder analyses are only performed to analyze the impacts on human health from radionuclides. Due to the depth of the waste in the post-closure configuration (> 15 ft) and the hypothetical construct of the scenario, there is no direct or ecological exposure route to residual waste in the tanks until an intrusion occurs. No ecological impacts from an inadvertent human intrusion into the tank are evaluated.

7.1 RESULTS

7.1.1 Groundwater Pathway Impacts

This analysis estimates the potential future radiological dose from contaminants regulated under the *Atomic Energy Act of 1954*, as amended (uranium, ^{99}Tc, ^{90}Sr, ^{137}Cs, and actinides).

The potential impacts to human health posed by the residual waste in tank AX-103 were evaluated in isolation from other sources using the methodology documented in RPP-ENV-61497. The WMA A-AX PA methodology represents the current approach being used to support the assessment of long-term human health impacts from tank residuals.

The human health impacts from existing residual wastes after two retrieval technologies have been applied, considering that COPCs for the groundwater pathway were evaluated with a variety of performance metrics. This analysis uses the maximum modeled groundwater concentrations for COPCs at the WMA A-AX fenceline, which were estimated using one-dimensional modeling of vadose zone and groundwater flow and transport. For example, the peak concentration at the fenceline for ^{99}Tc for the existing inventory estimate is estimated at 1.83 pCi/L. Using the 95% UCL inventory from the post-retrieval samples, the peak simulated groundwater concentration at the fenceline is 2.82 pCi/L. Note that the 95% UCL inventory for ^{99}Tc is 54% greater than the average inventory; due to linearity in the release and transport processes, the peak groundwater concentration is also 54% higher. The ^{99}Tc concentration that the EPA determined is equivalent to the 4 mrem/yr drinking water standard is 900 pCi/L. However, in 2021 DOE published updated dosimetry values; based on the updated dosimetry a concentration of 10,400 pCi/L of ^{99}Tc would yield a 4 mrem/yr drinking water dose (derived

from dose conversion factors reported in DOE-STD-1196-2021, *Derived Concentration Technical Standard*).

7.1.1.1 Radiological Impacts. Table 7-1 shows estimated WMA A-AX peak fenceline concentrations for the three detected radionuclides with fenceline groundwater concentrations greater than 1×10^{-9} pCi/L (^{99}Tc, ^{126}Sn and ^{129}I), the corresponding inventories, Federal MCLs, beta/photon dose rate equivalent, and groundwater pathway dose rate to an all-pathways representative person associated with residual waste left after retrieval (both average and 95% UCL inventory estimates).

Simulated groundwater concentration levels for the selected analytes indicate that the impacts from residual waste left in tank AX-103 after retrieval are 2 to 3 orders of magnitude below the EPA's derived concentrations for the MCL. Beta/photon dose rate equivalents from these three radionuclides are 2 to 3 orders of magnitude below the 4 mrem/yr regulatory standard. If non-detected results are considered and evaluated at one-half the detection limit, ^{99}Tc, ^{126}Sn and ^{129}I are still over 1×10^{-9} pCi/L and, of the non-detects, only ^{79}Se has a peak fenceline concentration greater than 1×10^{-9} pCi/L: 2.29×10^{-3} pCi/L (average inventory) and 6.97×10^{-3} pCi/L (upper-bound inventory). There is an insignificant increase in the peak beta/photon dose rate equivalent from the addition of ^{79}Se. The peak total beta/photon dose rate equivalent is 2 orders of magnitude below the regulatory standard, even when using upper-bound inventories with non-detects at one-half the detection limit.

The peak total groundwater pathway dose rate to an all-pathways representative person using the average inventory without non-detects is 7.5×10^{-3} mrem/yr, which is over 3 orders of magnitude lower than the regulatory standard of 25 mrem/yr. The primary contributor to this dose rate is ^{99}Tc, which contributes over 99% of the dose rate until about 7,000 years post-closure when ^{129}I groundwater concentration begins to increase. At the end of the simulation timeframe, ^{129}I is contributing about 40% of the total dose rate. Tin-126 contributes a very small amount of the total dose-rate at the end of the simulation. When using the most conservative inventory estimates (upper-bound inventories with non-detects evaluated at half the detection limit), the groundwater pathway dose rate is still 3 orders of magnitude below the regulatory standard. With these inventories, ^{79}Se becomes a contributor to total dose rate, contributing about 3% of the total dose rate at the end of the simulation. The atmospheric pathway of the all-pathways analysis is not performed in this EMCF based on a screening reported in RPP-CALC-64515, *Air Pathway Screening Evaluation for Single Shell Tank Residuals*. The radon evaluation was also not performed for this EMCF based on a screening reported in RPP-CALC-64554, *Radon Pathway Screening Evaluation for Single Shell Tank Residuals*.

Table 7-1. Estimated Groundwater Concentrations and Radiological Dose at Peak Year for Technetium-99, Tin-126 and Iodine-129 from Residual Inventories in Single-Shell Tank 241-AX-103.

Analyte	Above Detection Limits in Residual Waste	Inventory (Curies)	Peak Year (Years Post-Closure)	Waste Management Area A-AX Fenceline Concentration (pCi/L)[a]	K_d[b] (mL/g)	Derived Concentration for the Federal Maximum Concentration Level (pCi/L)	Beta/Gamma Dose Rate Equivalent (mrem/year)	Radiological Dose Rate – Groundwater Pathway (mrem/year)
Average Inventory Case								
Tc-99	Yes	7.70E-01	2,860	1.83E+00	0	900	8.12E-03	6.94E-03
I-129	Yes	6.66E-03	10,000	4.55E-03	0.2	1	1.82E-02	3.14E-03
Sn-126	Yes	1.34E+00	10,000	2.92E-09	0.5	--[d]	--[d]	9.04E-11
Upper-bound Inventory Case								
Tc-99	Yes	1.19E+00	2,860	2.82E+00	0	900	1.25E-02	1.07E-02
I-129	Yes	1.17E-02	10,000	7.98E-03	0.2	1	3.19E-02	5.50E-03
Sn-126	Yes	2.27E+00	10,000	4.95E-09	0.5	--	--[d]	1.53E-10
Regulatory Standard (Beta/Photon Emitter Dose)							**4**[e]	**25**[f]
Checker Review: Kearn Patrick Lee								

[a] GoldSim® Element: \Transport_Abstraction_Model\SZ_Fence_Conc\Peak_GW_Conc

[b] K_ds shown are for sand, which is the dominant sediment type. K_ds for silt are the same value except for ^{126}Sn which has a value of 1.5 mL/g. These K_d values do not include gravel correction, which would lower any non-zero values.

[c] GoldSim® element: \Exposure_Scenarios\Drinking_Water_Standards\Beta_Photon\Beta_Photon_Dose_by_Analyte

[d] "--" means no maximum concentration level or EPA derived concentration.

[e] 40 CFR 141.66, "Maximum Contaminant Levels for Radionuclides."

[f] DOE O 435.1, *Radioactive Waste Management*.

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In addition to dose rate results, the peak groundwater concentrations for other radionuclides are compared to the applicable drinking water standard specified in Title 40, *Code of Federal Regulations* (CFR), Part 141, "National Primary Drinking Water Regulations" (40 CFR 141), Subpart G—National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels, § 141.66, Maximum contaminant levels for radionuclides (40 CFR 141.66). The drinking water standard for total radium is 5 pCi/L; peak simulated concentrations of total radium are more than 20 orders of magnitude lower than this level. Peak concentrations for alpha emitters are also at least 20 orders of magnitude lower than the 15 pCi/L specified for gross alpha emitters in 40 CFR 141.66. The peak concentration for all uranium isotopes is less than 1×10^{-14} µg/L; therefore, the impact to groundwater from uranium is well below the 30 µg/L standard in 40 CFR 141.66.

7.1.1.2 Hazardous Chemical Impacts. Table 7-2 shows estimated inventory and related peak fenceline concentrations, Federal MCLs, CLARC MTCA Method A or B groundwater cleanup levels, and HQs associated with detected chemicals in residual waste left after retrieval.

Owing to its affinity to be sorbed on Hanford sediments, uranium from tank AX-103 residual waste does not arrive in groundwater at the WMA A-AX fenceline until the end of the period of analysis, only reaching ~2×10^{-15} µg/L at 10,000 years after closure.

The hexavalent chromium groundwater concentration at the WMA fenceline is 2.1×10^{-3} µg/L when using both the average and 95% UCL inventories. Chromium solubility in the residual waste pore water is constrained by a solubility limit developed from observations made for WMA C through multi-year leaching tests and identification of mineral phases. The effect of this solubility limit is that the concentration in the pore water remains steady at the solubility limit until the inventory is depleted. Therefore, chromium release from the tank into the vadose zone is the same regardless of whether the average or 95% UCL concentration is used until the inventory is depleted. This is 5 orders of magnitude below the MTCA Method B cleanup level for hexavalent chromium of 48 µg/L and 4 orders of magnitude below the WAC 173-201A-240, "Toxic Substances" ambient water quality criteria of 10 µg/L. Using the mass-balance model from EPA/600/R-15/271 for inhalation while showering, the peak HQ at the fenceline would be 4.6×10^{-5}, which is 5 orders of magnitude below the regulatory standard of 1. Using both an oral cancer slope factor of 0.5 $(mg/kg\text{-}d)^{-1}$ and the risk equation from Section H.4.1 of RPP-ENV-58813, Rev. 1, as well as the mass-balance model from EPA/600/R-15/271 for inhalation while showering, the peak cancer risk at the fenceline would be 1.9×10^{-8}, which is about 50 times below the regulatory standard of 1×10^{-6}. The peak hexavalent chromium groundwater concentration is 22 times lower than the CLARC MTCA Method B (cancer) cleanup level for hexavalent chromium (4.6×10^{-2} µg/L).

Trivalent chromium [Cr(III)] has a peak fenceline groundwater concentration of 8.3×10^{-5} µg/L when using both the average and 95% UCL inventories. The HQ of trivalent chromium at the fenceline using the residual inventory is 3.7×10^{-9}, 9 orders of magnitude below the regulatory standard of 1.

Table 7-2. Hazard Quotient and Groundwater Concentrations at Peak Year for Key Chemical Constituents Related to Residual Inventories in Single-Shell Tank 241-AX-103 Based on Best-Basis Inventory. (2 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kilograms)	Time of Peak (Years Post-Closure)	Waste Management Area A-AX Fenceline Concentration (µg/L)[a]	K_d[b] (mL/g)	Federal Maximum Concentration Level (µg/L)	CLARC[c] MTCA Method A or B (non-cancer) Groundwater Cleanup Levels (µg/L)	Hazard Quotient Residential Tap Water Scenario[d]	Cancer Risk Residential Tap Water Scenario[d]
Average Inventory Case									
Trivalent Chromium	Yes	1.99E+02	9,970	8.34E-05	0	100[e]	24,000	3.67E-09	0.00E+00
Hexavalent Chromium[f]	Yes	5.32E+00	9,740	2.06E-03	0	--[g]	48	4.58E-05	1.90E-08
Cyanide	Yes	7.71E-02	2,350	1.77E-03	0	200	5	1.21E-03	0.00E+00
Fluoride	Yes	1.38E+01	2,440	2.94E-01	0[h]	4,000	960	3.64E-04	0.00E+00
Nitrate	Yes	4.21E+01	2,350	9.67E-01	0	44,300[i]	115,100[i]	6.73E-06	0.00E+00
Nitrite	Yes	3.05E+01	2,350	7.01E-01	0	3,300[i]	5,260[i]	1.15E-04	0.00E+00
Nitrate-N	Yes	9.51E+00	2,350	2.18E-01	0	10,000	26,000	6.73E-06	0.00E+00
Nitrite-N	Yes	9.29E+00	2,350	2.13E-01	0	1,000	1,600	1.15E-04	0.00E+00
Upper-bound Inventory Case									
Trivalent Chromium	Yes	3.57E+02	9,830	8.34E-05	0	100	24,000	3.67E-09	0.00E+00
Hexavalent Chromium	Yes	8.01E+00	9,820	2.06E-03	0	--	48	4.58E-05	1.90E-08
Cyanide	Yes	1.15E-01	2,350	2.64E-03	0	200	5	1.80E-03	0.00E+00
Fluoride	Yes	2.51E+01	2,440	5.35E-01	0	4,000	960	6.61E-04	0.00E+00
Nitrate	Yes	1.28E+02	2,350	2.94E+00	0	44,300	115,100	2.05E-05	0.00E+00

Table 7-2. Hazard Quotient and Groundwater Concentrations at Peak Year for Key Chemical Constituents Related to Residual Inventories in Single-Shell Tank 241-AX-103 Based on Best-Basis Inventory. (2 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kilograms)	Time of Peak (Years Post-Closure)	Waste Management Area A-AX Fenceline Concentration (µg/L)[a]	K_d[b] (mL/g)	Federal Maximum Concentration Level (µg/L)	CLARC[c] MTCA Method A or B (non-cancer) Groundwater Cleanup Levels (µg/L)	Hazard Quotient Residential Tap Water Scenario[d]	Cancer Risk Residential Tap Water Scenario[d]
Nitrite	Yes	4.19E+01	2,350	9.63E-01	0	3,300	5,300	1.59E-04	0.00E+00
Nitrate-N	Yes	2.89E+01	2,350	6.64E-01	0	10,000	26,000	2.05E-05	0.00E+00
Nitrite-N	Yes	1.28E+01	2,350	2.93E-01	0	1,000	1,600	1.59E-04	0.00E+00
Regulatory Standard								**1**	**1.00E-06**
Checker Review: Kearn Patrick Lee									

EPA = U.S. Environmental Protection Agency MTCA = *Model Toxics Control Act*

[a] GoldSim® element: \Transport_Abstraction_Model\SZ_Fence_Conc\Peak_GW_Chem_Conc_fence

[b] K_ds shown are for sand, which is the dominant sediment type. K_ds for silt are the same value except for fluoride which has a value of 0.05 mL/g. These K_d values do not include gravel correction, which would lower any non-zero values.

[c] January 2023 Cleanup Levels and Risk Calculation (CLARC) master spreadsheet was retrieved from https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables on May 8, 2023.

[d] All exposure scenarios are described in RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*. GoldSim® element: \Exposure_Scenarios\Residential_Tap_Water_Scenario\Risk_Calculation_Results\AX_NonRad_HQ_Peak_by_Analyte

[e] Federal maximum contaminant level is for total chromium and is used for comparison because trivalent chromium has no Federal maximum contaminant level.

[f] Hexavalent chromium is the only carcinogenic chemical in this analysis. The CLARC Washington State *Model Toxics Control Act* (MTCA) (*Revised Code of Washington* 70A.305, "Hazardous Waste Cleanup—Model Toxics Control Act") Method B (cancer) cleanup level is 4.6×10^{-2} µg/L.

[g] "--" means no maximum concentration level.

[h] Fluoride has a K_d of 0.05 mL/g in silt. This affects transport through the Cold Creek unit silt hydrostratigraphic unit, which is a small fraction of the total distance between the bottom of tank 241-AX-103 and the water table.

[i] A derived limit for nitrate was calculated from the maximum contaminant level reported in 40 CFR 141, "National Primary Drinking Water Regulations" (10 mg/L) for nitrate as nitrogen (NO_3^--N) using the mass fraction of nitrogen in nitrate. The mass fraction of nitrogen in nitrate = mol wt N/mol wt NO_3^- = (14 g/mol)/(62 g/mol) = 0.226. The derived limit for nitrate = (10 mg/L NO_3^--N) × (1 mg NO_3^-/0.226 mg NO_3^--N) = 44.3 mg NO_3^-/L. The converted limit is often reported as 45 mg/L. An equivalent conversion was applied to the MTCA Method B groundwater limit to report the value in the calculated units, µg nitrate per liter groundwater. A similar conversion was necessary for nitrite; the tabulated values are in units of µg nitrite per liter groundwater.

1

The peak fenceline groundwater concentration at the WMA A-AX fenceline for nitrate is over 4 orders of magnitude below the Federal MCL and about 5 orders of magnitude below the MTCA Method B cleanup level when using the average residual waste inventory. The nitrite concentration using the same inventory is over 3 orders of magnitude below the Federal MCL and MTCA Method B cleanup level. Furthermore, the HQs are over 4 orders of magnitude below the regulatory standard of 1.0. Using the 95% UCL inventory for nitrate produces a peak fenceline groundwater concentration that is 4 orders of magnitude below the Federal MCLs, while using that inventory for nitrite produces a peak groundwater concentration that is over 3 orders of magnitude less than the Federal MCL. Groundwater concentrations from using the 95% UCL inventory for nitrate and nitrite are both 4 orders of magnitude below their respective Washington State cleanup levels. Estimated HQs for nitrate are 5 orders of magnitude below the regulatory standard of 1.0, and 3 orders of magnitude below for nitrite. After retrieval, groundwater hazard impacts from nitrate and nitrite are significantly below the regulatory standards.

When using the average inventory, the peak fenceline groundwater concentration at the WMA A-AX fenceline for fluoride is more than 4 orders of magnitude below its Federal MCL and 3 orders of magnitude below the MTCA Method B non-cancer limit. Fluoride's estimated HQ is 3 orders of magnitude below the regulatory standard of 1.0.

Cyanide has a peak fenceline groundwater concentration at the WMA A-AX fenceline that is 5 orders of magnitude below its Federal MCL and 3 orders of magnitude below the MTCA Method B non-cancer limit. Cyanide's estimated HQ is about 3 orders of magnitude below the regulatory standard of 1.0.

If non-detected results are considered and evaluated at one-half the detection limit, cobalt, selenium, and tin are added. These additional chemicals have HQs less than 3×10^{-5} considering both the average and upper-bound inventories. Only cobalt has a cancer risk, which is less than 1×10^{-13} considering both the average and upper-bound inventories.

7.1.2 Inadvertent Intruder Dose Impacts

This analysis evaluates the radiological doses and dose rates from hypothetical inadvertent intrusion scenarios for an acute Well Driller scenario and chronic Suburban Garden, Rural Pasture and Commercial Farm scenarios. This section presents detailed results from these scenarios, including contributions of exposure pathways and contributing radionuclides. Of all the inadvertent intruder scenarios, the acute Well Driller scenario has among the fewest sources of uncertainty because of the absence of environmental transport and partitioning mechanisms, such as crop uptake or fodder uptake, that are found in the chronic scenarios.

Inadvertent intruder doses and dose rates are estimated between 500 and 1,000 years post-closure. Intrusion into a tank without recognition by the driller before 500 years is not considered a credible event (RPP-ENV-61497) due to the thick grout layer poured into the tank to isolate the waste. NUREG-1854, *NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations – Draft Final Report for Interim Use* concludes that for deeper wastes when robust intruder barriers exist, it is appropriate to assume

that intrusion is prevented for at least 500 years. Additionally, the Modified RCRA Subtitle C Barrier design described by DOE/RL-93-33, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas* is assumed to meet the requirements for disposal of Class C waste established in Title 10, CFR, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste" (10 CFR 61), Subpart D—Technical Requirements for Land Disposal Facilities, § 61.55, Waste classification. This assumption is made because "the thicknesses of one or more of the barrier layers (e.g., grading fill [Layer 8] or topsoil [Layers 1 and/or 2]) could be modified (i.e., increased) to conform to" a 5-m (16.4-ft) depth that would preclude an excavation scenario into the waste.

The acute Well Driller exposure scenario for the Hanford Site assumes that, after a loss of institutional control and societal memory about the Hanford Site, a well is drilled through the tank to the water table and the driller is exposed to radiation from the drill cuttings brought to the surface. The well driller's exposure to drill cuttings is assumed for a total of five days (8 hours per day for a total of 40 hours). The dose is calculated by assuming that the cuttings are uniformly spread across the drill pad and are not diluted by mixing with clean soil on the drill pad. The chronic Suburban Garden exposure scenario for the Hanford Site assumes that a well is drilled through the tank at a future date, bringing drill cuttings containing contaminated material to the surface. The drill cuttings are distributed on the soil surface of a garden, thereby allowing an individual living at the site to become chronically exposed over a lifetime. The garden is used to provide 25% of the daily vegetable diet for a family of four living in the home. In addition to exposure from fruit and vegetable consumption, the resident is exposed by incidental soil ingestion, inhalation of the soil particulates, and external exposure. This exposure scenario is described in RPP-ENV-58813.

Table 7-3 shows the peak post-closure dose to a receptor from tank AX-103 residual waste using different inadvertent intruder exposure scenarios.

Using both the average and 95% UCL inventories, the estimated dose or dose rate to an inadvertent intruder is below the corresponding regulatory standards (500 mrem acute dose for the Well Driller scenario and 100 mrem/year chronic dose rate for the other exposure scenarios) during the performance period of between 500 and 1,000 years post-closure. Using the average inventory and only including radionuclides detected in the collected samples, a maximum acute exposure dose of 4.5 mrem is estimated at 500 years post-closure. Using the 95% UCL inventory and only including radionuclides detected in the collected samples, a maximum acute exposure dose of 7.3 mrem is estimated at 500 years post-closure. Using the average inventory, a maximum chronic exposure dose rate of 1.1 mrem/yr is estimated at 500 years post-closure (Suburban Garden scenario). Using the 95% UCL inventory, a maximum chronic exposure dose rate of 1.8 mrem/yr is estimated at 500 years post-closure (Suburban Garden scenario).

Table 7-4 shows the relative fraction of exposure pathways contributing to total dose or dose rate for each intruder scenario. These pathway contributions are evaluated at the year of peak potential exposure (i.e., 500 years post-closure). Overall dose decreases with the passage of time, and because of differing decay rates between radionuclides contributing to dose or dose rate, the pathway contribution fractions may change over time as well. The contributions of the various exposure pathways to the exposure scenarios are about the same when using either

inventory. The soil inhalation pathway contributes the most dose in the Well Driller scenario, while the external exposure pathway contributes the highest dose rate in the Rural Pasture and Commercial Farm scenarios. The Suburban Garden scenario gets most of the total dose rate from the vegetable ingestion exposure pathway.

Table 7-3. Potential Future Inadvertent Intruder Dose for Residual Waste in Tank 241-AX-103 for All Intruder Scenarios.

Years After Closure:	500	600	700	800	900	1,000
Calendar Year:	**2550**	**2650**	**2750**	**2850**	**2950**	**3050**
Average Inventory Case						
Well Driller (mrem)[1]	4.53E+00	4.29E+00	4.08E+00	3.91E+00	3.76E+00	3.63E+00
Rural Pasture (mrem/year)[2]	8.66E-01	7.82E-01	7.53E-01	7.32E-01	7.16E-01	7.01E-01
Suburban Garden (mrem/year)[2]	1.12E+00	1.05E+00	1.00E+00	9.64E-01	9.30E-01	9.01E-01
Commercial Farm (mrem/year)[2]	7.37E-03	7.08E-03	6.85E-03	6.65E-03	6.48E-03	6.33E-03
95% Upper Confidence Level Inventory Case						
Well Driller (mrem)[1]	7.33E+00	6.91E+00	6.56E+00	6.26E+00	6.00E+00	5.78E+00
Rural Pasture (mrem/year)[2]	1.42E+00	1.29E+00	1.24E+00	1.20E+00	1.17E+00	1.15E+00
Suburban Garden (mrem/year)[2]	1.81E+00	1.70E+00	1.61E+00	1.54E+00	1.49E+00	1.44E+00
Commercial Farm (mrem/year)[2]	1.21E-02	1.16E-02	1.12E-02	1.09E-02	1.06E-02	1.03E-02
Checker Review: Kearn Patrick Lee						

[1] Regulatory Standard = 500 mrem

[2] Regulatory Standard = 100 mrem/year

GoldSim® element: \Exposure_Scenarios\DOE_Exposure_Scenarios\Intruder_Dose_Calc\Intruder_Results\

Table 7-5 illustrates how eight key radionuclides contribute to the majority of dose or dose rate in each exposure scenario for the average inventory case. The table shows the percentage of dose or dose rate that each radionuclide contributes in both the primary exposure pathway and the total dose for each exposure scenario at the time of peak potential exposure (500 years post-closure). Plutonium-239 contributes the majority of dose or dose rate for every primary exposure pathway as shown in Table 7-5. Plutonium-239 is also the primary contributor to the total Well Driller dose and Suburban Garden dose rate. Americium-241 is the next important key contributing radionuclide, followed by ^{240}Pu. The acute Well Driller and chronic Commercial Farm scenarios have only ^{241}Am, ^{239}Pu, ^{240}Pu and ^{126}Sn making up more than 98% of both the total dose/dose rate and primary pathway dose/dose rate. Strontium-90 contributes a negligible amount of dose/dose rate to the Well Driller and Commercial Farm scenarios. The chronic Suburban Garden scenario includes these five radionuclides, but ^{90}Sr is a more substantial contributor, and ^{99}Tc contributes more than 2% of the total dose rate. Tin-126 contributes a substantial fraction of the total dose/dose rate and not the primary pathway's

dose/dose rate in all exposure scenarios. This is because it is the top contributor to the External Exposure pathway dose rate. The chronic Rural Pasture scenario is different from the other three scenarios in that ^{129}I, ^{63}Ni, ^{90}Sr and ^{126}Sn are significant contributors to the total dose rate, but not to the primary pathway's dose rate. This is because ^{63}Ni, ^{90}Sr and ^{129}I are the primary contributors to the Milk Ingestion pathway's dose rate, while ^{126}Sn contributes 91% of the External Exposure pathway's dose rate, and none of these radionuclides appreciably contribute to the remaining exposure pathways' dose rates.

Table 7-4. Relative Fraction of Exposure Pathways to Total Dose or Dose Rate at Year of Peak Potential Exposure for Inadvertent Intruder Scenarios.

Exposure Pathway	External Exposure	Soil Inhalation	Soil Ingestion	Milk Ingestion	Vegetable Ingestion
Average Inventory Case					
Well Driller	0.23	**0.65**	0.12	N/A	N/A
Rural Pasture	**0.49**	0.15	0.23	0.12	N/A
Suburban Garden	0.23	0.07	0.14	N/A	**0.57**
Commercial Farm	**0.52**	0.22	0.27	N/A	N/A
95% Upper Confidence Level Inventory Case					
Well Driller	0.24	**0.64**	0.12	N/A	N/A
Rural Pasture	**0.51**	0.15	0.22	0.12	N/A
Suburban Garden	0.24	0.07	0.13	N/A	**0.56**
Commercial Farm	**0.53**	0.21	0.26	N/A	N/A
Checker Review: Kearn Patrick Lee					

N/A = Not applicable

If radionuclides with non-detect values are considered, analytes flagged as a non-detect were evaluated at one-half the detection limit in accordance with EPA/540/1-89/002. Inventories of constituents not detected in the samples were calculated using the analytical method detection limits. Therefore, these specific inventories are considered conservative estimates. Detection limits reported for some radionuclides are high compared to template-based concentrations used in the BBI (RPP RPT-64056). Using the non-detect values (i.e., one-half the detection limit) in the average inventory, all doses and dose rates for all exposure scenarios at the time of peak potential exposure (500 years post-closure) are below their respective regulatory standards. When using non-detect values in the 95% UCL inventory (a hypothetical case for non-detected constituents since the concentration cannot be above the detection limit evaluated for the average inventory case) all doses and dose rates for all exposure scenarios at the time of peak potential exposure (500 years post-closure) are below their respective regulatory standards.

Table 7-5. Contribution of Key Radionuclides to Primary Exposure Pathway and Total Exposure by Exposure Scenario at the Time of Peak Potential Exposure: Average Inventory Case.

Exposure Pathway	Am-241	I-129	Ni-63	Pu-239	Pu-240	Sr-90	Sn-126	Tc-99	Contribution Sum
Well Driller									
Soil Inhalation	41.81%	--	--	46.56%	10.94%	--	--	--	99.33%
Total	33.73%	--	--	35.74%	8.40%	0.01%	20.93%	--	98.81%
Rural Pasture									
External Exposure	6.16%	--	--	0.05%	--	0.03%	90.85%	--	97.10%
Total	19.14%	0.18%	1.00%	18.04%	4.24%	6.65%	45.93%	2.75%	97.94%
Suburban Garden									
Vegetable Ingestion	37.37%	0.02%	0.03%	42.39%	9.96%	2.56%	2.93%	3.60%	98.87%
Total	31.07%	0.01%	0.01%	33.71%	7.92%	1.47%	22.30%	2.05%	98.55%
Commercial Farm									
External Exposure	7.45%	--	--	0.05%	--	0.03%	89.62%	--	97.15%
Total	23.85%	--	--	22.51%	5.29%	0.03%	46.51%	--	98.18%
Checker Review: Kearn Patrick Lee									

"--" indicates that the radionuclide contributes less than 0.01% of the dose or dose rate in this exposure pathway.

7.2 CONCLUSIONS

The future impacts on groundwater of the residual waste in tank AX-103 were evaluated using regulatory standards for groundwater. The estimated residual inventory results in an impact that is well below applicable standards.

The future impact from hypothetical inadvertent intrusion into the residual waste was evaluated using regulatory standards for acute and chronic exposure. Estimated acute doses and chronic dose rates from inadvertent intrusion into estimated residual waste inventories are well below the regulatory standards of 500 mrem (acute) and 100 mrem/yr (chronic). The estimated dose from intrusion into residual waste inventory in the acute Well Driller scenario is well below the acute regulatory standard of 500 mrem when considering either the average or the 95% UCL residual inventory. The estimated dose rates from residual waste inventory in all chronic scenarios are well below the chronic exposure standard of 100 mrem/yr when considering either the average or the 95% UCL residual inventory.

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ATTACHMENT 1

SOFTWARE INSTALLATION AND CHECKOUT FORMS

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: GoldSim Pro w/Radionuclide Transport Software Version No.: 12.1

EXECUTABLE INFORMATION:

2. Executable Name (include path):

[redacted] GoldSim.exe

3. Executable Size (bytes): 2661040

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

Not Applicable (Commercial Installer)

5. Operating System (include version number):

Not Applicable (Commercial Installer)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

WF42946

7. Operating System (include version number):

Windows 10 Enterprise, Version 1909, Build 18363.900

8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted] FirstModel.gsm

10. Procedure(s):

CHPRC-00224, Section 3.3

11. Libraries:

Radionuclide Transport Module

12. Input Files:

Not Applicable

13. Output Files:

Not Applicable

14. Test Cases:

GS-ITC-1

15. Test Case Results:

Results visually compared to those provided in section 3.3. The results match the example

16. Test Performed By: David J. Watson

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: GoldSim Pro w/Radionuclide Transport Software Version No.: 12.1

Prepared By:

19.	WILLIAM NICHOLS (Affiliate) Digitally signed by WILLIAM NICHOLS (Affiliate) Date: 2020.06.23 11:58:41 -07'00'		
	Software Owner (Signature)	Print	Date

20. Test Personnel:	David J. Watson Digitally signed by David J. Watson Date: 2020.06.23 11:54:48 -07'00'	David J. Watson	23 June 2020
	Sign	Print	Date
	Sign	Print	Date
	Sign	Print	Date

Approved By:

21.	Not required per CHPRC-00175, Rev. 3, Section 12.3		
	Software SME (Signature)	Print	Date

SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION

1. Software Name: GoldSim Pro with Radionuclide Transport Version No.: 12.1.3

EXECUTABLE INFORMATION

2. Executable Name *(include path)*:
[redacted]GoldSim.exe

3. Executable Size *(bytes)*: 2,661,040

COMPILATION INFORMATION

4. Hardware System *(i.e., property number or ID)*:
Acquired software, not applicable.

5. Operating System *(include version number)*:
Acquired software, not applicable.

INSTALLATION AND CHECKOUT INFORMATION

6. Hardware System *(i.e., property number or ID)*:
WF42946

7. Operating System *(include version number)*:
Windows 10 Enterprise, Version 22H2, Build 19045.3086

8. Open Problem Report? ☐ Yes ☒ No PR/CR No.: _____

TEST CASE INFORMATION

9. Directory/Path:
[redacted]\WF42946\v12.1.3\

10. Procedures:
RPP-PLAN-65454 Section 2.9.1

11. Libraries:
None

12. Input Files:
[redacted]\Test_Cases_v11.1.5\FRS-1_Test_Case.gsm

13. Output Files:
[redacted]\WF42946\v12.1.3\

14. Test Cases:
FRS-1_Test_Case.gsm

15. Test Case Results:
[redacted]\WF42946\v12.1.3\Test_Cases_v12.1.3\Test Case FRS-1 Verification.xlsx

16. Test Performed By: David J. Watson

17. Test Results: ☒ Satisfactory, Accepted for Use ☐ Unsatisfactory

18. Disposition *(include HISI update)*:
Run models for TC-1a/b and TC-1c archived at directory path identified above. This includes run logs for the test cases.

SOFTWARE INSTALLATION AND CHECKOUT FORM (Continued)

19. Prepared By *(Software Owner)*:

Kearn Patrick Lee
Print First and Last Name

Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.27 14:31:17 -07'00'
Signature / Date

20. Test Personnel:

Title: Scientist

David J. Watson
Print First and Last Name

Watson, David J Digitally signed by Watson, David J Date: 2023.06.27 13:50:57 -07'00'
Signature / Date

Title:

Print First and Last Name

Signature / Date

Title:

Print First and Last Name

Signature / Date

21. Approved By *(Software SME)*:

Kearn Patrick Lee
Print First and Last Name

Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.27 14:31:57 -07'00'
Signature / Date

ATTACHMENT 2

TANK RESIDUAL WASTE INVENTORIES AND VOLUMES

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Table Att-2-1 presents the average and upper-bound (95% UCL) inventories of constituents of concern remaining in tank 241-AX-103. These are the inventories that were initially provided and before they were modeled in GoldSim® to account for progeny ingrowth. Table Att-2-2 presents the radioactive constituents of concern decay corrected to January 1, 2050, from the BBI decay date of January 1, 2022. If radionuclides with non-detect values are considered, analytes flagged as a non-detect can be evaluated at one-half the detection limit in accordance with EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) Interim Final*. Table Att-2-3 presents radioactive constituents of concern that were flagged as non-detects, and their decay products, decay corrected to January 1, 2050.

Table Att-2-1. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[a]
1,1,1-Trichloroethane	71-55-6	<	2.79E-04	8.48E-04	kg
1,1,2,2-Tetrachloroethane	79-34-5	<	1.22E-04	3.71E-04	kg
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	<	1.22E-04	3.71E-04	kg
1,1,2-Trichloroethane	79-00-5	<	3.50E-04	1.06E-03	kg
1,1-Dichloroethene	75-35-4	<	1.64E-04	4.99E-04	kg
1,2,4-Trichlorobenzene	120-82-1	<	1.98E-04	6.02E-04	kg
1,2-Dichlorobenzene	95-50-1	<	1.18E-04	3.59E-04	kg
1,2-Dichloroethane	107-06-2	<	2.44E-04	7.42E-04	kg
1,4-Dichlorobenzene	106-46-7	<	1.29E-04	3.92E-04	kg
^{113m}Cd	378253-44-2	—	1.86E-01[b]	5.64E-01[c]	Ci
^{125}Sb	14234-35-6	<	1.39E+01	4.23E+01	Ci
^{126}Sn	15832-50-5	—	1.34E+00	2.27E+00	Ci
^{129}I	15046-84-1	—	6.66E-03	1.17E-02	Ci
^{134}Cs	13967-70-9	<	2.95E+01	8.97E+01	Ci
^{137}Cs	10045-97-3	—	3.08E+03	5.35E+03	Ci
^{137m}Ba	N/A	—	2.91E+03	5.06E+03	Ci
^{14}C	14762-75-5	—	7.58E-03	1.38E-02	Ci
^{151}Sm	15715-94-3	—	2.66E+03	4.41E+03	Ci
^{152}Eu	14683-23-9	<	1.12E+01	3.40E+01	Ci
^{154}Eu	15585-10-1	—	1.48E+01	2.25E+01	Ci
^{155}Eu	14391-16-3	<	1.36E+01	4.13E+01	Ci

Table Att-2-1. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[a]
1-Butanol	71-36-3	<	5.76E-03	1.75E-02	kg
2,4,5-Trichlorophenol	95-95-4	<	6.46E-02	1.96E-01	kg
2,4,6-Trichlorophenol	88-06-2	<	6.50E-02	1.98E-01	kg
2,4-Dinitrotoluene	121-14-2	<	6.55E-02	1.99E-01	kg
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	128-37-0	<	6.22E-02	1.89E-01	kg
^{226}Ra	13982-63-3	<	7.14E+01	2.17E+02	Ci
^{227}Ac	14952-40-0	—	1.24E-06[b]	3.76E-06[c]	Ci
^{228}Ra	15262-20-1	—	7.34E-04	1.33E-03	Ci
^{228}Th	14274-82-9	—	2.06E-01	3.65E-01	Ci
^{229}Th	15594-54-4	<	3.00E-01	9.12E-01	Ci
^{230}Th	14269-63-7	<	2.89E-02	8.79E-02	Ci
^{231}Pa	14331-85-2	<	3.38E+00	1.03E+01	Ci
^{232}Th	N/A	—	7.34E-04	1.33E-03	Ci
^{232}U	14158-29-3	—	1.39E-06	2.34E-06	Ci
^{233}U	13968-55-3	—	4.11E-02	7.32E-02	Ci
^{234}U	13966-29-5	<	3.95E-01	1.20E+00	Ci
^{235}U	15117-96-1	—	9.11E-04	1.52E-03	Ci
^{236}U	13982-70-2	<	4.12E-03	1.25E-02	Ci
^{237}Np	13994-20-2	—	1.49E-01	2.29E-01	Ci
^{238}Pu	13981-16-3	—	5.61E+00	8.94E+00	Ci
^{238}U	N/A	—	2.14E-02	3.58E-02	Ci
$^{239/240}$Pu	N/A	—	3.56E+01	5.32E+01	Ci
^{239}Pu	15117-48-3	—	2.86E+01	4.27E+01	Ci
^{240}Pu	14119-33-6	—	7.00E+00	1.05E+01	Ci
^{241}Am	14596-10-2	—	6.95E+01	1.21E+02	Ci
^{241}Pu	14119-32-5	—	2.48E+01	3.63E+01	Ci
^{242}Cm	15510-73-3	—	1.87E-01	3.25E-01	Ci
^{242}Pu	13982-10-0	<	6.92E-03	2.10E-02	Ci
$^{243/244}$Cm	N/A	—	5.36E-01	1.01E+00	Ci

Table Att-2-1. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[a]
^{243}Am	14993-75-0	—	3.01E-01	4.63E-01	Ci
^{243}Cm	15757-87-6	—	2.99E-02	5.63E-02	Ci
^{244}Cm	13981-15-2	—	5.18E-01	9.75E-01	Ci
2-Butanone	78-93-3	<	1.69E-03	5.14E-03	kg
2-Chlorophenol	95-57-8	<	5.62E-02	1.71E-01	kg
2-Ethoxyethanol	110-80-5	<	4.87E-02	1.48E-01	kg
2-Methylphenol	95-48-7	<	6.11E-02	1.86E-01	kg
2-Nitrophenol	88-75-5	<	5.82E-02	1.77E-01	kg
2-Nitropropane	79-46-9	<	2.09E-03	6.35E-03	kg
^{3}H	15086-10-9	<	7.93E-03	2.41E-02	Ci
4-Chloro-3-methylphenol	59-50-7	<	6.52E-02	1.98E-01	kg
4-Methyl-2-Pentanone	108-10-1	<	2.10E-03	6.38E-03	kg
4-Nitrophenol	100-02-7	<	6.01E-02	1.83E-01	kg
^{60}Co	10198-40-0	<	3.14E+00	9.55E+00	Ci
^{63}Ni	13981-37-8	—	8.79E+01	1.38E+02	Ci
^{79}Se	15758-45-9	<	1.09E-02	3.31E-02	Ci
^{90}Sr	10098-97-2	—	6.70E+04	9.86E+04	Ci
^{90}Y	10098-91-6	—	6.70E+04	9.86E+04	Ci
^{93m}Nb	378782-82-2	—	2.55E-01[b]	7.73E-01[c]	Ci
^{93}Zr	15751-77-6	—	4.52E-01[b]	1.37E+00[c]	Ci
^{94}Nb	14681-63-1	<	3.24E+00	9.85E+00	Ci
^{59}Ni	14336-70-0	—	1.08E+00[b]	3.27E+00[c]	Ci
^{99}Tc	14133-76-7	—	7.70E-01	1.19E+00	Ci
Acenaphthene	83-32-9	<	7.15E-02	2.17E-01	kg
Acetate	71-50-1	—	1.86E+00	2.70E+00	kg
Acetone	67-64-1	<	3.80E-03	1.16E-02	kg
Ag	7440-22-4	—	2.52E+01	4.38E+01	kg
Al	7429-90-5	—	4.15E+03	6.82E+03	kg

Table Att-2-1. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[a]
Aroclors (Total Polychlorinated Biphenyls)	1336-36-3	<	2.03E-02	6.17E-02	kg
As	7440-38-2	—	5.60E-01	9.17E-01	kg
B	7440-42-8	<	8.26E+00	2.51E+01	kg
Ba	7440-39-3	—	1.24E+01	1.95E+01	kg
Be	7440-41-7	<	1.65E+00	5.02E+00	kg
Benzene	71-43-2	<	1.54E-04	4.68E-04	kg
Benzo(a)pyrene	50-32-8	<	5.26E-02	1.60E-01	kg
Bi	7440-69-9	<	3.51E+00	1.07E+01	kg
Bis(2-ethylhexyl)phthalate	117-81-7	<	3.46E-01	1.05E+00	kg
Br	24959-67-9	<	8.35E-01	2.54E+00	kg
Butylbenzylphthalate	85-68-7	<	9.45E-02	2.87E-01	kg
Ca	7440-70-2	—	1.14E+02	1.55E+02	kg
Carbon disulfide	75-15-0	<	2.11E-04	6.41E-04	kg
Carbon tetrachloride	56-23-5	<	2.82E-04	8.57E-04	kg
Cd	7440-43-9	—	3.54E+00	6.07E+00	kg
Ce	7440-45-1	—	1.13E+01	1.84E+01	kg
Chlorobenzene	108-90-7	<	1.48E-04	4.50E-04	kg
Chloroform	67-66-3	<	1.83E-04	5.56E-04	kg
Cl	16887-00-6	—	1.27E+00	1.92E+00	kg
CN	57-12-5	—	7.71E-02	1.15E-01	kg
Co	7440-48-4	<	1.65E+00	5.02E+00	kg
Cr	7440-47-3	—	2.04E+02	3.65E+02	kg
Cresol (m & p)	1319-77-3	<	6.22E-02	1.89E-01	kg
Cu	7440-50-8	—	7.10E+00	1.14E+01	kg
Cyclohexanone	108-94-1	<	5.00E-02	1.52E-01	kg
Dibenz[a,h]anthracene	N/A	<	5.78E-02	1.76E-01	kg
Diethylphthalate	84-66-2	<	1.07E-01	3.25E-01	kg
Di-n-butylphthalate	84-74-2	<	4.52E-01	1.37E+00	kg
Di-n-octylphthalate	117-84-0	<	6.18E-02	1.88E-01	kg

Table Att-2-1. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[a]
Ethyl acetate	141-78-6	<	1.05E-03	3.19E-03	kg
Ethyl ether	60-29-7	<	3.07E-04	9.33E-04	kg
Ethylbenzene	100-41-4	<	1.92E-04	5.84E-04	kg
Eu	7440-53-1	<	2.17E+00	6.60E+00	kg
F	16984-48-8	—	1.38E+01	2.51E+01	kg
Fe	7439-89-6	—	2.09E+03	3.76E+03	kg
Fluoranthene	206-44-0	<	6.66E-02	2.02E-01	kg
Formate	12311-97-6	<	1.45E+00	4.41E+00	kg
Free OH	N/A	—	8.87E-02	1.36E-01	kg
Glycolate	666-14-8	<	4.39E-01	1.33E+00	kg
Hexachlorobenzene	118-74-1	<	7.43E-02	2.26E-01	kg
Hexachlorobutadiene	87-68-3	<	3.81E-04	1.16E-03	kg
Hexachloroethane	67-72-1	<	1.71E-04	5.20E-04	kg
Hexavalent Chromium[d]	18540-29-9	—	5.32E+00	8.01E+00	kg
Hg	7439-97-6	—	8.15E+00	1.27E+01	kg
K	7440-09-7	<	2.39E+01	7.27E+01	kg
Isobutanol	78-83-1	<	1.66E-01	5.05E-01	kg
La	7439-91-0	—	6.00E+00	1.06E+01	kg
Li	7439-93-2	<	3.41E+00	1.04E+01	kg
Methylenechloride	75-09-2	<	1.14E-04	3.47E-04	kg
Mg	7439-95-4	—	1.75E+01	2.42E+01	kg
Mn	7439-96-5	—	9.91E+01	1.54E+02	kg
Mo	7439-98-7	<	2.79E+00	8.48E+00	kg
Morpholine, 4-nitroso-	59-89-2	<	5.99E-02	1.82E-01	kg
Na	7440-23-5	—	8.94E+02	2.72E+03	kg
Naphthalene	91-20-3	<	6.00E-02	1.82E-01	kg
Nb	7440-03-1	<	1.96E+00	5.96E+00	kg
Nd	7440-00-8	—	1.78E+01	3.02E+01	kg
NH3	7664-41-7	—	7.93E-02	1.17E-01	kg

Table Att-2-1. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[a]
Ni	7440-02-0	—	5.46E+01	9.00E+01	kg
Nitrobenzene	98-95-3	<	5.60E-02	1.70E-01	kg
N-Nitrosodimethylamine	62-75-9	<	4.57E-02	1.39E-01	kg
N-Nitroso-di-n-propylamine	621-64-7	<	6.29E-02	1.91E-01	kg
NO_2	14797-65-0	—	3.05E+01	4.19E+01	kg
NO_3	14797-55-8	—	4.21E+01	1.28E+02	kg
Oxalate	338-70-5	—	2.81E+02	4.80E+02	kg
Pb	7439-92-1	—	1.76E+02	3.12E+02	kg
Pd	7440-05-3	<	5.78E+00	1.76E+01	kg
Pentachlorophenol	87-86-5	<	6.74E-02	2.05E-01	kg
Phenol	108-95-2	<	5.97E-02	1.81E-01	kg
PO_4	14265-44-2	—	3.51E+02	5.24E+02	kg
Pr	7440-10-0	—	3.55E+00	5.82E+00	kg
Pyrene	129-00-0	<	4.78E-02	1.45E-01	kg
Pyridine	110-86-1	<	3.88E-02	1.18E-01	kg
Rb	7440-17-7	<	2.65E+01	8.06E+01	kg
Rh	7440-16-6	—	2.92E+00	4.70E+00	kg
Ru	7440-18-8	—	3.67E+01	5.64E+01	kg
Sb	7440-36-0	—	1.20E-01	3.65E-01	kg
Se	7782-49-2	<	3.33E-01	1.01E+00	kg
Si	7440-21-3	<	9.10E+02	2.77E+03	kg
Sm	7440-19-9	—	3.73E+00	6.06E+00	kg
Sn	7440-31-5	<	3.41E+00	1.04E+01	kg
SO_4	14808-79-8	—	4.11E+01	6.79E+01	kg
Sr	7440-24-6	—	2.95E+00	4.09E+00	kg
Ta	7440-25-7	<	2.45E+01	7.45E+01	kg
Te	13494-80-9	<	5.00E+00	1.52E+01	kg
Tetrachloroethene	127-18-4	<	2.87E-04	8.72E-04	kg
Th	7440-29-1	—	6.67E+00	1.19E+01	kg

Table Att-2-1. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[a]
Thiosulfate	14383-50-7	<	7.91E-01	2.40E+00	kg
Ti	7440-32-6	—	2.86E+00	4.07E+00	kg
Tl	7440-28-0	<	3.20E+00	9.73E+00	kg
Toluene	108-88-3	<	1.51E-04	4.59E-04	kg
Trans-1,3-Dichloropropene	10061-02-6	<	3.42E-04	1.04E-03	kg
Tributyl phosphate	126-73-8	<	8.01E-02	2.44E-01	kg
Trichloroethene	79-01-6	<	1.54E-04	4.68E-04	kg
Trichlorofluoromethane	75-69-4	<	1.49E-04	4.53E-04	kg
Trivalent Chromium[e]	16065-83-1	N/A	1.99E+02	3.57E+02	kg
UTOTAL	N/A	—	6.44E+01	1.08E+02	kg
V	7440-62-2	<	1.96E+00	5.96E+00	kg
Vinyl chloride	75-01-4	<	2.53E-04	7.69E-04	kg
W	7440-33-7	—	4.11E+00	6.05E+00	kg
Xylene (m & p)	108-28-3M	<	4.18E-04	1.27E-03	kg
Xylene (o)	95-47-6	<	1.75E-04	5.32E-04	kg
Xylenes (total)	1330-20-7	<	5.93E-04	1.80E-03	kg
Y	7440-65-5	—	3.29E+00	5.03E+00	kg
Zn	7440-66-6	—	2.82E+00	4.29E+00	kg
Zr	7440-67-7	<	2.29E+00	6.96E+00	kg
Checker Review: Kearn Patrick Lee					

Source: RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*.

CAS = Chemical Abstract Services Ci = curie kg = kilogram N/A = not applicable

[a] Radionuclide concentrations are decay corrected to January 1, 2022.

[b] No post-retrieval analysis for this constituent. Estimated value from RPP-RPT-59854, *Derivation of Best-Basis Inventory for Tank 241-AX-103 as of April 1, 2023.*

[c] Calculated using the following equation: $UCL = \hat{I} + 2 \times \hat{I} \times RSD(\hat{I})$, where $\hat{I}$ is the inventory estimate and $RSD(\hat{I})$ is the RSD of the inventory estimate. The inventory RSD was calculated using: $RSD^2(\hat{I}) \cong RSD^2(\overline{C}) + RSD^2(D) + RSD^2(\hat{V})$, where $RSD^2(\hat{I})$ is the squared inventory RSD, $RSD^2(\overline{C})$ is 1, $RSD^2(D)$ is the squared average density RSD, and $RSD^2(\hat{V})$ is the squared total volume RSD.

[d] Hexavalent chromium inventories are in Appendix D of RPP-RPT-64056.

[e] Trivalent chromium is calculated by subtracting the hexavalent chromium mass from the total chromium mass.

1

Table Att-2-2. Inventory Estimates for Detected Radionuclides in Tank 241-AX-103 Residual Solids Decay-Corrected to January 1st, 2050 (Ci).

Radionuclide	Average Inventory	Upper-Bounding Inventory
^{241}Am	6.70E+01	1.16E+02
^{243}Am	3.00E-01	4.62E-01
^{14}C	7.55E-03	1.37E-02
^{113m}Cd	4.70E-02	1.42E-01
^{243}Cm	1.53E-02	2.89E-02
^{244}Cm	1.77E-01	3.34E-01
^{137}Cs	1.62E+03	2.81E+03
^{154}Eu	1.55E+00	2.35E+00
^{129}I	6.66E-03	1.17E-02
^{93m}Nb	3.85E-01	1.17E+00
^{59}Ni	1.08E+00	3.27E+00
^{63}Ni	7.24E+01	1.14E+02
^{237}Np	1.50E-01	2.30E-01
^{238}Pu	4.50E+00	7.17E+00
^{239}Pu	2.86E+01	4.27E+01
^{240}Pu	6.98E+00	1.04E+01
^{241}Pu	6.41E+00	9.38E+00
^{228}Ra	7.34E-04	1.33E-03
^{151}Sm	2.14E+03	3.55E+03
^{126}Sn	1.34E+00	2.27E+00
^{90}Sr	3.41E+04	5.03E+04
^{99}Tc	7.70E-01	1.19E+00
^{232}Th	7.34E-04	1.33E-03
^{232}U	1.05E-06	1.76E-06
^{233}U	4.11E-02	7.32E-02
^{235}U	9.12E-04	1.52E-03
^{238}U	2.14E-02	3.58E-02
^{93}Zr	4.52E-01	1.37E+00
Checker Review: Kearn Patrick Lee		

GoldSim® Elements: **Average_Inventory_2050**, **UCF95_Inventory_2050** (Live Model)

1

Table Att-2-3. Inventory Estimates for Non-Detect Radionuclides and their Decay Products in Tank 241-AX-103 Residual Solids Evaluated at One Half the Detection Limit and Decay-Corrected to January 1st, 2050 (Ci).

Constituent	Average Inventory	Upper-Bounding Inventory
^{227}Ac*	9.97E-01	3.03E+00
^{60}Co	3.95E-02	1.20E-01
^{152}Eu	1.34E+00	4.06E+00
^{155}Eu	1.15E-01	3.51E-01
^{3}H	8.21E-04	2.49E-03
^{231}Pa	1.69E+00	5.13E+00
^{210}Pb*	2.07E+01	6.28E+01
^{242}Pu	3.46E-03	1.05E-02
^{226}Ra	3.53E+01	1.07E+02
^{222}Rn*	3.53E+01	1.07E+02
^{79}Se	5.45E-03	1.66E-02
^{229}Th	1.50E-01	4.55E-01
^{230}Th	1.45E-02	4.41E-02
^{234}U	1.98E-01	6.01E-01
^{236}U	2.07E-03	6.27E-03
Checker Review: Kearn Patrick Lee		

* Radionuclide is a decay product and has no initial inventory.

GoldSim® Elements: **\Average_Inventory_2050**, **\UCF95_Inventory_2050** ("Half_Detection_Limit" scenario)

Table Att-2-4 contains residual waste volume estimates for tank 241-AX-103, as measured by the Residual Volume Measurement System (laser scanning system) and the 95% UCL volume.

Table Att-2-4. Tank 241-AX-103 Residual Waste Volume Estimates.

Waste Component	Actual Volume from Laser		95% UCL Volume[1]	
	ft^3	gal	ft^3	gal
Tank floor solids	687	5,139	947	7,081
Waste on walls and stiffener rings[2]	39	295	39	295
Waste on Air Lift Circulators[2]	51	383	51	383
Waste on Risers[2]	8	58	8	58
Total[3]	785	5,875	1,045	7,817
Checker Review: Kearn Patrick Lee				

Source: RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*.

1 ft^3 = 7.481 gal UCL = upper confidence level

[1] Per RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*, the actual volume is the measured Residual Volume Measurement System volume. One standard deviation for the Leica BLK360 is ±6mm. The 95% UCL is the actual plus two times the standard deviation.

[2] The 95% upper confidence level volume is assumed to be equal to the calculated volume for the wall, stiffener rings and waste in air lift circulators, risers, and instruments.

[3] Totals rounded to nearest gallon and cubic foot. Total sums may differ due to rounding.

BLK360 is a registered trademark of Leica Geosystems AG, Heerbrugg, Switzerland.

REFERENCES

EPA/540/1-89/002, 1989, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) Interim Final*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C.

RPP-23403, 2020, *Single-Shell Tank Component Closure Data Quality Objectives*, Rev. 7, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-59854, 2023, *Derivation of Best-Basis Inventory for Tank 241-AX-103 as of April 1, 2023*, Rev. 5, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-64056, 2023, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

ATTACHMENT 3

RESIDENTIAL TAP WATER SCENARIO PARAMETER INPUTS

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Table Att-3-1. Scenario-Specific Parameters Used for Residential Tap Water Scenario.

Parameter	Equation Symbol	Value	Units	GoldSim® Element Name	Reference
Exposure Frequency, Exposure Duration, and Exposure Time Variables					
Exposure frequency—resident	EF_r	350	days/year	EF_r	RPP-ENV-58813, Rev. 1, Table H-1
Exposure duration—resident	ED_r	26	year	ED_r	RPP-ENV-58813, Rev. 1, Table H-1
Exposure duration—adult resident	$ED_{r\text{-}a}$	20	year	ED_ra	RPP-ENV-58813, Rev. 1, Table H-1
Exposure duration—child resident	$ED_{r\text{-}c}$	6	year	ED_rc	RPP-ENV-58813, Rev. 1, Table H-1
Immersion event frequency	EV_r	1	events/day	EV_r	RPP-ENV-58813, Rev. 1, Table H-1
Resident exposure time	ET_r	24	hours/day	ET_r	RPP-ENV-58813, Rev. 1, Table H-1
Carcinogenic averaging time—resident	AT_c	25,550	days	AT_c	RPP-ENV-58813, Rev. 1, Table H-2
Noncarcinogenic averaging time—resident	AT_{nc}	2,190	days	AT_nc	RPP-ENV-58813, Rev. 1, Table H-2
Inhalation and Ingestion Rates					
Drinking water ingestion rate—adult resident	$IRW_{r\text{-}a}$	2.6	L/day	IRW_ra	RPP-RPT-60885, Rev. 1, Table B-9
Drinking water ingestion rate—child resident	$IRW_{r\text{-}c}$	0.77	L/day	IRW_rc	RPP-RPT-60885, Rev. 1, Table B-9
Immersion event time/Event duration—adult resident	$t_{r\text{-}a\text{-}event}$	0.71	hours/event	t_event_ra	RPP-ENV-58813, Rev. 1, Table H-1
Immersion event time/Event duration—child resident	$t_{r\text{-}c\text{-}event}$	0.54	hours/event	t_event_rc	RPP-ENV-58813, Rev. 1, Table H-1
Inhalation Pathway					
Andelman volatilization factor	K	0.5	L/m^3	K	RPP-ENV-58813, Rev. 1, Table H-1
Skin Surface Area and Dermal Absorbed Dose Variables					
Skin surface area—adult resident	$SA_{r\text{-}a}$	19,665	cm^2	SA_ra	RPP-RPT-60885, Rev. 1, Table B-9
Skin surface area—child resident	$SA_{r\text{-}c}$	6,365	cm^2	SA_rc	RPP-RPT-60885, Rev. 1, Table B-9
Body weight—adult	BW_a	81	kg	BW_a	RPP-RPT-60885, Rev. 1, Table B-9
Body weight—child	BW_c	15	kg	BW_c	RPP-ENV-58813, Rev. 1, Table H-2
Checker Review: Kearn Patrick Lee					

References:

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-60885, 2022, *Model Package Report System Model for the WMA A-AX Performance Assessment*, Rev. 1, Washington River Protection Solutions, LLC/Orano Federal Services, LLC/INTERA, Inc., Richland, Washington.

GoldSim® simulation software is a registered trademark of GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

REFERENCES

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-60885, 2022, *Model Package Report System Model for the WMA A-AX Performance Assessment*, Rev. 1, Washington River Protection Solutions, LLC/Orano Federal Services, LLC/INTERA, Inc., Richland, Washington.

ATTACHMENT 4

CONTAMINANT-SPECIFIC EXPOSURE PATHWAY PARAMETER INPUTS USED FOR THE RESIDENTIAL TAP WATER SCENARIO

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Table Att-4-1. Chemical-Specific Parameters Used for Residential Tap Water Scenario in the Waste Management Area A-AX System Model. (2 sheets)

GoldSim® Element Name ⟶	RfDo	Sfo	RfCi[a,b]	IUR[b]	GIABS_CHEM	Kp[b]
Chemical Name	Oral Reference Dose (RfDo) (mg/kg-day)	Oral Cancer Slope Factor (CSFo) $(mg/kg\text{-}day)^{-1}$	Inhalation Reference Concentration (RfC) (mg/m^3)	Inhalation Unit Risk (IUR) $(\mu g/m^3)^{-1}$	Fraction of Contaminant Absorbed in Gastrointestinal Tract (GIABS) (unitless)	Dermal Permeability Coefficient (Kp) (cm/hr)
Aluminum	1	—[c]	0.005	—	1	0.001
Boron	0.2	—	0.02	—	1	0.001
Chromium	1.5	—	—	—	0.013	0.001
Cobalt	0.0003	—	0.000006	0.009	1	0.0004
Cyanide	0.0006	—	0.0008	—	1	0.001
Fluoride	0.04[d]	—	0.013	—	1	0.001
Hexavalent Chromium	0.003[e]	0.5[d]	0.0001[e]	0.084[e]	0.025[e]	0.002
Iron	0.7	—	—	—	1	0.001
Lead	—	—	—	—	1	0.0001
Manganese	0.024	—	0.00005	—	0.04	0.001
Mercury	0.0003	—	0.0003	—	0.07	0.001
Nickel	0.02	—	0.00009	0.00026	0.04	0.0002
Nitrate	7.1	—	—	—	1	0.001
Nitrite	0.3	—	—	—	1	0.001
Selenium	0.005	—	0.02	—	1	0.001
Strontium	0.6	—	—	—	1	0.001

Table Att-4-1. Chemical-Specific Parameters Used for Residential Tap Water Scenario in the Waste Management Area A-AX System Model. (2 sheets)

GoldSim® Element Name →	RfDo	Sfo	RfCi[a,b]	IUR[b]	GIABS_CHEM	Kp[b]
Chemical Name	Oral Reference Dose (RfDo) (mg/kg-day)	Oral Cancer Slope Factor (CSFo) $(mg/kg\text{-}day)^{-1}$	Inhalation Reference Concentration (RfC) (mg/m^3)	Inhalation Unit Risk (IUR) $(\mu g/m^3)^{-1}$	Fraction of Contaminant Absorbed in Gastrointestinal Tract (GIABS) (unitless)	Dermal Permeability Coefficient (Kp) (cm/hr)
Tin	0.6	—	—	—	1	0.001
Tributyl phosphate	0.01	0.009	—	—	1	0.023
Uranium	0.0002[d]	—	0.00004	—	1	0.001
Checker Review: Kearn Patrick Lee						

Source: RPP-ENV-62206, 2020, *Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington,* Rev. 0, Washington River Protection Solutions, LLC/CH2M HILL Plateau Remediation Company/ INTERA, Inc./ORANO Federal Services, LLC/Tec-Geo, Inc., Richland, Washington, Table G-1.

[a] While no reference concentration values are available for this contaminant list, a value of 1×10^9 µg/m^3 was entered for each contaminant in GoldSim® to prevent "divide by zero" errors. Doing so resulted in exceedingly small values that have no impact on the final results.

[b] RPP-RPT-60885, 2022, *Model Package Report System Model for the WMA A-AX Performance Assessment*, Rev. 1, Washington River Protection Solutions, LLC/Orano Federal Services/INTERA, Inc., Richland, Washington, Table B-10.

[c] "—" indicates there is no value available for this chemical. Oral Reference Dose (GoldSim® Element: RfDo) entries in the model are assigned a value of 1E+09 mg/kg-day. Oral Slope Factor (GoldSim® Element: Sfo) entries in the model are assigned a value of 0 kg-day/mg. Inhalation Reference Concentration (GoldSim® Element: RfCi) entries in the model are assigned a value of 1E+09 mg/m^3. Inhalation Unit Risk (GoldSim® Element: IUR) entries in the model are assigned a value of 0 m^3/µg.

[d] U.S. Environmental Protection Agency Regional Screening Levels website (United States Environmental Protection Agency, Queried 08/15/2022, [Regional Screening Levels (RSLs) - Generic Tables], https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables).

[e] RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./Washington River Protection Solutions, LLC, Richland, Washington, Table A-5.

GoldSim® simulation software is a registered trademark of GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

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RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington, Table A-5.

RPP-ENV-62206, 2020, *Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington*, Rev. 0, Washington River Protection Solutions, LLC/CH2M HILL Plateau Remediation Company/INTERA, Inc./ ORANO Federal Services, LLC/Tec-Geo, Inc., Richland, Washington.

RPP-RPT-60885, 2022, *Model Package Report System Model for the WMA A-AX Performance Assessment*, Rev. 1, Washington River Protection Solutions, LLC/Orano Federal Services/INTERA, Inc., Richland, Washington.

U.S. Environmental Protection Agency Regional Screening Levels website (United States Environmental Protection Agency, Queried 08/15/2022, [Regional Screening Levels (RSLs) - Generic Tables], https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables).

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ATTACHMENT 5

ALL-PATHWAYS REPRESENTATIVE PERSON SCENARIO PARAMETER INPUTS

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Table Att-5-1. Parameters Used for Calculating All-Pathways Dose at Waste Management Area A-AX.

Parameter	Notation	Value	Unit	GoldSim® Parameter Name	Reference
Enrichment factor	E_f	0.7	unitless	Enrichment_Factor_AP	RPP-ENV-58813, Table P-2
Exposure frequency	EF	350	days/yr	Exposure_Frequency_AP	RPP-ENV-58813, Table P-2
Soil moisture content	θw	0.06	unitless	Water_Content_AP	RPP-ENV-58813, Section O.9.1
Fraction of locally-produced animal products (beef, dairy, poultry, eggs) that are consumed	F_a	1	unitless	Animal_Fraction_AP	RPP-ENV-58813, Table P-2
Fraction of locally-produced crops (fruits and vegetables) that are consumed	F_v	0.25	unitless	Veg_Fraction_AP	RPP-ENV-58813, Table P-2
Ratio of radionuclide concentrations in indoor versus outdoor air	I/O	0.3	unitless	Indoor_Outdoor_Ratio	RPP-ENV-58813, Table P-2
Inhalation rate – indoors	INH_{in}	7300	m^3/yr	Indoor_Inhalation_Rate_AP	RPP-ENV-58813, Table P-2
Inhalation rate – outdoors	INH_{out}	12775	m^3/yr	Outdoor_Inhalation_Rate_AP	RPP-ENV-58813, Table P-2
Inhalation rate – water vapor	INH_w	20	m^3/day	InhalationRate_WV	RPP-ENV-58813, Table P-2
Bioconcentration factor from resuspension/soil adhesion for fodder	B'_p	0.1	(pCi/kg dry weight of fodder)/ (pCi/kg dry weight of soil)	Resuspension_FodderSoil_BCF_AP	RPP-ENV-58813, Table O-2
Crop-soil bioconcentration factor from all resuspension/soil adhesion processes	B'_v	0.004	(pCi/kg dry weight of crop)/ (pCi/kg dry weight of soil)	Resuspension_VegSoil_BCF_AP	RPP-ENV-58813, Table O-2
Beef ingestion rate	IR_b	101.9	kg/yr	Beef_Ingestion_Rate_AP	RPP-ENV-58813, Table P-2
Crop ingestion rate (includes fruits and vegetables)	IR_c	272.3	kg/yr	Veg_Ingestion_Rate_AP	RPP-ENV-58813, Table P-1
Egg ingestion rate	IR_e	40.5	kg/yr	Egg_Ingestion_Rate_AP	RPP-ENV-58813, Table P-2
Fodder ingestion rate for beef	$IR_{fodder,b}$	11.77	kg/day	Beef_Ingestion_Rate_AP	RPP-ENV-58813, Table O-2
Fodder ingestion rate for dairy cattle	$IR_{fodder,d}$	16.9	kg/day	Milk_Fodder_Ingestion_Rate_AP	RPP-ENV-58813, Table O-2
Fodder ingestion rate for poultry	$IR_{fodder,p}$	0.2	kg/day	Poultry_Fodder_Ingest_Rate_AP	RPP-ENV-58813, Table O-2
Milk ingestion rate	IR_m	311.3	L/yr	Milk_Ingestion_Rate_AP	RPP-ENV-58813, Table P-2
Poultry ingestion rate	IR_p	99.4	kg/yr	Poultry_Ingestion_Rate_AP	RPP-ENV-58813, Table P-1
Soil ingestion rate	IR_s	108.6	mg/day	Soil_Ingestion_Rate_AP	RPP-ENV-58813, Table P-1
Soil ingestion rate for beef	$IR_{s,b}$	0.39	kg/day	Beef_Soil_Ingestion_Rate_AP	RPP-ENV-58813, Table O-2
Soil ingestion rate for dairy cattle	$IR_{s,d}$	0.41	kg/day	Milk_Soil_Ingestion_Rate_AP	RPP-ENV-58813, Table O-2
Soil ingestion rate for poultry	$IR_{s,p}$	0.022	kg/day	Poultry_Soil_Ingest_Rate_AP	RPP-ENV-58813, Table O-2
Drinking water ingestion rate	IR_w	2.66	L/day	Water_Ingestion_Rate_AP	RPP-ENV-58813, Table P-1
Water ingestion rate for beef	$IR_{w,b}$	53	L/day	Beef_Water_Ingestion_Rate_AP	RPP-ENV-58813, Table O-2
Water ingestion rate for dairy cattle	$IR_{w,d}$	92	L/day	Milk_Water_Ingestion_Rate_AP	RPP-ENV-58813, Table O-2
Water ingestion rate for poultry	$IR_{w,p}$	1	L/day	Poultry_Water_Ingest_Rate_AP	RPP-ENV-58813, Table O-2
Andelman Volatilization Factor	K	0.5	L/m^3	Volatilization_factor	RPP-ENV-58813, Table P-2
Mass loading factor	M	6.66E-5	g/m^3	Mass_Loading_Factor_AP	RPP-ENV-58813, Table P-2
Fraction of time spent indoors	t_{in}	0.4	Unitless	Indoor_Time_Fraction_AP	RPP-ENV-58813, Table P-2
Fraction of time spent outdoors	t_{out}	0.486	Unitless	Outdoor_Time_Fraction_AP	RPP-ENV-58813, Table P-2
Checker Review: Kearn Patrick Lee					

Reference: RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*.

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Table Att-5-2. Bioconcentration Factors Used for Calculating All Pathway Doses at Waste Management Area A-AX.[ab] (2 sheets)

Radionuclide	Beef (BCF_{beef})[c] (day/kg)	Poultry ($BCF_{poultry}$)[d] (day/kg)	Egg (BCF_{egg})[e] (day/kg)
Ac-227	2.00E-05	4.00E-03	2.00E-03
Am-241	5.00E-05	6.00E-03	9.00E-03
Am-243	5.00E-05	6.00E-03	9.00E-03
C-14	4.89E-02	4.16E+00	3.12E+00
Cd-113m	1.00E-03	1.70E+00	1.00E-01
Cm-243	2.00E-05	4.00E-03	2.00E-03
Cm-244	2.00E-05	4.00E-03	2.00E-03
Co-60	3.00E-02	9.70E-01	3.30E-02
Cs-137	5.00E-02	2.70E+00	4.00E-01
Eu-152	2.00E-03	4.00E-03	7.00E-03
Eu-154	2.00E-03	4.00E-03	7.00E-03
Eu-155	2.00E-03	4.00E-03	7.00E-03
H-3	3.36E+01	3.36E+01	3.36E+01
I-129	4.00E-02	8.70E-03	2.40E+00
Nb-93m	1.00E-06	3.00E-04	1.00E-03
Ni-59	5.00E-03	1.00E-03	1.00E-01
Ni-63	5.00E-03	1.00E-03	1.00E-01
Np-237	1.00E-03	4.00E-03	2.00E-03
Pa-231	5.00E-06	4.00E-03	2.00E-03
Pb-210	8.00E-04[f]	2.00E-01[g]	8.00E-01[g]
Pu-238	1.00E-04	3.00E-03	8.00E-03
Pu-239	1.00E-04	3.00E-03	8.00E-03
Pu-240	1.00E-04	3.00E-03	8.00E-03
Pu-241	1.00E-04	3.00E-03	8.00E-03
Pu-242	1.00E-04	3.00E-03	8.00E-03
Ra-226	1.00E-03	3.00E-02	2.00E-05
Ra-228	1.00E-03	3.00E-02	2.00E-05
Rn-222	0.00+00	0.00+00	0.00+00
Se-79	1.00E-01	9.70E+00	1.60E+01

Table Att-5-2. Bioconcentration Factors Used for Calculating All Pathway Doses at Waste Management Area A-AX.[ab] (2 sheets)

Radionuclide	Beef (BCF_{beef})[c] (day/kg)	Poultry ($BCF_{poultry}$)[d] (day/kg)	Egg (BCF_{egg})[e] (day/kg)
Sm-151	2.00E-03	4.00E-03	7.00E-03
Sn-126	1.00E-02	2.00E-01	8.00E-01
Sr-90	1.00E-02	2.00E-02	3.50E-01
Tc-99	1.00E-04	3.00E-02	3.00E+00
Th-229	1.00E-04	4.00E-03	2.00E-03
Th-230	1.00E-04	4.00E-03	2.00E-03
Th-232	1.00E-04	4.00E-03	2.00E-03
U-232	8.00E-04	1.20E+00	9.90E-01
U-233	8.00E-04	1.20E+00	9.90E-01
U-234	8.00E-04	1.20E+00	9.90E-01
U-235	8.00E-04	1.20E+00	9.90E-01
U-236	8.00E-04	1.20E+00	9.90E-01
U-238	8.00E-04	1.20E+00	9.90E-01
Zr-93	1.00E-06	6.00E-05	2.00E-04
Checker Review: Kearn Patrick Lee			

[a]RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Table N-3.

[b]Fodder and Grass (B_p), Vegetables, Fruit and Grain (B_v) and Milk (BCF_{milk}) bioconcentration values are contained in Attachment 8.

[c]GoldSim® element name: BCF_Beef.

[d]GoldSim® element name: BCF_Poultry.

[e]GoldSim® element name: BCF_egg.

[f]NCRP Report No. 129, *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies*.

[g]NUREG/CR-5512, *Residual Radioactive Contamination From Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, Final Report*.

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NCRP Report No. 129, 1999, *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies*, National Council on Radiation Protection, Bethesda, Maryland.

NUREG/CR-5512, 1992, *Residual Radioactive Contamination From Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, Final Report*, PNL-7994, Vol. 1. U.S. Nuclear Regulatory Commission, Washington, D.C.

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

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ATTACHMENT 6

INADVERTENT INTRUDER SCENARIO PARAMETER INPUTS

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Table Att-6-1. Input Parameters Used for Calculating Doses to Inadvertent Intruders for Selected Acute and Chronic Exposure Scenarios at Waste Management Area A-AX. (4 sheets)

Parameter	Notation	Value	Unit	GoldSim® Parameter Name
Common to All Intruder Scenarios[a]				
Soil dry bulk density for soil layers below the Waste Management Area	ρ_{sl}, ρ_s	1.67[b]	g/cm^3	Cuttings_Bulk_Density
Soil dry bulk density in the pasture	ρ_p	2.05	g/cm^3	TargetField_Bulk_Density
Bulk density of residual waste	ρ_{ws}	2.05	g/cm^3	Waste_Bulk_Density
Time of intrusion	T	500 (tanks)	years (post-closure)	Tanks_Intrusion_Time
Depth to groundwater	Z_{gw}	8,700[c]	cm	Groundwater_Depth
Acute Well Driller Intruder Scenario[d]				
Soil ingestion rate—Well Driller	$IR_{s,wd}$	100	mg/day	Soil_Ingestion_Rate_WD
Exposure frequency—Well Driller	EF_{wd}	5	days/yr	Exposure_Frequency_WD
Enrichment factor	E_f	4	unitless	Enrichment_Factor_WD
Outdoor inhalation rate—Well Driller	$INH_{out,wd}$	12,775	m^3/yr	Outdoor_Inhalation_Rate_WD
Mass loading factor	M	6.66E-05	g/m^3	Mass_Loading_Fact_WD
Fraction of time spent outdoors	$t_{out,wd}$	0.0046	unitless	Outdoor_Time_Fraction_WD
Chronic Rural Pasture Intruder Scenario[e]				
Area of the well	A_{well}	558.6	cm^2	Well_Area_RP
Diameter of the well	D_{well}	26.67	cm	Well_Diameter_RP
Area of rural pasture	A_{rp}	5.00E+07	cm^2	Target_Field_Area_RP
Tilled depth of rural pasture	Z_{rp}	15	cm	Tilled_Depth_RP
Soil ingestion rate—resident	$IR_{s,rp}$	100	mg/day	Soil_Ingestion_Rate_RP
Exposure frequency—resident	EF_{rp}	350	days/yr	Exposure_Frequency_RP

Table Att-6-1. Input Parameters Used for Calculating Doses to Inadvertent Intruders for Selected Acute and Chronic Exposure Scenarios at Waste Management Area A-AX. (4 sheets)

Parameter	Notation	Value	Unit	GoldSim® Parameter Name
Milk ingestion rate	IR_m	155.96	L/yr	Milk_Ingestion_Rate_RP
Fraction of locally-produced dairy products that are consumed	F_a	1	unitless	Fraction_Of_Dairy_Consumed_RP
Water ingestion rate for dairy cattle	$IR_{w,d}$	92	L/day	Cattle_Water_Ingestion_Rate_RP
Soil ingestion rate for dairy cattle	$IR_{s,d}$	0.41	kg/day	Cattle_Soil_Ingestion_Rate_RP
Fodder ingestion rate for dairy cattle	$IR_{fodder,d}$	16.9	kg/day	Cattle_Fodder_Ingestion_Rate_RP
Pasture-soil bioconcentration factor through uptake	B_p	Table Att-7-1	(pCi/kg dry weight of crop)/ (pCi/kg dry weight of soil)	BCF_Uptake_FodderSoil
Pasture-soil bioconcentration factor from resuspension processes	B'_p	0.1	(pCi/kg dry weight of crop)/ (pCi/kg dry weight of soil)	Resuspension_FodderSoil_BCF_RP
Enrichment factor	E_f	0.7	unitless	Enrichment_Factor_RP
Indoor inhalation rate—resident	$INH_{in,r}$	7,300	m^3/yr	Indoor_Inhalation_Rate_RP
Mass loading factor	M	6.66E-05	g/m^3	Mass_Loading_Factor_RP
Fraction of time spent indoors—Rural Pasture	$ti_{n,rp}$	0.656	unitless	Indoor_Time_Fraction_RP
Outdoor inhalation rate—Rural Pasture	INH_{out_rp}	9,125	m^3/yr	Outdoor_Inhalation_Rate_RP
Fraction of time spent outdoors—Rural Pasture	t_{out}	0.16	unitless	Outdoor_Time_Fraction_RP
Ratio of radionuclide concentrations in indoor versus outdoor air	I/O	0.3	unitless	Indoor_Outdoor_Ratio_IN
Chronic Suburban Garden Intruder Scenario[f]				
Diameter of the well	D_{well}	16.51	cm	Well_Diameter_SG
Area of the well	A_{well}	214.08	cm^2	Well_Area_SG
Area of home construction lot (target field)	A_{tf}	25,000,000	cm^2	Target_Field_Area_SG

Table Att-6-1. Input Parameters Used for Calculating Doses to Inadvertent Intruders for Selected Acute and Chronic Exposure Scenarios at Waste Management Area A-AX. (4 sheets)

Parameter	Notation	Value	Unit	GoldSim® Parameter Name
Tilled depth of garden	Z_g	15	cm	Tilled_Depth_SG
Soil ingestion rate—Suburban Garden	$IR_{s,sg}$	100	mg/day	Soil_Ingestion_Rate_SG
Exposure frequency—resident	EF_{sg}	350	day/yr	Exposure_Frequency_SG
Crop (fruit and vegetables) ingestion rate	I_{rc}	106.51	kg/yr	Veg_Ingestion_Rate_SG
Crop-soil bioconcentration factor from uptake	B_v	Table Att-7-1	(pCi/kg fresh wt crop)/ (pCi/kg dry wt soil)	BCF_Uptake_VegSoil
Crop-soil bioconcentration factor from resuspension/soil adhesion	B'_v	0.004	(pCi/kg fresh wt crop)/ (pCi/kg dry wt soil)	Resuspension_VegSoil_BCF_SG
Fraction of locally-produced crop (fruit and vegetables) that are consumed	F_v	0.25	unitless	Fraction_Of_Veg_Consumed_SG
Enrichment factor	E_f	0.7	unitless	Enrichment_Factor_SG
Indoor inhalation rate—Suburban Garden	$INH_{in,sg}$	7,300	m^3/yr	Indoor_Inhalation_Rate_SG
Mass loading factor	M	6.66E-05	g/m^3	Mass_Loading_Factor_SG
Fraction of time spent indoors—Suburban Garden	$t_{in,sg}$	0.656	unitless	Indoor_Time_Fraction_SG
Outdoor inhalation rate—Suburban Garden	$INH_{out,sg}$	9,125	m^3/yr	Outdoor_Inhalation_Rate_SG
Fraction of time spent outdoors	$t_{out,sg}$	0.08	unitless	Outdoor_Time_Fraction_SG
Ratio of radionuclide concentrations in indoor versus outdoor air	I/O	0.3	unitless	Indoor_Outdoor_Ratio_IN
Chronic Commercial Farm Intruder Scenario[g]				
Area of the well	A_{well}	1,379.51	cm^2	Well_Area_CF
Diameter of the well	D_{well}	41.91	cm	Well_Diameter_CF
Area of Commercial Farm	A_{cf}	6.48E+09	cm^2	Target_Field_Area_CF

Table Att-6-1. Input Parameters Used for Calculating Doses to Inadvertent Intruders for Selected Acute and Chronic Exposure Scenarios at Waste Management Area A-AX. (4 sheets)

Parameter	Notation	Value	Unit	GoldSim® Parameter Name
Tilled depth of Commercial Farm	Z_{cf}	15	cm	Tilled_Depth_CF
Soil ingestion rate—Commercial Farm	$IR_{s,cf}$	100	mg/day	Soil_Ingestion_Rate_CF
Exposure frequency—Commercial Farm	EF_{cf}	180	days/yr	Exposure_Frequency_CF
Enrichment factor	E_f	0.7	unitless	Enrichment_Factor_CF
Indoor inhalation rate—Commercial Farm	$INH_{in,cf}$	7,300	m^3/yr	Indoor_Inhalation_Rate_CF
Mass loading factor	M	6.66E-05	g/m^3	Mass_Loading_Factor_CF
Fraction of time spent indoors—Commercial Farm	$t_{in,cf}$	0	unitless	Indoor_Time_Fraction_CF
Outdoor inhalation rate—Commercial Farm	$INH_{out,cf}$	10,950	m^3/yr	Outdoor_Inhalation_Rate_CF
Fraction of time spent outdoors—Commercial Farm	$t_{out,cf}$	0.164	unitless	Outdoor_Time_Fraction_CF
Ratio of radionuclide concentrations in indoor versus outdoor air	I/O	0.3	unitless	Indoor_Outdoor_Ratio_IN
Checker Review: Kearn Patrick Lee				

[a]RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./Washington River Protection Solutions, LLC, Richland, Washington, Table R-2.

[b]RPP-RPT-60101, 2021, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*, Rev. 0, CH2M HILL Plateau Remediation Company/INTERA, Inc./TecGeo, Inc./Washington River Protection Solutions, LLC, Richland, Washington, Table B-8.

[c]DOE/RL-2016-67, 2017, *Hanford Site Groundwater Monitoring Report for 2016*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

[d]RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Table R-3.

[e]RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Table R-4.

[f]RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Table R-5.

[g]RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Table R-6.

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DOE/RL-2016-67, 2017, *Hanford Site Groundwater Monitoring Report for 2016*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-60101, 2021, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*, Rev. 0, CH2M HILL Plateau Remediation Company/INTERA, Inc./TecGeo, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

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ATTACHMENT 7

DOSE CONVERSION FACTORS

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Table Att-7-1. Dose Conversion Factors Used for Calculating Inadvertent Intruder Doses at Waste Management Area A-AX. (2 sheets)

Radionuclide	Inhalation (mrem/pCi)	Ingestion (mrem/pCi)	External Exposure Groundwater Pathway (mrem/yr)/(pCi/g)
Ac-227	5.96E-01	1.45E-03	1.57E+00
Am-241	1.56E-01	8.81E-04	3.41E-02
Am-243	1.54E-01	8.73E-04	6.98E-01
C-14	8.21E-06	2.34E-06	1.05E-05
Cd-113m	4.33E-04	9.51E-05	5.06E-04
Cm-243	1.20E-01	6.66E-04	4.55E-01
Cm-244	1.01E-01	5.59E-04	9.83E-05
Co-60	4.14E-05	2.03E-05	1.27E+01
Cs-137	1.70E-05	4.92E-05	2.66E+00
Eu-152	3.67E-04	6.44E-06	5.47E+00
Eu-154	4.26E-04	9.66E-06	5.99E+00
Eu-155	5.11E-05	1.67E-06	1.42E-01
H-3	1.97E-07	7.77E-08	0.00E+00
I-129	1.50E-04	4.48E-04	1.01E-02
Nb-93m	2.26E-06	6.59E-07	8.12E-05
Ni-59	5.48E-07	2.95E-07	0.00E+00
Ni-63	2.01E-06	7.33E-07	0.00E+00
Np-237	8.51E-02	4.63E-04	8.57E-01
Pa-231	8.77E-01	2.07E-03	1.49E-01
Pb-210	4.48E-03	3.77E-03	4.76E-03
Pu-238	1.72E-01	9.73E-04	1.18E-04
Pu-239	1.86E-01	1.07E-03	2.30E-04
Pu-240	1.86E-01	1.07E-03	1.14E-04
Pu-241	3.31E-03	1.93E-05	4.61E-06
Pu-242	1.77E-01	1.01E-03	9.99E-05
Ra-226	1.41E-02	1.68E-03	2.48E-02
Ra-228	1.14E-02	5.92E-03	1.26E+01
Rn-222	0.00E+00	0.00E+00	8.70E+00
Se-79	6.22E-06	1.73E-05	1.45E-05

Table Att-7-1. Dose Conversion Factors Used for Calculating Inadvertent Intruder Doses at Waste Management Area A-AX. (2 sheets)

Radionuclide	Inhalation (mrem/pCi)	Ingestion (mrem/pCi)	External Exposure Groundwater Pathway (mrem/yr)/(pCi/g)
Sm-151	3.64E-05	5.00E-07	7.68E-07
Sn-126	6.14E-04	2.36E-05	9.25E+00
Sr-90	1.45E-04	1.33E-04	1.92E-02
Tc-99	1.64E-05	3.33E-06	9.80E-05
Th-229	2.79E-01	2.25E-03	1.24E+00
Th-230	5.44E-02	9.36E-04	9.43E-04
Th-232	9.47E-02	1.03E-03	4.07E-04
U-232	3.19E-02	1.49E-03	7.96E+00
U-233	1.44E-02	2.23E-04	1.09E-03
U-234	1.41E-02	2.15E-04	3.13E-04
U-235	1.25E-02	2.03E-04	5.91E-01
U-236	1.29E-02	2.02E-04	1.68E-04
U-238	1.16E-02	1.94E-04	8.89E-02
Zr-93	3.34E-05	3.70E-06	0.00E+00
Checker Review: Kearn Patrick Lee			

Source: RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./Washington River Protection Solutions, LLC, Richland, Washington, Table N-1.

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Table Att-7-2. Dose Conversion Factor Multipliers Used for Calculating Doses to Inadvertent Intruders at Waste Management Area A-AX.

Radionuclide	Inhalation Multiplier (unitless)	Ingestion Multiplier (unitless)
Ac-227	1.118	1.595
Am-243	1.00	1.005
Np-237	1.00	1.011
Pb-210	4.268	2.728
Ra-226	1.009	1.001
Ra-228	23.33	1.242
Sn-126	1.003	1.087
Sr-90	1.043	1.1
Th-229	1.213	1.468
U-232	6.541	1.649
U-235	1.00	1.008
U-238	1.003	1.089
Checker Review: Kearn Patrick Lee		

Source: RPP-CALC-61254, 2019, *Inadvertent Intruder Dose Calculation Update for the Integrated Disposal Facility Performance Assessment*, Rev. 3, Washington River Protection Solutions, LLC/ Orano Federal Services LLC, Richland, Washington.

REFERENCES

RPP-CALC-61254, 2019, *Inadvertent Intruder Dose Calculation Update for the Integrated Disposal Facility Performance Assessment*, Rev. 3, Washington River Protection Solutions, LLC/Orano Federal Services LLC, Richland, Washington.

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

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ATTACHMENT 8

BIOCONCENTRATION FACTORS

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Table Att-8-1. Bioconcentration Factors Used for Calculating Inadvertent Intruder Doses at Waste Management Area A-AX. (2 sheets)

Radionuclide	Fodder and Grass (B_p) (pCi/kg fresh weight of fodder)/(pCi/kg dry weight of soil)	Vegetables, Fruit, and Grain (B_v) (pCi/kg fresh weight of crop)/(pCi/kg dry weight of soil)	Milk (BCF_{milk}) day/L
Ac-227	4.00E-03	1.00E-03	2.00E-06
Am-241	4.00E-03	1.00E-03	2.00E-06
Am-243	4.00E-03	1.00E-03	2.00E-06
C-14	7.00E-01	7.00E-01	1.05E-02
Cd-113m	1.00E+00	5.00E-01	2.00E-03
Cm-243	4.00E-03	1.00E-03	2.00E-06
Cm-244	4.00E-03	1.00E-03	2.00E-06
Co-60	2.00E+00	8.00E-02	2.00E-03
Cs-137	2.00E-01	4.00E-02	1.00E-02
Eu-152	5.00E-02	2.00E-03	6.00E-05
Eu-154	5.00E-02	2.00E-03	6.00E-05
Eu-155	5.00E-02	2.00E-03	6.00E-05
H-3	2.86E+01	2.86E+01	3.36E+01
I-129	1.00E-01	2.00E-02	1.00E-02
Nb-93m	1.00E-01	1.00E-02	2.00E-06
Ni-59	1.00E+00	5.00E-02	2.00E-02
Ni-63	1.00E+00	5.00E-02	2.00E-02
Np-237	1.00E-01	2.00E-02	1.00E-05
Pa-231	5.00E-02	1.00E-02	5.00E-06
Pb-210	9.00E-02	4.00E-03	3.00E-04
Pu-238	1.00E-03	1.00E-03	1.00E-06
Pu-239	1.00E-03	1.00E-03	1.00E-06
Pu-240	1.00E-03	1.00E-03	1.00E-06
Pu-241	1.00E-03	1.00E-03	1.00E-06
Pu-242	1.00E-03	1.00E-03	1.00E-06
Ra-226	2.00E-01	4.00E-02	1.00E-03
Ra-228	2.00E-01	4.00E-02	1.00E-03
Rn-222	0.00E+00	0.00E+00	0.00E+00
Se-79	5.00E-01	1.00E-01	1.00E-02

Table Att-8-1. Bioconcentration Factors Used for Calculating Inadvertent Intruder Doses at Waste Management Area A-AX. (2 sheets)

Radionuclide	Fodder and Grass (B_p) (pCi/kg fresh weight of fodder)/(pCi/kg dry weight of soil)	Vegetables, Fruit, and Grain (B_v) (pCi/kg fresh weight of crop)/(pCi/kg dry weight of soil)	Milk (BCF_{milk}) day/L
Sm-151	5.00E-02	2.00E-03	6.00E-05
Sn-126	1.00E+00	3.00E-01	1.00E-03
Sr-90	4.00E+00	3.00E-01	2.00E-03
Tc-99	4.00E+01	5.00E+00	1.00E-03
Th-229	1.00E-03	1.00E-03	5.00E-06
Th-230	1.00E-03	1.00E-03	5.00E-06
Th-232	1.00E-03	1.00E-03	5.00E-06
U-232	1.00E-01	2.00E-03	4.00E-04
U-233	1.00E-01	2.00E-03	4.00E-04
U-234	1.00E-01	2.00E-03	4.00E-04
U-235	1.00E-01	2.00E-03	4.00E-04
U-236	1.00E-01	2.00E-03	4.00E-04
U-238	1.00E-01	2.00E-03	4.00E-04
Zr-93	5.00E-03	1.00E-03	6.00E-07
Checker Review: Kearn Patrick Lee			

Source: RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./Washington River Protection Solutions, LLC, Richland, Washington, Table N-3.

REFERENCE

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

ATTACHMENT 9

RADIONUCLIDE-SPECIFIC SHIELDING FACTORS

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Table Att-9-1. Radionuclide-Specific Shielding Factors Used in Calculating Inadvertent Intruder Doses at Waste Management Area A-AX.

Radionuclide	Shielding Factor (ε) (unitless)	Radionuclide	Shielding Factor (ε) (unitless)
Ac-227	0.4	Pu-240	0.1
Am-241	0.2	Pu-241	0.4
Am-243	0.3	Pu-242	0.1
C-14	0.4	Ra-226	0.4
Cd-113m	0.3	Ra-228	0.4
Cm-243	0.4	Rn-222	0.4
Cm-244	0.1	Se-79	0.1
Co-60	0.4	Sm-151	0.1
Cs-137	0.3	Sn-126	0.3
Eu-152	0.4	Sr-90	0.3
Eu-154	0.4	Tc-99	0.2
Eu-155	0.3	Th-229	0.4
H-3	0.4	Th-230	0.3
I-129	0.1	Th-232	0.2
Nb-93m	0.1	U-232	0.3
Ni-59	0.4	U-233	0.4
Ni-63	0.4	U-234	0.2
Np-237	0.3	U-235	0.4
Pa-231	0.4	U-236	0.1
Pb-210	0.1	U-238	0.1
Pu-238	0.1	Zr-93	0.4
Pu-239	0.3	—	—
Checker Review: Kearn Patrick Lee			

Source: RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./Washington River Protection Solutions, LLC, Richland, Washington, Table N-4.

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REFERENCE

RPP-ENV-58813, 2016, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*, Rev. 1, INTERA, Inc./Ramboll Environ, Inc./ Washington River Protection Solutions, LLC, Richland, Washington.

ATTACHMENT 10

DERIVED CONCENTRATIONS OF BETA AND PHOTON EMITTERS

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Table Att-10-1. Derived Concentrations of Beta and Photon Emitters in Drinking Water Yielding a Dose of 4 mrem/yr to the Total Body or to Any Critical Organ Used in the Waste Management Area A-AX System Model.

Nuclide	pCi/L
^{14}C	2,000
^{60}Co	100
^{137}Cs	200
^{152}Eu	200
^{154}Eu	60
^{155}Eu	600
^{3}H	20,000
^{129}I	1
^{93m}Nb	1,000
^{59}Ni	300
^{63}Ni	50
^{241}Pu	300
^{151}Sm	1,000
^{90}Sr	8
^{99}Tc	900
^{93}Zr	2,000
Checker Review: Kearn Patrick Lee	

Note: There are no derived concentrations for uranium isotopes.

Reference: EPA 816-F-00-002, 2002, *Implementation Guidance for Radionuclides*, Appendix I, U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, Washington, D.C.

REFERENCE

EPA 816-F-00-002, 2002, *Implementation Guidance for Radionuclides*, U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, Washington, D.C.

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ATTACHMENT 11

INVENTORY SCREENING ANALYSIS

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PURPOSE

The purpose of this screening analysis is to determine whether those constituents reported in RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment* that are not included in the Waste Management Area (WMA) A-AX system model should be modeled, or whether they can be screened out from further analysis.

METHODOLOGY

Determining whether the constituents in question should be added to the analysis requires determining their potential of reaching groundwater in the model time frame. A constituent's inventory and distribution coefficient (K_d) determine the magnitude and timing of groundwater contamination from post-closure releases of residual waste to the environment. Therefore, the potential groundwater impact can be evaluated by applying a constituent in question's inventory to a surrogate in the system model. The surrogates are assigned by matching each constituent in question's K_d value to a surrogate's K_d value. Since only a few discreet K_d values are modeled, a constituent in question without an exact K_d value match is matched to a surrogate with the nearest K_d value. While K_d values are available through the Washington State Department of Ecology's Cleanup Levels and Risk Calculation (CLARC) tables (Cleanup Levels and Risk Calculation [CLARC], Queried 05/08/2023, [CLARC data tables and other technical information], https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables), the screening first treats all constituents in question as having a K_d value of 0 mL/g and compares the resulting fenceline concentrations against the Federal Maximum Contaminant Levels (MCLs, µg/L) and Washington State Maximum Contaminant Levels (WMCLs, µg/L) listed in the CLARC tables. If no contaminants in question impact groundwater in 10,000 years, then they are screened out. Contaminants in question that impact groundwater using a K_d value of 0 mL/g are then modeled using surrogates chosen as previously described.

ASSUMPTIONS AND INPUTS

There are 117 chemical constituents with inventories reported in RPP-RPT-64056 that are not included in the WMA A-AX system model, which will be used to perform the risk assessment in the upcoming tank 241-AX-103 (AX-103) Retrieval Data Report (RDR). Since this screening analysis compares fenceline concentrations to MCLs and WMCLs, constituents without MCLs or WMCLs have been removed leaving 30 constituents (Table Att-11-1). This analysis uses the inventories reported in RPP-RPT-64056 (Table Att-11-2).

This screening analysis assumes that all 30 constituents with MCLs, and which are not included in the WMA A-AX system model, have K_d values derived from the CLARC tables to develop a conservative value for each chemical constituent for modeling. Every K_d value between 0.2 mL/g and 1 mL/g is set to 0.2 mL/g (most conservative), and values less than 0.2 mL/g are rounded down to the nearest tenth (e.g., 0.1 or 0). Constituents with non-gravel corrected K_d values greater than 1 mL/g have been determined to only reach the groundwater in insignificant

levels (e.g., 22 orders of magnitude or greater below the MCL) in 10,000 years and are therefore screened out. Table Att-11-3 shows the 30 constituents with their conservatively-estimated K_d values.

Table Att-11-1. Maximum Contaminant Levels and Distribution Coefficient Values for Analytes Reported in RPP-RPT-64056 but Not Included in the Waste Management Area A-AX System Model.

Chemical Name	Federal Maximum Contaminant Level (µg/L)	Washington State Maximum Contaminant Level (µg/L)	K_d (Distribution Factor for metals and organics) (L/kg)
Antimony	6	6	45
Arsenic, inorganic	10	10	29
Barium and compounds	2,000	2,000	41
Benzene	5	5	0.062
Benzo[a]pyrene	0.2	0.2	968.774
Beryllium	4	4	790
Bis(2-ethylhexyl) phthalate (DEHP)	6	6	111.123
Cadmium (potable groundwater & surface water)	5	5	6.7
Carbon tetrachloride	5	5	0.152
Chlorobenzene	100	100	0.224
Chloroform	80	80	0.053
Copper	1,300	1,300	22
Dichlorobenzene;1,2-	600	600	0.379
Dichlorobenzene;1,4-	75	75	0.616
Dichloroethane;1,2- (EDC)	5	5	0.038
Dichloroethylene;1,1-	7	7	0.065
Ethylbenzene	700	700	0.204
Hexachlorobenzene	1	1	80
Methylene chloride	5	5	0.01
Pentachlorophenol	1	1	0.592
Polychlorinated biphenyls (PCBs)	0.5	0.5	78.1
Tetrachloroethylene (PCE)	5	5	0.265
Thallium, soluble salts	2	2	71
Toluene	1,000	1,000	0.14
Trichlorobenzene;1,2,4-	70	70	1.659
Trichloroethane;1,1,1-	200	200	0.135
Trichloroethane;1,1,2-	5	5	0.075
Trichloroethylene (TCE)	5	5	0.094
Vinyl chloride	2	2	0.02173
Xylenes	10,000	10,000	0.233
Checker Review: Kearn Patrick Lee			

References:

Cleanup Levels and Risk Calculation (CLARC), Queried 05/08/2023, [CLARC data tables and other technical information], https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables.

RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*.

Table Att-11-2. Inventory Estimates for Analytes with Maximum Contaminant Levels in Tank 241-AX-103 Residual Solids but not Included in the Waste Management Area A-AX System Model.

Chemical Name	Chemical Abstract Services Number	< Detection Limit	Average Inventory	95% UCL Inventory	Inventory Units
1,1,1-Trichloroethane	71-55-6	<	2.79E-04	8.48E-04	kg
1,1,2-Trichloroethane	79-00-5	<	3.50E-04	1.06E-03	kg
1,1-Dichloroethene	75-35-4	<	1.64E-04	4.99E-04	kg
1,2,4-Trichlorobenzene	120-82-1	<	1.98E-04	6.02E-04	kg
1,2-Dichlorobenzene	95-50-1	<	1.18E-04	3.59E-04	kg
1,2-Dichloroethane	107-06-2	<	2.44E-04	7.42E-04	kg
1,4-Dichlorobenzene	106-46-7	<	1.29E-04	3.92E-04	kg
Aroclors (Total PCB)	1336-36-3	<	2.03E-02	6.17E-02	kg
As	7440-38-2	—	5.60E-01	9.17E-01	kg
Ba	7440-39-3	—	1.24E+01	1.95E+01	kg
Be	7440-41-7	<	1.65E+00	5.02E+00	kg
Benzene	71-43-2	<	1.54E-04	4.68E-04	kg
Benzo(a)pyrene	50-32-8	<	5.26E-02	1.60E-01	kg
Bis(2-ethylhexyl)phthalate	117-81-7	<	3.46E-01	1.05E+00	kg
Carbon tetrachloride	56-23-5	<	2.82E-04	8.57E-04	kg
Cd	7440-43-9	—	3.54E+00	6.07E+00	kg
Chlorobenzene	108-90-7	<	1.48E-04	4.50E-04	kg
Chloroform	67-66-3	<	1.83E-04	5.56E-04	kg
Cu	7440-50-8	—	7.10E+00	1.14E+01	kg
Ethylbenzene	100-41-4	<	1.92E-04	5.84E-04	kg
Hexachlorobenzene	118-74-1	<	7.43E-02	2.26E-01	kg
Methylenechloride	75-09-2	<	1.14E-04	3.47E-04	kg
Pentachlorophenol	87-86-5	<	6.74E-02	2.05E-01	kg
Sb	7440-36-0	—	1.20E-01	3.65E-01	kg
Tetrachloroethene	127-18-4	<	2.87E-04	8.72E-04	kg
Tl	7440-28-0	<	3.20E+00	9.73E+00	kg
Toluene	108-88-3	<	1.51E-04	4.59E-04	kg
Trichloroethene	79-01-6	<	1.54E-04	4.68E-04	kg
Vinyl chloride	75-01-4	<	2.53E-04	7.69E-04	kg
Xylenes (total)	1330-20-7	<	5.93E-04	1.80E-03	kg
Checker Review: Kearn Patrick Lee					

kg = kilogram PCB = polychlorinated biphenyl UCL = upper confidence level

Source: RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*.

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Table Att-11-3. K_d Values Derived from the CLARC Tables.

CAS Number	Constituent	CLARC-listed K_d (L/kg)	Surrogate K_d (L/kg)
71-55-6	1,1,1-Trichloroethane	0.135	0.1
79-00-5	1,1,2-Trichloroethane	0.075	0
75-35-4	1,1-Dichloroethene	0.065	0
120-82-1	1,2,4-Trichlorobenzene	1.659	1*
95-50-1	1,2-Dichlorobenzene	0.379	0.2
107-06-2	1,2-Dichloroethane	0.038	0
106-46-7	1,4-Dichlorobenzene	0.616	0.2
1336-36-3	Aroclors (Total PCB)	78.1	1
7440-38-2	As	29	1
7440-39-3	Ba	41	1
7440-41-7	Be	790	1
71-43-2	Benzene	0.062	0
50-32-8	Benzo(a)pyrene	968.774	1
117-81-7	Bis(2-ethylhexyl)phthalate	111.123	1
56-23-5	Carbon tetrachloride	0.152	0.1
7440-43-9	Cd	6.7	1
108-90-7	Chlorobenzene	0.224	0.2
67-66-3	Chloroform	0.053	0
7440-50-8	Cu	22	1
100-41-4	Ethylbenzene	0.204	0.2
118-74-1	Hexachlorobenzene	80	1
75-09-2	Methylenechloride	0.01	0
87-86-5	Pentachlorophenol	0.592	0.2
7440-36-0	Sb	45	1
127-18-4	Tetrachloroethene	0.265	0.2
7440-28-0	Tl	71	1
108-88-3	Toluene	0.14	0.1
79-01-6	Trichloroethene	0.094	0
75-01-4	Vinyl chloride	0.02173	0
1330-20-7	Xylenes (total)	0.233	0.2
Checker Review: Kearn Patrick Lee			

CAS = Chemical Abstract Services
CLARC = Cleanup Levels and Risk Calculation
K_d = distribution coefficient
PCB = polychlorinated biphenyl

* Chemical constituents with derived K_d values of 1 are screened out of the analysis.

Only 30 chemical constituents of those presented in RPP-RPT-64056 and which are not included in the WMA A-AX system model are at detectable levels. Of those, 5 have an MCL and WMCL: arsenic, barium, cadmium, copper and antimony. While all the constituents in this analysis but these 5 could be screened out on this basis, the entire list of 30 detected constituents is retained for analysis. When chemicals with K_d values greater than or equal to 1 mL/g are removed, 18 chemical constituents remain for analysis.

The screening analysis uses a residual waste volume of 785 ft^3 (5,875 gal) reported in RPP-RPT-63817, *Laser Scanning Waste Volume Estimate for Tank 241-AX-103*.

All other modeling assumptions match those used in the WMA A-AX Performance Assessment (PA) (RPP-ENV-61497, *Preliminary Performance Assessment of Waste Management Area A-AX, Hanford Site, Washington*) and groundwater impacts analysis (RPP-ENV-62206, *Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington*) and are detailed in RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

CALCULATIONS

Four surrogate analytes are used to represent the chemical constituents that are not in the WMA A-AX system model. Each surrogate has a unit inventory (1 kg) entered into the model[16]. The analytes used for the screening are: nitrate (K_d = 0 mL/g), selenium (K_d = 0.1 mL/g), cobalt (K_d reassigned to 0.2 mL/g) and aluminum (K_d reassigned to 1 mL/g). The grout K_d values for these analytes are reassigned to 0 mL/g. Since a unit inventory is entered for each analyte, the resulting peak fenceline concentration represents the scaling factor (µg/L/kg) to multiply an inventory by to calculate the corresponding fenceline concentration. Groundwater concentrations have been demonstrated to be proportional to inventory changes, provided no solubility constraints have been applied in the transport network of the model.

The inventory multiplication factors for the derived K_d values obtained from the WMA A-AX system model are entered into an Excel®[17] spreadsheet. The 95% upper confidence level (UCL) inventories from RPP-RPT-64056 are multiplied by the appropriate inventory multiplication factor for each constituent in the analysis to calculate a peak fenceline concentration. The spreadsheet also performs the calculation for the average inventories, but these values are not reported because the higher concentration values are still below the concentration limits. These fenceline concentrations are then Boolean compared in Excel® to each of the CLARC screening values listed in Table Att-11-1.

[16] Model is saved as "AX-103_RDR_Screening_Run.gsm".

[17] Excel® is a registered trademark of Microsoft Corporation in the U.S. and other countries.

Description of Model Changes

This model uses the model described in RPP-RPT-60885 as its basis. This model file was created from the version-controlled "AX-104_RDR_Screening.gsm" model file that was used to support RPP-CALC-65381, *Potential Groundwater Impacts and Inadvertent Intruder Doses from Tank 241-AX-104 Residuals Using Post-Retrieval Inventories*. The model file was adapted for this analysis by performing the following:

- Added 1 kg to Al, Co, Se and NO3 for AX-103 in **\Inventory\Initial_Chem_Inventory**
- Changed Al, Co, Se and NO3 for AX-104 to 0 kg in **\Inventory\Initial_Chem_Inventory**
- Changed AX-103's residual waste volume to 785 ft^3 in **\Input_Parameters\Eng_Sys_Transport_Param\Res_Waste_Vol_Source**.

RESULTS

Running the model with the unit inventories provided the inventory multiplication factors found in Table Att-11-4.

Table Att-11-4. Inventory Multiplication Factors.

K_d (mL/g)	Multiplication Factor (µg/L per kg)	GoldSim® Element
0	2.30E-02	\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_Kd0
0.1	1.38E-02	\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_Kd01
0.2	9.79E-03	\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_Kd02
1	2.02E-24	\Transport_Abstraction_Model\SZ_Fence_Conc\Peak_kd1
Checker Review: Kearn Patrick Lee		

GoldSim® simulation software is a registered trademark of GoldSim Technology Group LLC of Seattle, Washington (see http://www.goldsim.com).

When the 95% UCL inventories for constituents in Table Att-11-2 with K_d values less than 1 mL/g are multiplied by the appropriate inventory multiplication factor for the constituent's K_d value, the resulting peak fenceline concentrations are 3 to 9 orders of magnitude below the corresponding MCLs (Table Att-11-5). Constituents with a K_d value of 1 mL/g or greater have a multiplication factor of 2.02×10^{-24} µg/L per kg, which results in exceedingly minute concentrations, and are excluded from the rest of the analysis.

Table Att-11-5. Peak Groundwater Concentrations for Chemical Constituents with a Maximum Contaminant Limit.

CAS Number	Constituent	Washington State Maximum Contaminant Level (µg/L)*	Fenceline Concentration (µg/L)
71-55-6	1,1,1-Trichloroethane	200	5.84E-06
79-00-5	1,1,2-Trichloroethane	5	1.22E-05
75-35-4	1,1-Dichloroethene	7	5.73E-06
95-50-1	1,2-Dichlorobenzene	600	1.76E-06
107-06-2	1,2-Dichloroethane	5	8.52E-06
106-46-7	1,4-Dichlorobenzene	75	1.92E-06
71-43-2	Benzene	5	5.38E-06
56-23-5	Carbon tetrachloride	5	5.90E-06
108-90-7	Chlorobenzene	100	2.20E-06
67-66-3	Chloroform	80	6.39E-06
100-41-4	Ethylbenzene	700	2.86E-06
75-09-2	Methylenechloride	5	3.98E-06
87-86-5	Pentachlorophenol	1	1.00E-03
127-18-4	Tetrachloroethene	5	4.27E-06
108-88-3	Toluene	1,000	3.16E-06
79-01-6	Trichloroethene	5	5.38E-06
75-01-4	Vinyl chloride	2	8.83E-06
1330-20-7	Xylenes (total)	10,000	8.83E-06
Checker Review: Kearn Patrick Lee			

* For all chemicals in this table, the Washington State Maximum Contaminant Levels (WAC 246-290, "Group A Public Water Supplies") are equal to the Federal Maximum Contaminant Levels (40 CFR 141, "National Primary Drinking Water Regulations").

Note: All constituents in this table have non-detect values in the sample results and are evaluated at one-half the detection limit.

Based on the results of the analysis, the 30 constituents that are not in the GoldSim® model's species list and which have MCLs can be screened out of further analysis for the tank AX-103 RDR. The remaining 94 constituents that are not in the model's species list and which have no MCLs can also be screened out of further analysis.

REFERENCES

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*, as amended.

Cleanup Levels and Risk Calculation (CLARC), Queried 05/08/2023, [CLARC data tables and other technical information], https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables.

RPP-CALC-65381, 2023, *Potential Groundwater Impacts and Inadvertent Intruder Doses from Tank 241-AX-104 Residuals Using Post-Retrieval Inventories*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ENV-61497, 2020, *Preliminary Performance Assessment of Waste Management Area A-AX, Hanford Site, Washington*, Rev. 0, INTERA, Inc./CH2M HILL Plateau Remediation Company/Washington River Protection Solutions, LLC/Tec-Geo, Inc./ ORANO Federal Services, LLC, Richland, Washington.

RPP-ENV-62206, 2020, *Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington*, Rev. 0, Washington River Protection Solutions, LLC/CH2M HILL Plateau Remediation Company/INTERA, Inc./ ORANO Federal Services, LLC/Tec-Geo, Inc., Richland, Washington.

RPP-RPT-60885, 2022, *Model Package Report System Model for the WMA A-AX Performance Assessment*, Rev. 1, Washington River Protection Solutions, LLC/Orano Federal Services, LLC/INTERA, Inc., Richland, Washington.

RPP-RPT-63817, 2022, *Laser Scanning Waste Volume Estimate for Tank 241-AX-103*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-64056, 2023, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

WAC 246-290, "Group A Public Water Supplies," *Washington Administrative Code*, as amended.

ATTACHMENT 12

CHECKING INFORMATION

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CHECKER LOG FOR SYSTEM MODELS

Project and Environmental Model Calculation Specific Information:

Project: AX-103 Retrieval

Responsible Manager or Designee, and Position *(Print First and Last Name)*: Marcel Bergeron

Originating Group or Department: Closure and Interim Measures | Date: 6/26/2023

Environmental Model Calculation File Report and Revision No.: RPP-CALC-65649 Rev. 0

Environmental Model Calculation File Title: EMCF for AX-103 RDR (title too long for this field)

Check: Environmental Model Calculation File Document Elements

	List where Information is Described *(EMCF Section Number)*	Is the Description Correct and Sufficient? Yes	No	If No, describe deficiency:	Checker Signature
Purpose	Section 1.1	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 13:56:59 -07'00'
Calculation Approach	Section 3.0	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 13:57:31 -07'00'
Assumptions	Section 4.1	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 13:58:06 -07'00'
Inputs *(reference detailed checklist below as well)*	Section 4.2 and Attachments 2-11	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 13:58:56 -07'00'
Equations used	Points to model package reports RPP-RPT-60885 and RPP-RPT-63634, which is the purpose of those reports.	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 14:00:42 -07'00'
Conclusions	Section 7.2	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 14:01:21 -07'00'
References	Section 8.0 and Attachments 2-11	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 14:01:54 -07'00'

Check: Controlled Software Use

	List where Information is Described *(EMCF Section Number)*	Is the Criteria Met? Yes	No	If No, describe deficiency:	Checker Signature
Software used in the calculation is appropriate for application	Section 5.4	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 14:02:44 -07'00'
Software use is approved and properly validated in accordance with approved software management plan	Verified run dates on the models were after software approval date (6/21/23). Confirmed earlier work submitted for checking matched the runs made with the software after the software QA documentation was approved.	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.28 11:10:49 -07'00'
Software use is properly documented	Section 5	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.28 11:12:11 -07'00'

CHECKER LOG FOR SYSTEM MODELS (Continued)

	List where Information is Described *(EMCF Section Number)*	Is the Criteria Met? Yes	No	If No, describe deficiency:	Checker Signature
Verify data was input correctly to approved software or spreadsheets	Input values documented in Section 4.2 and Attachments 2-11 match model file(s).	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 14:04:18 -07'00'
If a spreadsheet is used, verify inputs/outputs of calculation(s) to ensure accuracy	Sections 3.4, 5.1, Attachment 11. Spreadsheets were reviewed and determined to perform calculations correctly.	◉	○		Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 14:08:32 -07'00'

Check: Perform Calculation to Verify Free of Errors

	Describe how calculation was performed	List any discrepancies encountered *(If none, enter "None")*	Checker Signature
Perform the environmental model calculation as described to verify it is free of errors	Replicated model runs after verifying that all changes to a previously checked model were implemented correctly.	None. Identified issues that would impact the numerical output were resolved through iterative corrections and re-runs.	Lee, Kearn P Digitally signed by Lee, Kearn P Date: 2023.06.26 14:14:26 -07'00'

Check: Process Model Parameterization *(Specify Values and Units in Each Column)*

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Simulation duration	Section 3.4	Yes	Yes, both the document and the model state 10,000 years.
Simulation time step control	Section 3.4	Yes	Yes, both the document and the model are consistent.
Simulated chemical list	Attachment 2	Yes	Yes, both the document and the model are consistent.
Simulated radionuclides list	Attachment 2	Yes	Yes, both the document and the model are consistent.
External model components identified and documented or referenced	Sections 3.4, 5.1, Attachment 11.	Yes	Supplemental model files and spreadsheets supporting the main dose calculation are identified and documented.

CHECKER LOG FOR SYSTEM MODELS (Continued)

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
External model linkages *(dynamic link libraries, etc.)* checked	Not Applicable - No external model linkages.	Not Applicable	Not Applicable
If model is probabilistic, stochastic distributions are defined and consistent	Not Applicable - Model is deterministic.	Not Applicable	Not Applicable
Input units are declared and of correct dimensionality	Input values documented in Section 4.2 and Attachments 2-11 identify proper values in the declared units.	Yes - for new model changes only. Some input values are consistent with previous model revisions, but may have updated values in the next TPA App I model(s).	Yes.
Equations used in the model file are presented in EMCF and consistent	No. The EMCF points to the Model Package Reports for this information to reduce redundancy. This is an acceptable way to perform and document hte calculation.	Not Applpicable	Not Applpicable
Check: Further Checks ***(Record additional checks performed and results)***			
Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Inventory: Radiological Decay Correction. Does the inventory *(source term)* include radionuclides, and if so, is it decay-corrected to the appropriate date for inclusion as a source?	Yes. The initial radionuclide inventory was decay corrected to a consistent date, the assumed date of closure.	Yes. Decay model was reviewed and correctly performs the calculation.	Yes.
Inventory: Mass Balance. Is mass balance of inventory maintained in system model calculation(s)?	The EMCF does not present mass balance information, but the model does contain mass balance calculations, which were reviewed and found to have no discrepancies needing resolution.	Not Applicable.	Not Applicable.
All checker notes are detailed in AX_103_RDR_Model_Checker_Notes_DJW_backcheck2.docx. This checker file will be archived in EMMA.	Issues identified during checking were noted and corrected. The corrected inforamtion is reported in the EMCF.	Avg Inv with 1/2 Detection Limit: Mass balance errors for any species exceeding 1e-6 g, were <0.5%. Errors for I-129, Se-79 and Tc-99 were	Not Applicable.

CHECKER LOG FOR SYSTEM MODELS (Continued)

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
		0.001% or less; Sr-90 and Cs-137 were 0.011% or less.	