ECF-HANFORD-22-0109
Revision 0

Hanford Site Composite Analysis Special Analysis: Inventory and Solid Waste Release Modeling for the LLBG Sensitivity Case

UCAQ-22-01 Inventory Discrepancies for 218-E-12B, 218-W-3A, and 218-W-3AE in the Hanford Site Composite Analysis

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

Contractor for the U.S. Department of Energy
under Contract 89303320DEM000030

CPCCo
Central Plateau
Cleanup Company

P.O. Box 1464
Richland, Washington 99352

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INTERA, Inc.

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

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APPROVED
By Janis Aardal at 3:10 pm, Nov 15, 2022

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ENVIRONMENTAL CALCULATION COVER PAGE

SECTION 1 - Completed by the Responsible Manager

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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Terms

CA	composite analysis
CACIE	Composite Analysis Cumulative Impact Evaluation
CASWR	Composite Analysis Solid Waste Release
Cat1	Category 1
Cat3	Category 3
CPCCo	Central Plateau Cleanup Company
CY	calendar year
DOE	U.S. Department of Energy
ECF	environmental calculation file
LLBG	low-level burial ground
MCL	maximum contaminant level
PA	performance assessment
SDWA	*Safe Drinking Water Act of 1974*
STOMP	Subsurface Transport Over Multiple Phases
SWITS	Solid Waste Information and Tracking System
TC & WM EIS	Tank Closure and Waste Management Environmental Impact Statement
TSD	treatment, storage, and disposal
WAC	waste acceptance criteria

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1 Purpose

This environmental calculation file (ECF) documents the methodologies, assumptions, and results of four sensitivity analyses that reevaluate the representativeness of solid-waste radionuclide inventory and release rate from three solid waste sites included in the recently completed Hanford Site Composite Analysis (CA) (DOE-RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020)*, Rev. 1) (hereinafter called the CA Update). Specifically, this ECF reevaluates the representativeness of the base case inventory and radionuclide waste release rates from three solid waste sites (i.e., 218-E-12B, 218-W-3A, and 218-W-3AE) and two radionuclides (i.e., carbon-14 [C-14] and technetium-99 [Tc-99]). These three waste sites and two radionuclides were identified as being the most significant contributors to groundwater contamination and dose in the CA Update for the Inner Area boundary at times periods after the compliance period.

This ECF first evaluates the representativeness of the C-14 and Tc-99 inventory and second, radionuclide release rates for the three waste sites[1]. If the inventory and release rates assumed in the CA Update are determined to be not representative, as hypothesized in the CA Update, then this ECF evaluates the impact of more representative inventories and release rates on the transfer of radionuclides to the vadose zone.

The four analyses described in this ECF are as follows:

- **218-E-12B C-14 Inventory and Release Rate Sensitivity Case** – Determine the representativeness of the C-14 inventory and associated waste release rate from the 218-E-12B waste site assumed in the CA Update. If the inventory and associated waste release are more appropriately characterized as being different from the assumptions in the CA Update, then update the predicted C-14 release rate and compare the results to the results presented in the CA Update (DOE/RL-2019-52).
- **218-W-3A C-14 Inventory and Release Rate Sensitivity Case** – Determine the representativeness of the C-14 inventory and associated waste release rate from the 218-W-3A waste site assumed in the CA Update. If the inventory and associated waste release are more appropriately characterized as being different from the assumptions in the CA Update, then update the predicted C-14 release rate and compare the results to the results presented in the CA Update (DOE/RL-2019-52).
- **218-W-3AE Tc-99 Release Rate Sensitivity Case** – Determine the representativeness of the Tc-99 inventory and associated waste release rate from the 218-W-3AE waste site assumed in the CA Update. If the inventory and associated waste release are more appropriately characterized as being different from the assumptions in the CA Update, then update the predicted Tc-99 release rate and compare the results to the results presented in the CA Update (DOE/RL-2019-52).
- **218-W-3AE Tc-99 Release Footprint Sensitivity Case –** Determine the representativeness of the Tc-99 waste area footprint for the 218-W-3AE waste site assumed in the CA Update. If the footprint of the waste is more appropriately characterized as being different from the assumptions in the CA Update, then update the predicted Tc-99 release rate and compare the results to the result presented in the CA Update (DOE/RL-2019-52).

[1] The focus of this ECF is on the nonrepresentative inventories and solid waste release rates documented in the CA Update (DOE/RL-2019-52). It is possible that other solid waste site inventories and solid waste release rates used in the CA Update are also not consistent with available information in the Solid Waste Information Tracking System. Therefore, the reevaluation of the solid waste inventory and release information should include other dose-significant radionuclides (i.e., iodine-129 [I-129] and uranium-238 [U-238]), and other solid waste sites, in future work.

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2 Background

The CA Update (DOE/RL-2019-52) identifies the assumed inventory and release rate of C-14 and Tc-99 from three DOE O 435.1, *Radioactive Waste Management*, waste sites as being over conservative and not representative of the expected inventory and release rate from these waste sites. The three waste sites and associated radionuclides that were identified as being nonrepresentative are as follows:

- C-14 inventory in 218-E-12B within the B-63 vadose zone model domain in the 200 East Area Low-Level Burial Ground (LLBG)
- C-14 inventory in 218-W-3A within the LLBG-200W A vadose zone model domain in the 200 West Area LLBG
- Tc-99 release rate in 218-W-3AE within the LLBG-200W A vadose zone model domain in the 200 West Area LLBG (Figure 2-1).

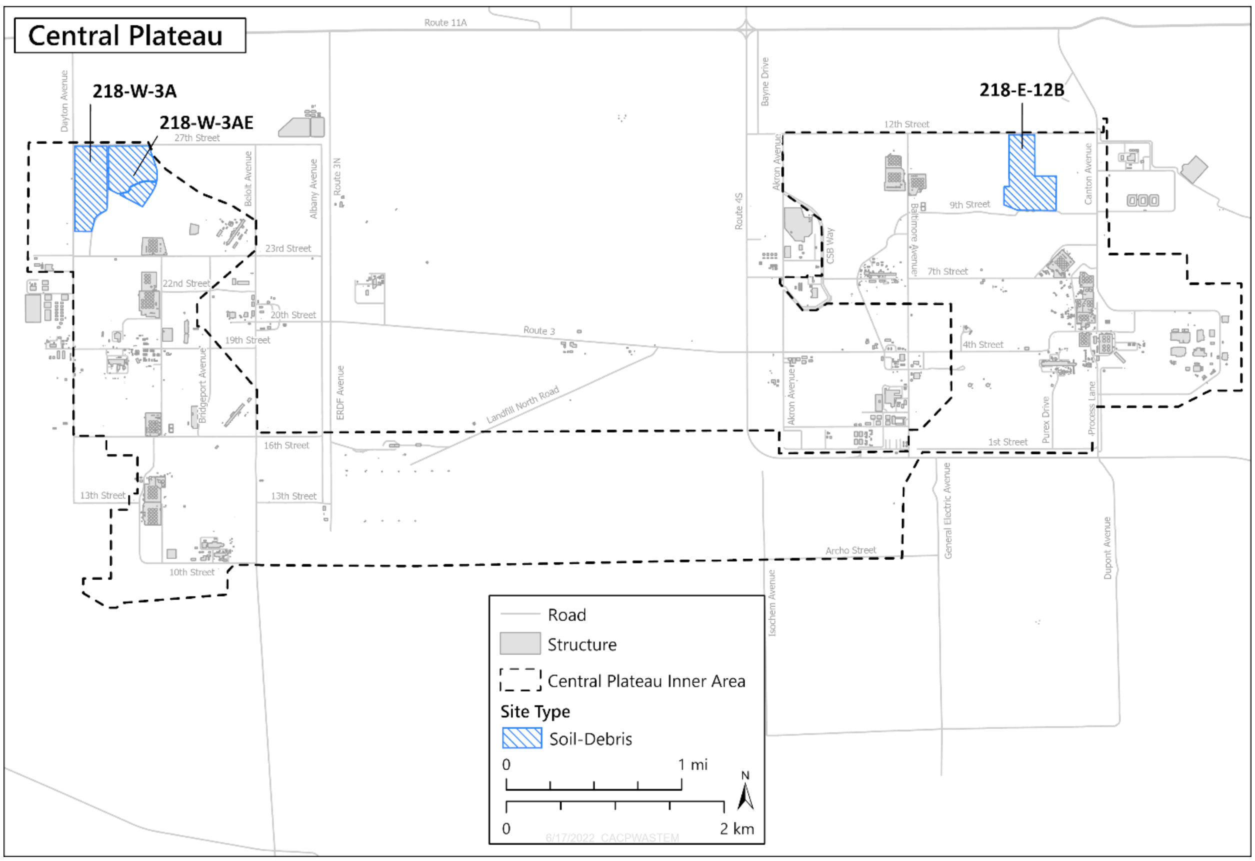


Figure 2-1. Location of the Solid Waste Disposal Sites Concerned by the CA Maintenance Within Hanford Central Plateau and Corresponding Waste Form Submodel Assignment Considered in the CA Update

Although the conservative inventory and waste release assumptions did not affect the predicted groundwater pathway doses relative to the compliance boundary during the compliance period (from CY 2070 to CY 3070) and did not affect the predicted pathway doses for the CA compliance boundary during the post compliance time period (from CY 3070 to CY 12070), the conservative assumptions did result in predicted groundwater pathway doses that exceed the administrative limit relative to the Inner Area boundary during the post compliance time period. As a result, the CA recommended that these conservative assumptions be re-evaluated during CA Maintenance. The purpose of this ECF is to re-evaluate these conservative assumptions.

In the future work section of the CA Update (Section 8.2 of DOE/RL-2019-52), the following activities were recommended for CA Maintenance:

- Inactive trenches of 200 West Area and 200 East Area LLBGs[2]
  - 218-E-12B (part of B 63 vadose zone model domain and 200 East Area LLBG)
    - Verify that the C-14 inventory is associated with activated metal within the naval reactor compartments disposed in Trench 94. Revise the release rate and predicted transfer rate of C-14 to groundwater accordingly.
  - 218-W-3A (part of LLBG-200W A vadose zone model domain and 200 West Area LLBG)
    - Evaluate the C-14 inventory in the Solid Waste Information and Tracking System (SWITS) and the solid waste type associated with the C-14 inventory. Revise the predicted transfer rate accordingly.
  - 218-W-3AE (part of LLBG-200W A vadose zone model domain and 200 West Area LLBG)
    - Verify that the Tc-99 inventory in SWITS is associated with Category 3 (Cat3) waste, including unirradiated fuel from N Reactor, and revise the solid waste release model and predicted transfer rate accordingly.
  - All inactive trenches – evaluate the spatial distribution of mobile potentially dose-significant radionuclide activity (e.g., C-14, Tc-99, and I-129) in inactive trenches to determine the expected area of release to the vadose zone. Use an appropriate waste release area and location correlated to the actual spatial distribution.
  - All inactive trenches – evaluate whether the inventory of mobile potentially dose-significant radionuclides (e.g., C-14, Tc-99, and I-129) disposed in the inactive trenches of the LLBGs should be categorized as soil-debris (i.e., Category 1 [Cat1]) or Cat3. Use an appropriate waste release model correlated to the actual waste categorization.

This background section summarizes the key results presented in the CA Update that relate to the inventory and release rate of C-14 and Tc-99 from the three waste sites and summarizes the relevant CA results. The discussion starts with a summary of the key assumptions in the CA Update (DOE/RL-2019-52) related to the three solid waste sites.

2.1 Summary of Key Assumptions in Composite Analysis

The future work identified in Section 8.2 of DOE/RL-2019-52 is based on the key assumptions summarized in Table 2-1 (derived from Table 8-1 of DOE/RL-2019-52). The key solid waste sources contributing to the groundwater dose results are summarized in Table 2-2 (derived from Table 7-1 of DOE/RL-2019-52).

[2] The inactive trenches of the 200 West Area and 200 East Area LLBGs are maintained by the LLBGs PA Maintenance program. However, these inactive trenches were reanalyzed in the CA with different assumptions than adopted in the PAs. Maintenance activities related to the inactive trenches may be addressed in a future PA completed to accommodate the Final Closure Plan for these waste sites.

Table 2-1. Key Assumptions in the Updated Hanford Site CA Relative to Peak Dose Results

Key Assumption	Significance	Potential Reduction of Uncertainty
Inventory and waste release from wastes disposed in inactive trenches of 200 East Area and 200 West Area LLBGs.	The CA update recalculated the release and transfer to groundwater for the inactive trenches of the LLBGs based on assumptions consistent with the TC & WM EIS. This overstated the expected inventory, release, and transfer to groundwater of C-14 from 218-E-12B and 218-W-3A and Tc-99 from 218-W-3AE.	Reevaluate the inventory and waste form disposed in the inactive trenches of the 200 East Area and 200 West Area LLBGs to quantify the effect of the assumptions in the CA.

Source: Modified from Table 8-1 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020)*.

Reference: DOE/EIS-0391, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

CA = Composite analysis

LLBG = Low-level burial grounds

TC & WM EIS = Tank Closure and Waste Management Environmental Impact Statement

2.2 Summary of Solid Waste Sources Contributing to Predicted Peak Groundwater Concentration and Groundwater Pathway Dose in Composite Analysis

Three boundaries were evaluated in the CA Update (i.e., the CA compliance boundary, and two sensitivity boundary cases, the Inner Area boundary and Outer Area boundary). The Inner Area boundary is the most restrictive of the three boundaries evaluated and reflects the smallest possible footprint reduction under DOE's current closure strategy (DOE/RL-2009-10) though it is not designated a future site boundary (the Inner and Outer Area boundaries are designated to guide the cleanup strategy and are used as example boundaries for purposes of evaluating the sensitivity of dose results to boundary location). Of the three evaluated boundaries, only the Inner Area boundary results in predicted groundwater pathway doses that exceed the 100 mrem/yr administrative dose limit at or beyond this boundary. This exceedance occurs about 300 years after the 1,000-year postclosure compliance period (Section 6.1.6 in DOE/RL-2019-52). The key waste sources and radionuclides that contribute significantly to this unrepresentative groundwater dose are C-14 from the 218-E-12B waste site in the 200 East Area, C-14 from the 218-W-3A waste site in the 200 West Area, and Tc-99 from the 218-W-3AE waste site in the 200 West Area.

Table 2-2. Summary of Key Sources Contributing to Predicted Groundwater Concentration Results in the Postcompliance Period

Radionuclide	Location	Time	Key Source(s)	Comments
C-14	Northern edge of inner area boundary	CY 3570	218-E-12B (DOE O 435.1 source)	The C-14 inventory (129.9 Ci decayed to 2070) assumed to be in soil-debris in the 218-E-12B waste site is released and transported through the vadose zone resulting in a large transfer to groundwater with a peak transfer rate occurring at about CY 3570 (about 500 years after the end of the CA compliance period). The large inventory assumed is based on information in the TC & WM EIS (Table S-52a in DOE/EIS-0391). The large inventory is associated with activated metal in the naval reactor vessel internal structure. The release rate assumed for soil-debris is not representative of the slow release rate expected from the disposed naval reactor compartments. The highest concentrations and doses are about 300 m to the north of the 218-E-12B Trenches due to the dip of the top of the basalt in this area. The predicted C-14 plume emanating from this source area migrates with the groundwater away from the source area and is dispersed and diluted before intersecting the CA compliance boundary.
C-14	Northern part of 200 West Area	CY 3570	218-W-3A (DOE O 435.1 source)	The C-14 inventory (288.4 Ci decayed to 2070) assumed to be in soil-debris in the 218-W-3A waste site is released and transported through the vadose zone resulting in a large transfer to groundwater with a peak transfer rate occurring at about CY 3570 (about 500 years after the end of the CA compliance period). The large inventory assumed is based on information in the TC & WM EIS (Table S-43a in DOE/EIS-0391). However, the SWITS indicates a C-14 inventory of 1.7405 Ci, of which 1.7166 Ci were disposed of prior to September 26, 1988. The SWITS inventory is more representative of the actual inventory disposed in 218-W-3A. It is worth noting that the large C-14 inventory evaluated in the TC & WM EIS had an insignificant contribution to the predicted groundwater concentration and associated dose beneath and downgradient of the source because the TC & WM EIS assumed a C-14 K_d of 4 mL/g, which precluded transport through the vadose zone within the 10,000-year modeled period considered in DOE/EIS-0391.

Table 2-2. Summary of Key Sources Contributing to Predicted Groundwater Concentration Results in the Postcompliance Period

Radionuclide	Location	Time	Key Source(s)	Comments
				The highest predicted concentrations and doses in the CA occur beneath and downgradient of 218-W-3A. The predicted peak dose 100 m downgradient of the 218-W-3A source exceeds the DOE M 435.1-1 performance objective. However, this predicted peak occurs after the 1,000-year compliance period and is overstated due to the nonrepresentative inventory assumed. The predicted C-14 plume emanating from this source area migrates with the groundwater to the east away from the source area and is dispersed and diluted before intersecting the CA compliance boundary.
Tc-99	Northern part of 200 West Area	CY 3570	218-W-3AE (DOE O 435.1 source)	The Tc-99 inventory (35.0 Ci) assumed to be in soil-debris in the 218-W-3AE waste site is released and transported through the vadose zone resulting in a large transfer to groundwater with a peak transfer rate occurring at about CY 3570 (about 500 years after the end of the CA compliance period). The large inventory assumed is based on information in the TC & WM EIS (Table S-43a in DOE/EIS-0391). The highest concentrations and doses occur beneath and downgradient of 218-W-3AE. The predicted peak dose 100 m downgradient of the 218-W-3AE source exceeds the DOE M 435.1-1 performance objective. However, this predicted peak occurs after the 1,000-year compliance period. These predicted Tc-99 concentrations and associated doses are larger than predicted in the 200 West Area LLBG PA (WHC-EP-0645) due to a reduced specific discharge (therefore less dilution) in the CA model based on updated saturated zone information available since the completion of the PA in 1996. The predicted Tc-99 plume emanating from this source area migrates with the groundwater away from the source area and is dispersed and diluted before intersecting the CA compliance boundary.

Source: Modified from Table 7-1 of DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020)*.

Note: Complete reference citations are provided in Chapter 8 of this document.

CA = composite analysis

CY = calendar year

K_d = distribution coefficient

PA = performance assessment

SWITS = Solid Waste Information and Tracking System

TC & WM EIS = Tank Closure and Waste Management Environmental Impact Statement

As reported in the CA Update (DOE/RL-2019-52) the predicted exceedance of the administrative dose limit at or beyond the Inner Area boundary relates to the conservative assumption in the CA Update that the C-14 inventory in the inactive trenches of the 200 East Area (i.e., 218-E-12B) and 200 West Area (i.e., 218-W-3A) LLBGs is based on the estimates in DOE/EIS-0391, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (hereinafter called the TC & WM EIS) and that the inventory is characterized as soil-debris. The C-14 inventory in 218-E-12B waste site is more appropriately characterized as representing the inventory in the activated metal in the naval reactor compartments disposed in Trench 94 that is expected to have a low release rate (i.e., a fractional release rate of about 1.0E-07 yr^{-1})[3]. The C-14 inventory in the 218-W-3A waste site assumed in the TC & WM EIS is not consistent with the reported as-disposed inventory in SWITS. The Tc-99 inventory in the 218-W-3AE waste site is represented in the CA Update as soil-debris, which is not consistent with the reported waste forms for this inventory reported in SWITS. The CA Update recommended that these inconsistencies be addressed during CA Maintenance.

Figure 2-2 and Figure 2-3 illustrate the predicted C-14 and Tc-99 concentrations in groundwater at CY 4070, respectively. These plots correspond to model year 2052, as the saturated zone flow and transport model started in CY 2018. These plots represent times close to the peak concentration time of CY 3370[4]. These plots illustrate the location of the key contributing sources to the groundwater concentration at this time (i.e., 218-E-12B and 218-W-3A for C-14 and 218-W-3AE for Tc-99).

Figure 2-4 and Figure 2-5 illustrate the predicted time variation of the peak C-14 and Tc-99 concentration, respectively Within, At, and Beyond the CA compliance boundary. These plots illustrate that the time of the peak concentration within the CA compliance boundary occurs at about CY 3300 (simulation year 1300) for C-14 and about CY 3600 (simulation year 1600) for Tc-99[5]. Although these times occur after the 1,000-year CA compliance period that is assumed to end in CY 3070, they are sufficiently close to the end of the compliance period and indicate concentrations far in exceedance of the *Safe Drinking Water Act of 1974* (SDWA) maximum contaminant levels (MCLs; 2,000 pCi/L for C-14 and 900 pCi/L for Tc-99), that they warranted further investigation as to their cause and representativeness.

[3] The C-14 inventory assigned to 218-E-12B is based on the inventory presented in Table S-52a in DOE/EIS-0391. This inventory appears to include the assumed C-14 inventory contained in the activated metals of the naval reactor compartments that are disposed in Trench 94. The release rate of radionuclides from the activated metals results in an insignificant release to the vadose zone and transfer to the saturated zone as evaluated in DOE/RL-88-20, *Hanford Facility Dangerous Waste Permit Application, Low-Level Burial Grounds*, and DOE/EIS-0259, *Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Cruiser, Ohio Class, and Los Angeles Class Naval Reactor Plants.* Therefore, if the C-14 in 218-E-12B can be definitively attributed to the C-14 in the activated metals of the naval reactor compartments, the release rate and transfer to groundwater would be expected to be nil.

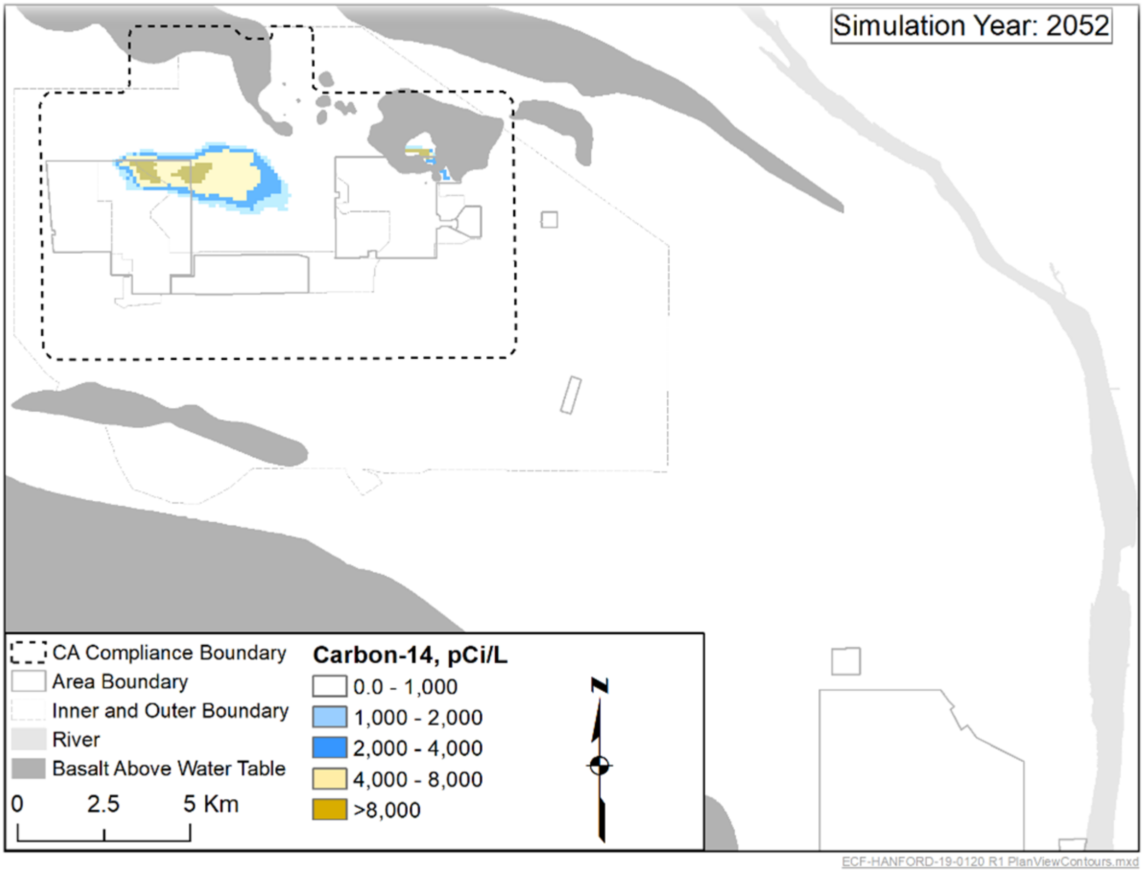
[4] The saturated zone flow and transport model results are presented at discrete times chosen *a priori* rather than after evaluating the time of the peak concentration. While the time and concentration associated with the peak groundwater concentrations are saved in the model results files, the plot files are at specified times. CY 4070 (model year 2052) is a representative time after the time of the peak concentration in CY 3370.

[5] The peak Tc-99 concentration within the compliance boundary occurs at simulation year 0 (corresponding to CY 2018) and is the result of past liquid discharge sites causing Tc-99 contamination in the suprabasalt aquifer in the Central Plateau.

2.3 Summary of Solid Waste Sources Contributing to Predicted Radionuclide Release and Transfer to Groundwater in Composite Analysis

The key radionuclide sources contributing to the predicted peak groundwater concentration and associated groundwater pathway dose are C-14 from the 218-E-12B and 218-W-3A waste sites and Tc-99 from the 218-W-3AE waste site. The 218-E-12B waste site is within the B-63 vadose zone model while the 218-W-3A and 218-W-3AE waste sites are within the LLBG-200W A vadose zone model (Table 2-3). The location of the B-63 and LLBG-200W A vadose zone models is illustrated in Figure 2-6. The solid waste sites within the B-63 and LLBG-200W A vadose zone models are illustrated in Figure 2-7 and Figure 2-8, respectively.

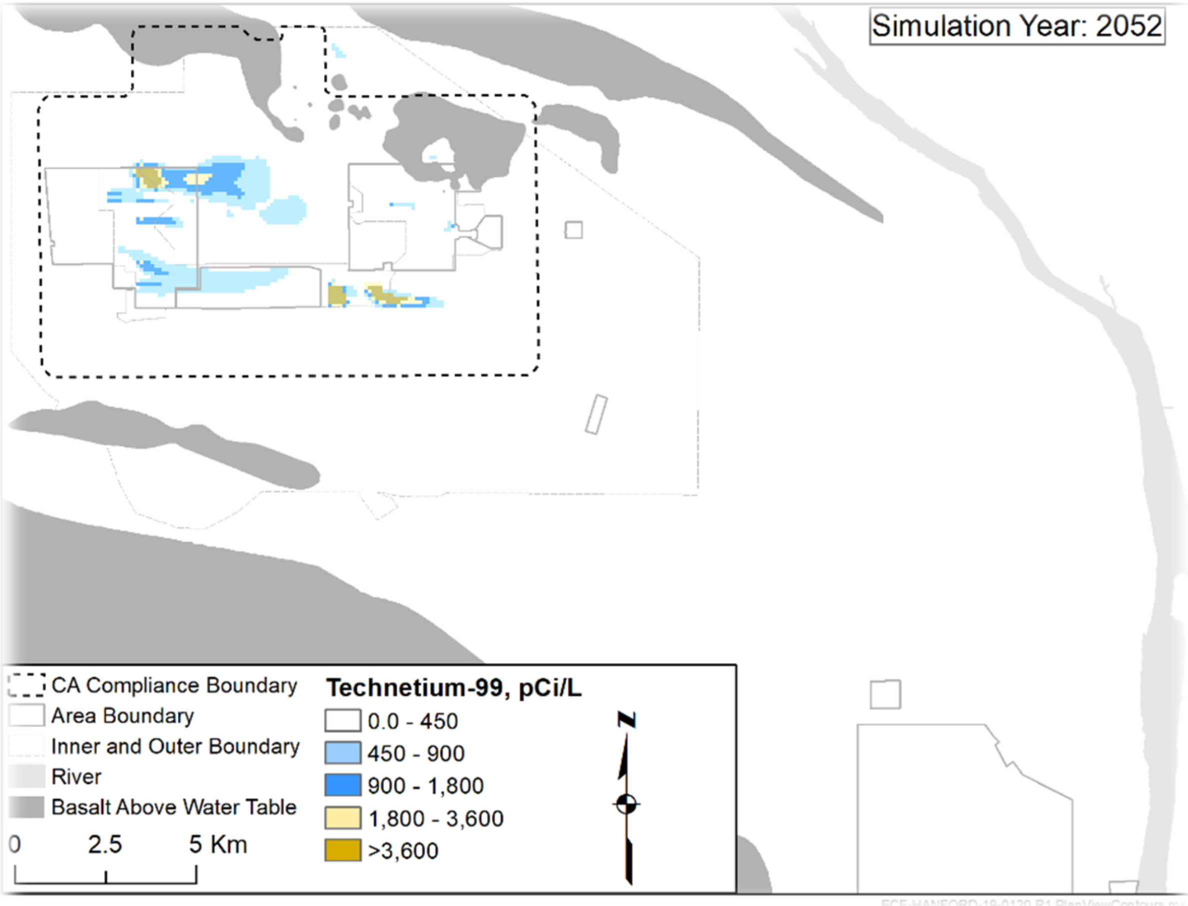
The assumed inventory of C-14 in the 218-E-12B waste site is 130 Ci based on information presented in Table S-52a of DOE/EIS-0391. The assumed inventory of C-14 in the 218-W-3A waste site is 288 Ci based on the information presented in Table S-43a of DOE/EIS-0391. The assumed inventory of Tc-99 in the 218-W-3AE waste site is assumed to be 35 Ci. The waste form for each of these waste sites is assumed to be characterized as soil-debris.



Source: Figure C-62 in ECF-HANFORD-19-0120, *Predictive Contaminant Transport Simulation with the P2R Model for the Composite Analysis Base Case* Reproduced with notes from Figure 5-233 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020).*

Note: Simulation year 2052 corresponds to CY 4070. The largest C-14 concentrations at this time correspond to releases from the 218-E-12B waste site within the B-63 vadose zone model domain in the northern part of the 200 East Area and releases from the 218-W-3A waste site within the LLBG-200W A vadose zone model domain in the northern part of the 200 West Area. The time of peak C-14 transfer to groundwater occurs at about CY 3500 for both the 218-E-12B and 218-W-3A waste sites. The SDWA MCL for C-14 is 2,000 pCi/L. The temporal evolution of the peak C-14 groundwater concentration within the Inner Area boundary is illustrated in Figure 2-4.

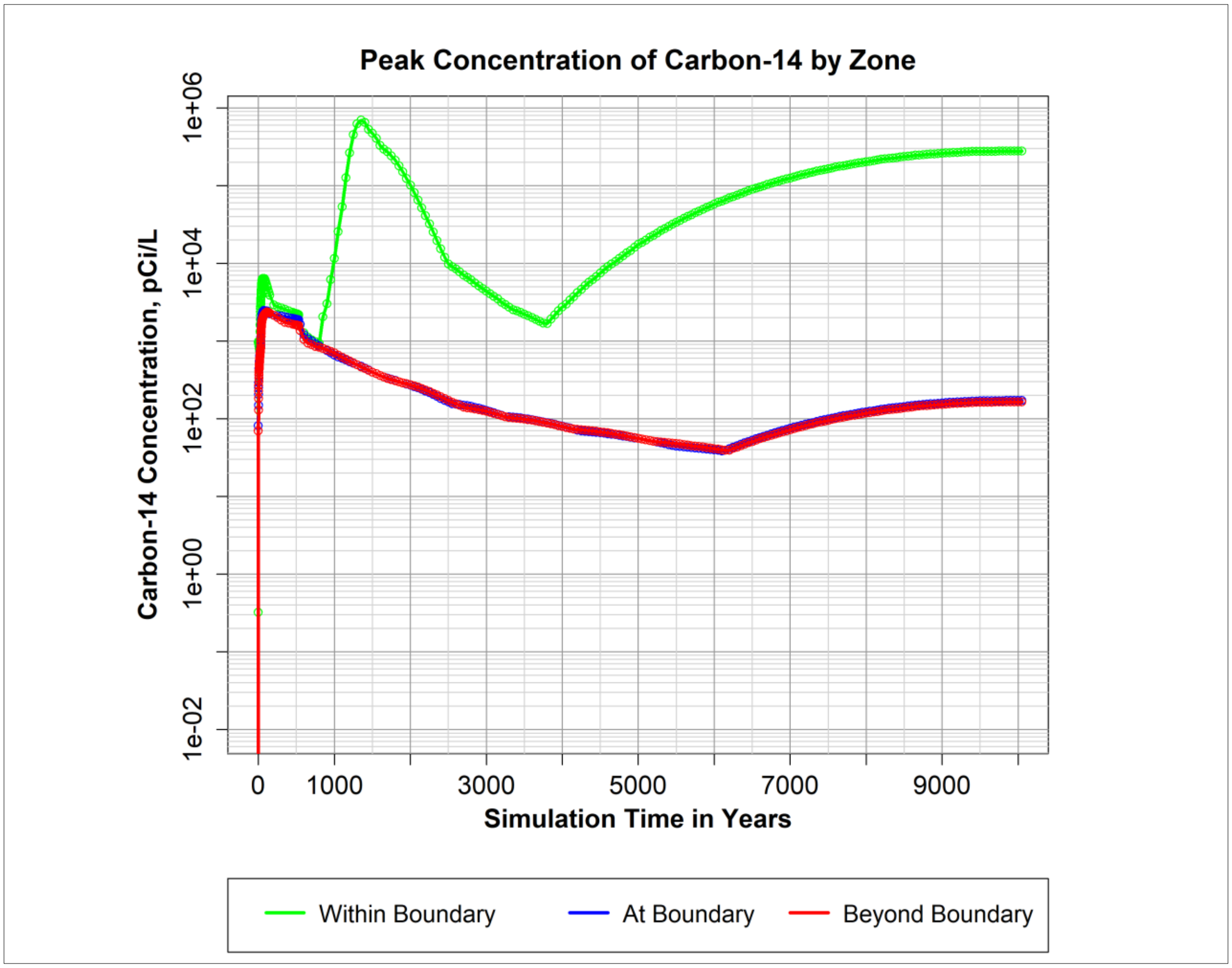
Figure 2-2. Carbon-14 Concentration Simulated 2052 Years from the Start of Simulation



Source: Figure C-18 in ECF-HANFORD-19-0120, *Predictive Contaminant Transport Simulation with the P2R Model for the Composite Analysis Base Case.* Reproduced with notes from Figure 5-239 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020).*

Note: Simulation year 2052 corresponds to CY 4070. The largest Tc-99 concentrations at this time correspond to releases from the 218-W-3AE waste site within the LLBG-200W A vadose zone model domain in norther part of the 200 West Area. High concentrations are also noted beneath the US Ecology site and the BC Cribs and Trenches to the south of the 200 East Area. The time of peak Tc-99 transfer to groundwater occurs at about CY 3500 for the 218-W-3AE waste site. The SDWA MCL for Tc-99 is 900 pCi/L. The temporal evolution of the peak Tc-99 groundwater concentration is illustrated in Figure 2-5.

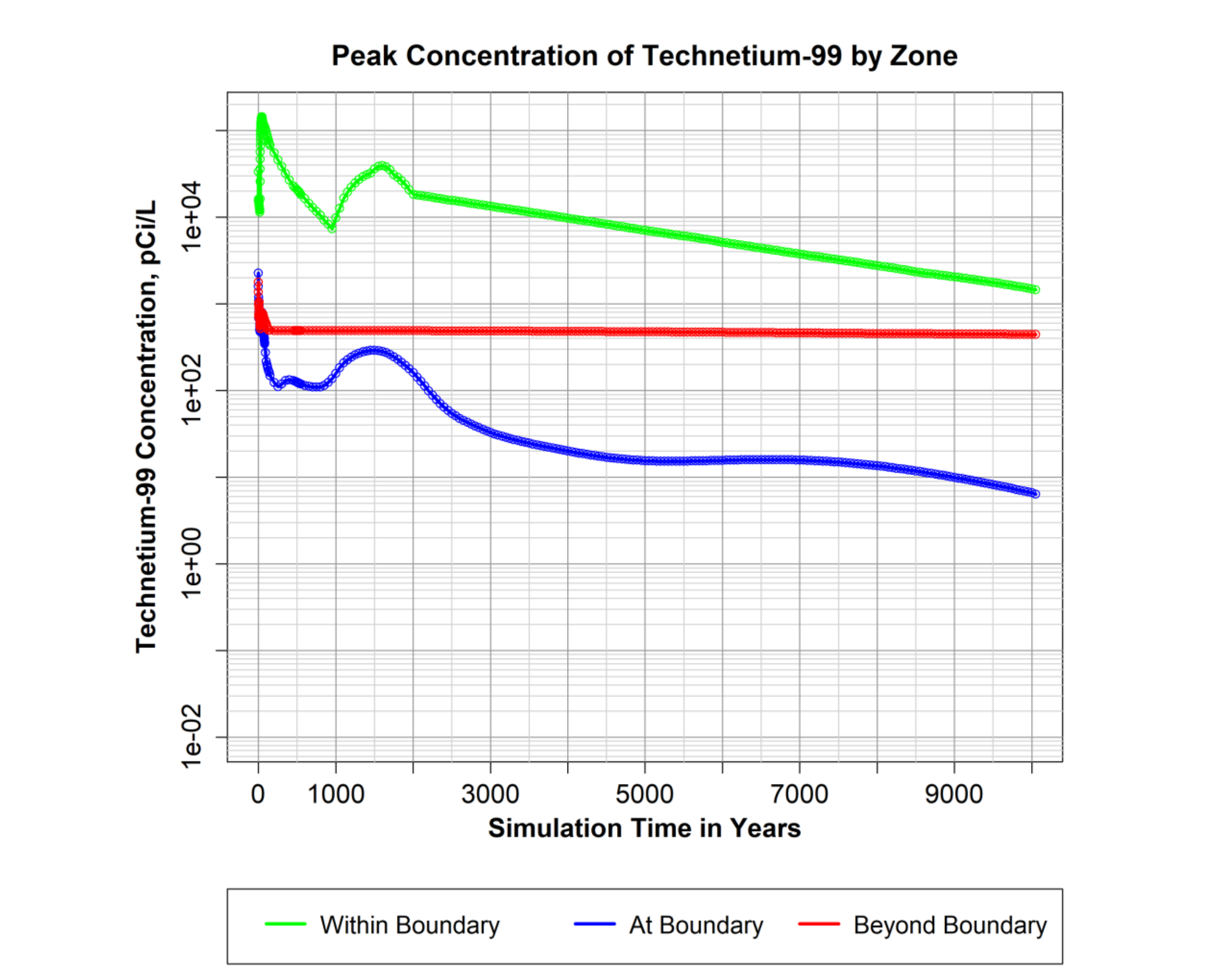
Figure 2-3. Technetium-99 Concentration Simulated 2052 Years from the Start of Simulation



Source: Figure C-66 in ECF-HANFORD-19-0120, *Predictive Contaminant Transport Simulation with the P2R Model for the Composite Analysis Base Case.* Reproduced with notes from Figure 5-235 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020).*

Note: The peak concentration within the CA compliance boundary occurs at about simulation year 1300, corresponding to about CY 3300. The actual time of peak C-14 concentration occurs at CY 3370. The increase in C-14 concentration from simulation year 4000 to simulation year 10000 is the result of releases from the US Ecology site. The SDWA MCL for C-14 is 2,000 pCi/L.

Figure 2-4. Peak Concentration of Carbon-14 from the Start of Simulation to the End of Simulation Within, At, and Beyond the Compliance Boundary



Source: Figure C-22 in ECF-HANFORD-19-0120, *Predictive Contaminant Transport Simulation with the P2R Model for the Composite Analysis Base Case.* Reproduced with notes from Figure 5-241 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020).*

Note: The Tc-99 concentration peak within the CA compliance boundary that occurs immediately after simulation year 0 (CY 2018) is associated with Tc-99 released from past liquid discharge sites on the Central Plateau. The Tc-99 concentration peak that occurs at about simulation year 1600 (i.e., about CY 3600) is due to Tc-99 releases and transfer to groundwater from the 218-W-3A waste site.

Figure 2-5. Peak Concentration of Technetium-99 from the Start of Simulation to the End of the Simulation Within, At, and Beyond the CA Compliance Boundary

Table 2-3. Waste Site Release Operational Boundary and Composite Analysis Solid Waste Release Submodel Assignments

Waste Site Name[a]	Release Start Assignment[b]	Operational Boundary	CASWR Submodel	VZ Model Assignment[c]
218-E-12B	2014	200 East	Soil-Debris	B-63 Area
218-W-3A	2014	200 West	Soil-Debris	LLBG 200W A
218-W-3AE	2014	200 West	Soil-Debris	LLBG 200W A

a. EMDT-GR-0036, *Hanford Site Disposition Baseline (HSDB) Waste Site List*.

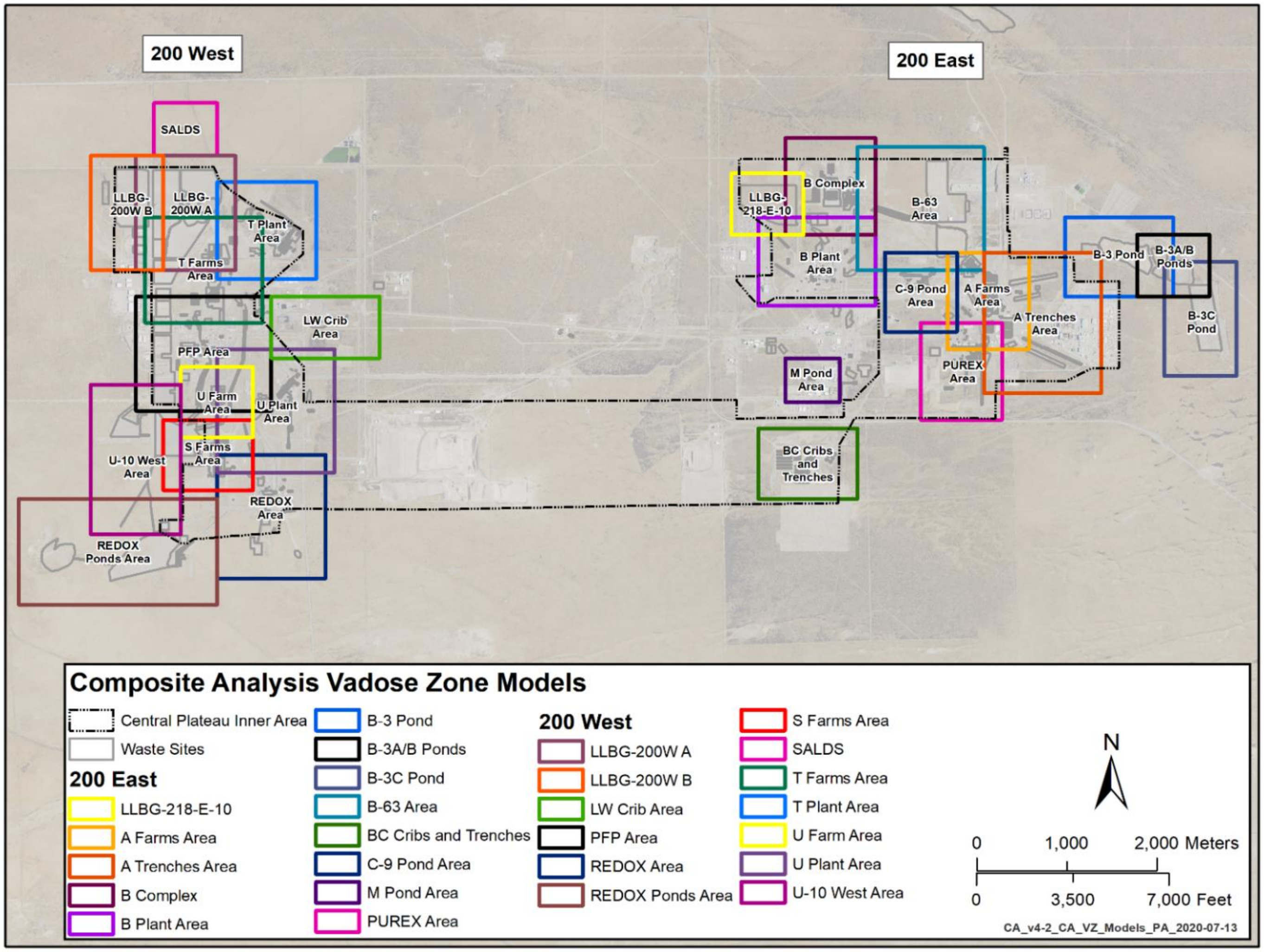
b. Description of year assignment and corresponding reference outlined in EMDT-MO-0032, *Dates for Last Disposal of Solid Waste at Hanford Site Central Plateau Waste Sites Evaluated in the Updated Composite Analysis*. Date assignments begin January 1st of the year listed.

c. EMDT-GR-0043, *CA Solid Waste Release Models Allocation to Vadose Zone Models*.

CASWR = Composite Analysis Solid Waste Release

VZ = vadose zone

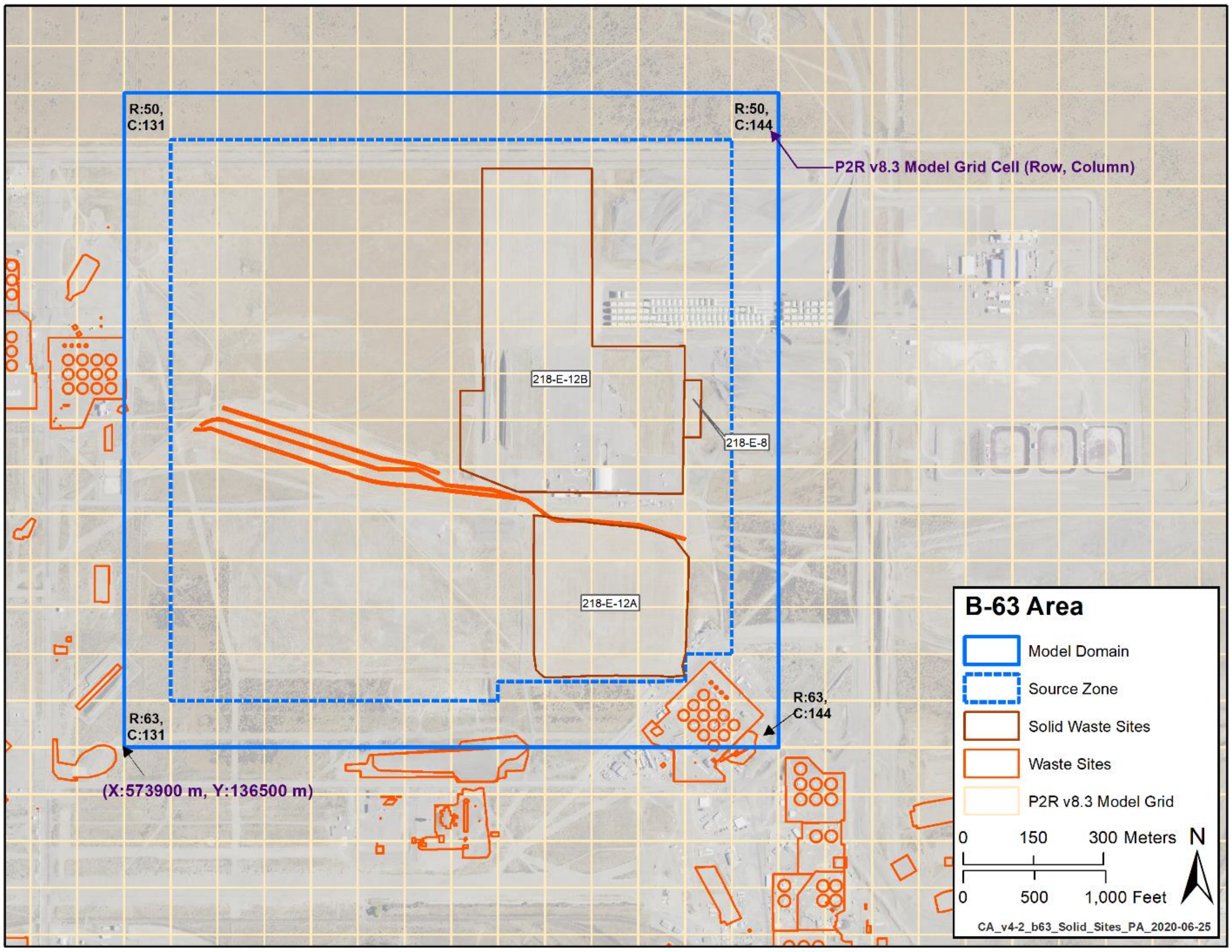
The predicted C-14 release from waste sites and transfer to groundwater from the B-63 vadose zone model domain are illustrated in Figure 2-9. The predicted C-14 release from waste sites and transfer to groundwater from the LLBG-200W A vadose zone model domain are illustrated in Figure 2-10. The predicted Tc-99 release from waste sites and transfer to groundwater from the LLBG-200W A vadose zone model domain are illustrated in Figure 2-11. The predicted Tc-99 release from the 218-W-3AE waste site is illustrated in Figure 2-12. These figures illustrate that the predicted C-14 and Tc-99 transfer to groundwater are dominated by the release rate of C-14 from the 218-E-12B and 218-W-3A waste sites and the release rate of Tc-99 from the 218-W-3AE waste site.



Source: Figure 4-8 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020)*.

Note: Some vadose zone model domains have overlapping extents to ensure that lateral boundaries are sufficiently far from the liquid contaminant sources so that spreading of contaminant migration is not impacted.

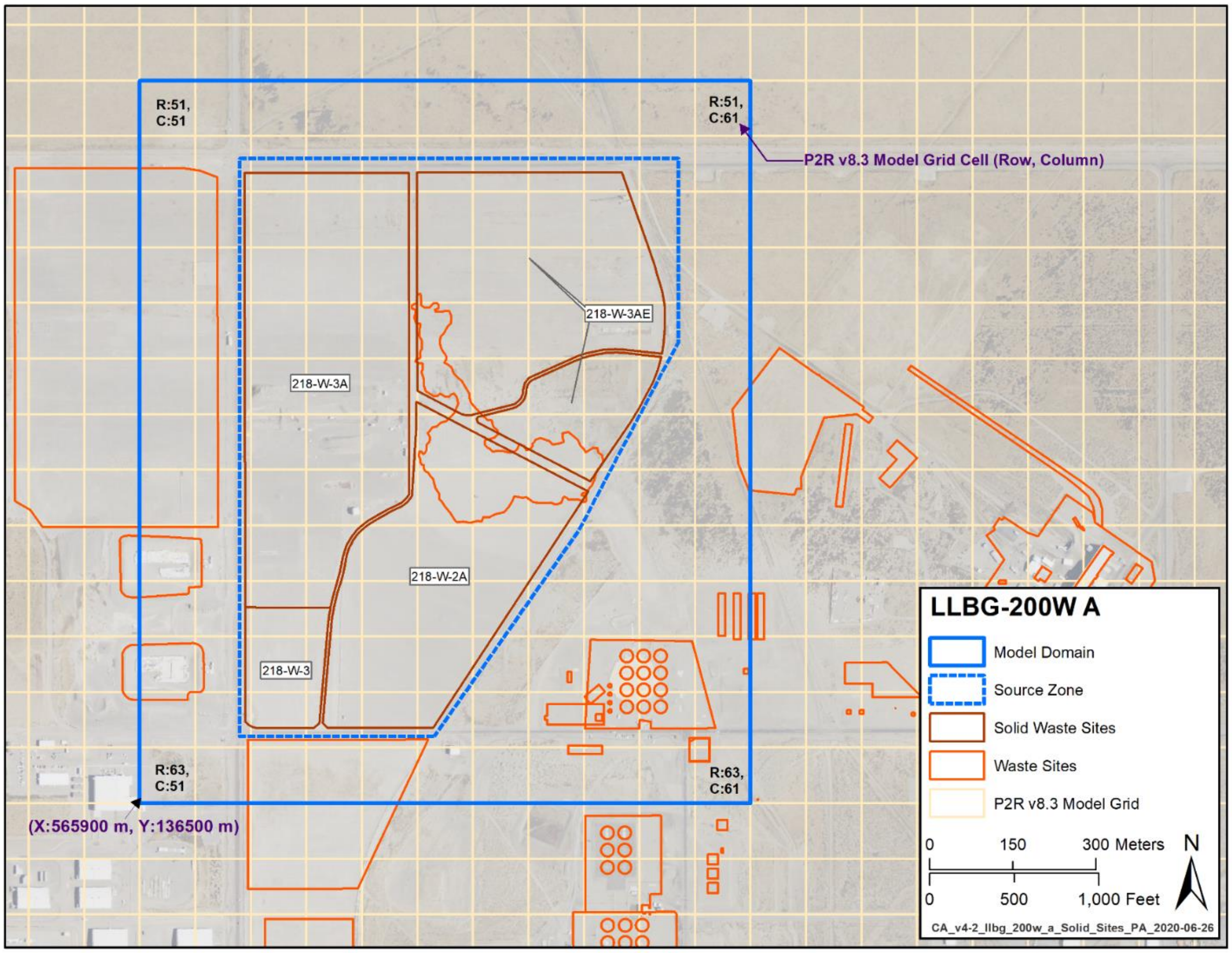
Figure 2-6. Central Plateau Vadose Zone Model Extents



Source: Figure 4-8 in ECF-HANFORD-19-0044, *Vadose Zone Model for B-63 Area for Composite Analysis*. Reproduced as Figure 5-72 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020)*.

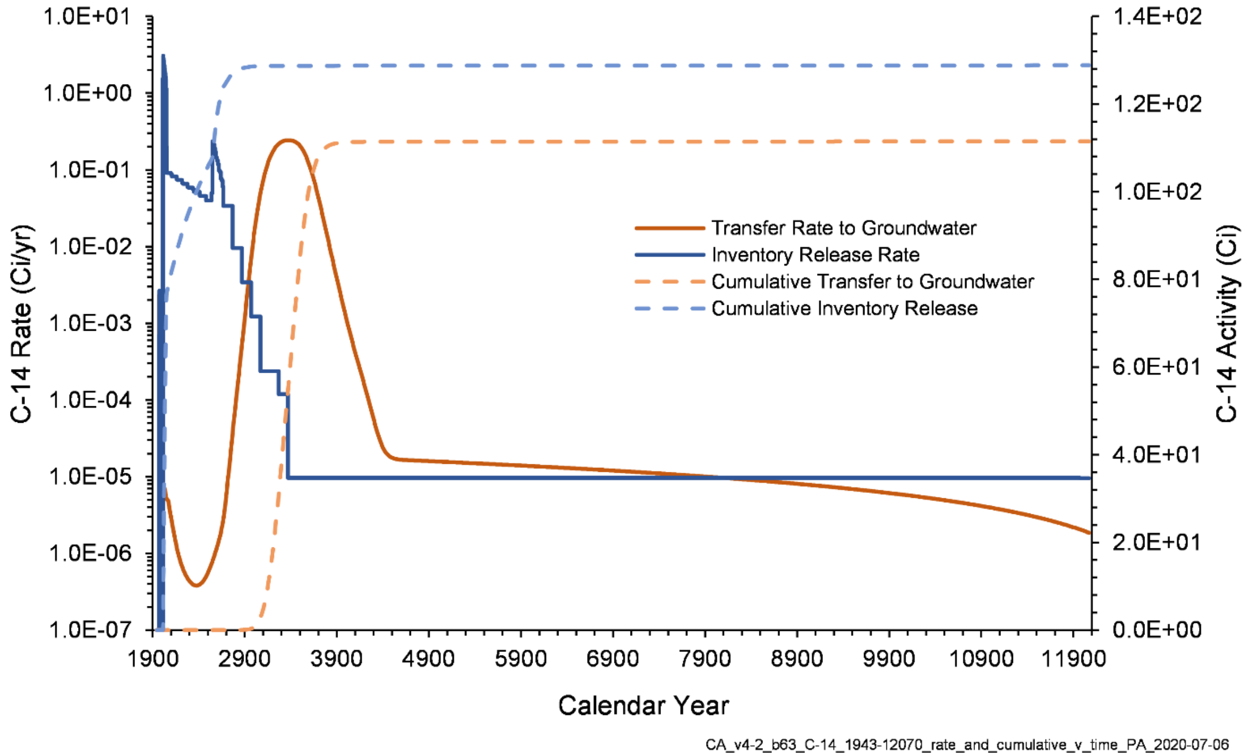
Note: Trench 94 is to the northeast of 218-E-12B. The naval reactor compartments disposed in Trench 94 are apparent in the figure.

Figure 2-7. Waste Sites in the B-63 Area Model with Solid Source Inventory



Source: Figure 4-8 in ECF-HANFORD-19-0048, *Vadose Zone Model for LLBG-W A for Composite Analysis*. Reproduced as Figure 5-95 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020).*

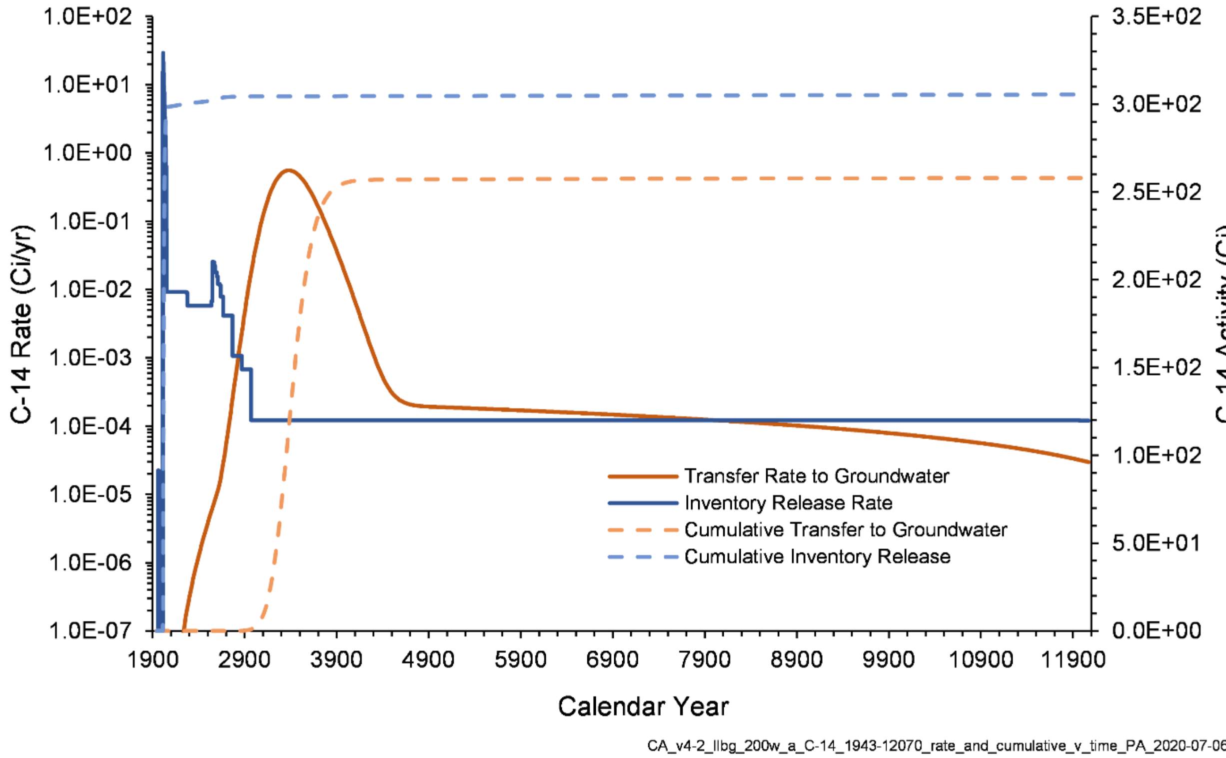
Figure 2-8. Waste Sites in the LLBG-200W A Model with Solid Source Inventory



Source: Figure 7-4 in ECF-HANFORD-19-0044, *Vadose Zone Model for B-63 Area for Composite Analysis*. Reproduced as Figure 5-73 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020).*

Note: The C-14 released and transferred to groundwater is dominated by the release from the 218-E-12B waste site. The delay between the time C-14 is released to the vadose zone and transferred to groundwater is due to transport in the vadose zone which is impacted by the reduction in recharge rate due to the surface cover assumed to be placed over the 218-E-12B waste site.

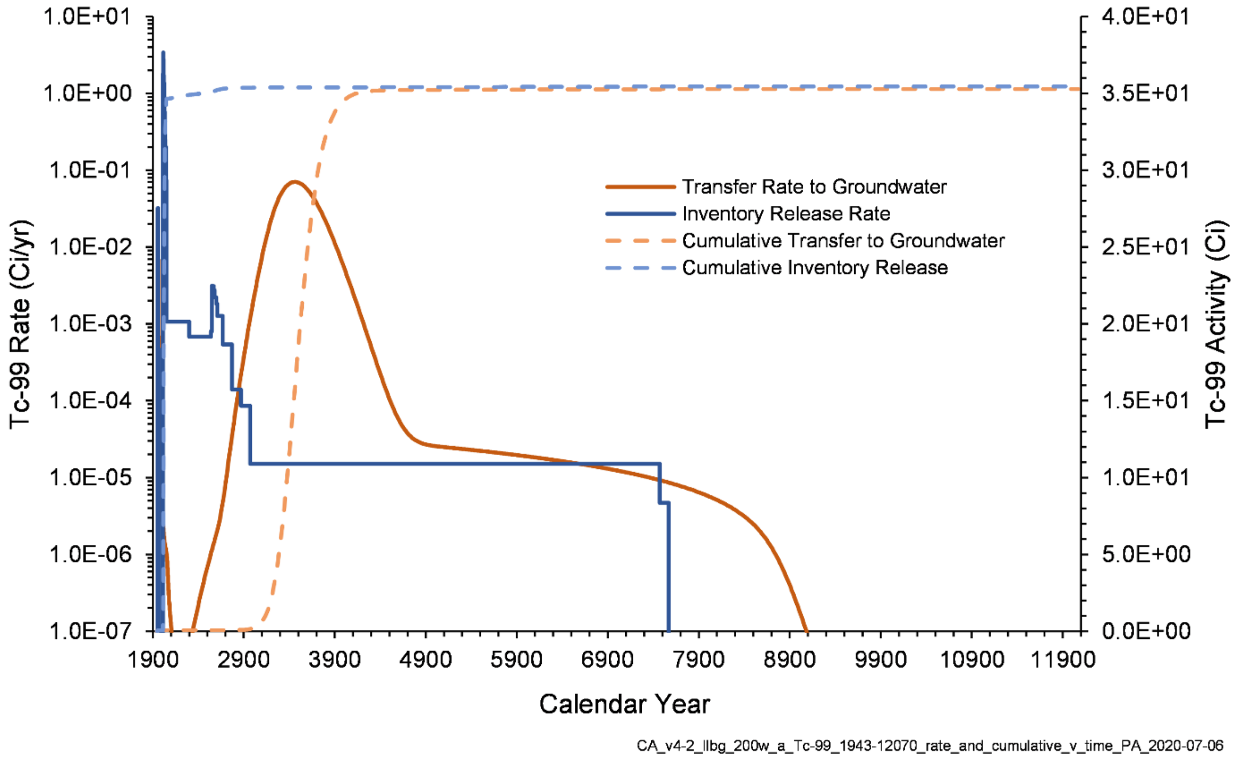
Figure 2-9. Carbon-14 Inventory Release from Waste Sites and Transfer to Groundwater from the B-63 Area Model from 1943–12070



Source: Figure 7-4 in ECF-HANFORD-19-0048, *Vadose Zone Model for LLBG-W A for Composite Analysis*. Reproduced as Figure 5-96 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020).*

Note: The inventory release rate is dominated by releases from 218-W-3A and 218-W-3AE. The inventory of C-14 in 218-W-3A is 288.8 Ci and the inventory of C-14 in 218-W-3AE is 14.5 Ci based on information provided in Table S-43a of DOE/EIS-0391. This inventory is assumed to be in soil-debris. The delay between the time C-14 is released to the vadose zone and transferred to groundwater is due to transport in the vadose zone which is impacted by the reduction in recharge rate due to the surface cover assumed to be placed over the 218-W-3A waste site.

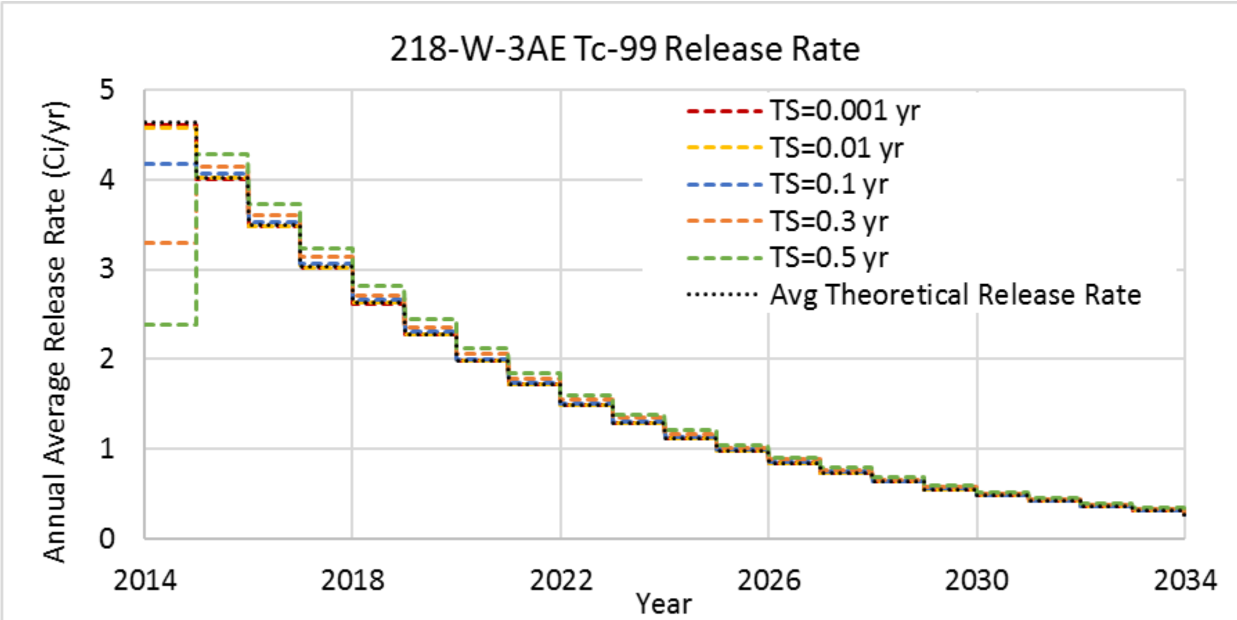
Figure 2-10. Carbon-14 Inventory Release from Waste Sites and Transfer to Groundwater from the LLBG-200W A Model



Source: Figure 7-26 in ECF-HANFORD-19-0048, *Vadose Zone Model for LLBG-W A for Composite Analysis*. Also presented in Figure 5-98 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020)*.

Note: The inventory release rate is dominated by releases from 218-W-3AE which occurs in the first decades after CY 2014 (see Figure 2-12). The inventory of Tc-99 in 218-W-3AE is 35.5 Ci. This inventory is assumed to be represented as a soil -debris waste form. The delay between the time Tc-99 is released to the vadose zone and transferred to groundwater is due to transport in the vadose zone which is impacted by the reduction in recharge rate due to the surface cover assumed to be placed over the 218-W-3AE waste site.

Figure 2-11. Technetium-99 Inventory Release from Waste Sites and Transfer to Groundwater from the LLBG-200W A Model



Source: Figure 4-21 in CP-62766, *Model Package Report: Composite Analysis Solid Waste Release Model (CASWR Model)*. Reproduced as Figure 4-4 in DOE/RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020).*

Note: Time steps of 0.01 year for the first 20 and the 0.3 year for the remaining time were adopted for the soil-debris submodel used in the CA. The inventory of Tc-99 in 218-W-3AE is 35 Ci. These release results assume that entire inventory is represented as soil-debris. In the 20 years from 2014 to 2034, these results indicate that about 33 Ci are released to the vadose zone. That is over 90% of the 35 Ci are released in the first 20 years based on the soil-debris model assumptions.

Figure 2-12. Technetium-99 Release Rates from the Soil-Debris Submodel Used for the 218-W-3AE Waste Site

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3 Methodology

This section first describes the methodology developed for assessing the four sensitivity cases that focus on the three solid waste sites concerned by the CA Maintenance (Section 3.1). The approaches common to the four sensitivity cases are next presented for updating solid waste site inventories (Section 3.2) and waste form assignment (Section 3.3) considering the information available in the SWITS database.
The methodologies for performing solid waste release calculations with the Composite Analysis Solid Waste Release (CASWR) model developed in GoldSim® (CP-62766, *Model Package Report: Composite Analysis Solid Waste Release Model (CASWR Model)*) and subsequent data reduction for vadose zone modeling are detailed in Sections 3.4 and 3.5, respectively.

3.1 Sensitivity Cases Approach

The following sections present the assessment methodologies for the four sensitivity cases that focus on C-14 and Tc-99 inventory and release rate from three waste sites, 218-E-12B, 218-W-3A, and 218-W-3AE. The focus on C-14 and Tc-99 at these three waste sites is due to the significance of these radionuclides and waste sites to the CA predicted groundwater dose in the Inner Area. The importance of the assumptions associated with the inventory and waste release and associated transfer to groundwater was identified in the key assumptions in the CA Update (DOE/RL-2019-52).

If this reevaluation using information from SWITS identifies significant differences from the assumptions used in the CA Update, it may be appropriate to evaluate with other radionuclides in separate ECF(s)/special analyses in future work.

3.1.1 218-E-12B C-14 Inventory Sensitivity Case

The following steps are performed to evaluate the representativeness of the inventory in the 218-E-12B waste site:

1. Assimilate the as-disposed C-14 inventory in the 218-E-12B waste site from SWITS.
2. Determine if the as-disposed C-14 inventory in the 218-E-12B waste site is from Trench 94.
3. Compare the as-disposed C-14 inventory reported in SWITS to the C-14 inventory disposed and planned for disposal in Trench 94 from naval reactor records.
4. Evaluate the representativeness of the C-14 release rate depending on the waste form type.

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3.1.2 218-W-3A C-14 Inventory Sensitivity Case

The following steps are performed to evaluate the representativeness of the inventory in the 218-W-3A waste site:

1. Assimilate the as-disposed C-14 inventory in the 218-W-3A waste site from SWITS.
2. Compare the as-disposed C-14 inventory reported in SWITS to the C-14 inventory reported in DOE/EIS-0391[6].
3. Evaluate the waste form associated with the C-14 inventory reported in SWITS.
4. Evaluate the representativeness of the C-14 release rate depending on the waste form type.

3.1.3 218-W-3AE Tc-99 Inventory Sensitivity Case

The following steps are performed to evaluate the representativeness of the Tc-99 inventory and waste form in the 218-W-3AE waste site:

1. Assimilate the as-disposed Tc-99 inventory in the 218-W-3AE waste site from SWITS.
2. Evaluate the waste form type associated with the as-disposed Tc-99 inventory in the 218-W-3AE waste site.
3. Evaluate the representativeness of the Tc-99 release rate depending on the waste form type.

3.1.4 218-W-3AE Waste Release Footprint Sensitivity Case

The following steps are performed to evaluate the representativeness of the predicted Tc-99 release rate to the vadose zone:

1. Assimilate the location of the as-disposed Tc-99 inventory in the 218-W-3AE waste site from SWITS.
2. Evaluate the representativeness of location of the Tc-99 inventory and associated waste forms in the 218-W-3AE waste site.
3. Evaluate the representativeness of the Tc-99 release rate depending on the waste form type.

3.2 Inventory Revision Approach

The CA Update (DOE/RL-2019-52) identified the assumed inventory and release rate of C-14 and Tc-99 from three DOE O 435.1 waste sites (218-E-12B, 218-W-3A, and 218-W-3AE) as not to be representative of the expected inventory and release rate from these waste sites. The following are the three identified waste sites and associated radionuclides that were identified as being nonrepresentative:

- C-14 inventory in 218-E-12B
- C-14 inventory in 218-W-3A
- Tc-99 release rate in 218-W-3AE

[6] Based on a preliminary review documented in DOE/RL-2019-52, it was determined that the C-14 inventory for 218-W-3A reported in Table S-43a of DOE/EIS-0391 is not representative. The cause for this discrepancy was not determined. Whether there is a need to identify the cause for this discrepancy will be evaluated. As summarized in DOE/EIS-0391 and DOE/RL-2019-52, the C-14 inventory in the TC & WM EIS did not have a significant impact on the predicted groundwater concentrations or dose due to the assumed distribution coefficient of 4.0 mL/g in the vadose zone, which precluded transport of this radionuclide to groundwater within the 10,000-year time period analyzed in the TC & WM EIS.

The inventories used for these sites for the CA Update (DOE/RL-2019-52) were primarily based on the inventories in the TC & WM EIS (DOE/EIS-0391). The details of the CA inventory development were presented in the CA inventory data package (CP-61786, *Inventory Data Package for the Hanford Site Composite Analysis*). To address the unrepresentativeness of the C-14 and Tc-99 inventories at waste sites 218-E-12B, 218-W-3A, and 218-W-3AE, a specific analysis was performed to calculate the C-14 and Tc-99 inventories using the original disposal records from the SWITS database, which contains the disposal package-specific inventories for the individual radionuclides at these the sites.

The new dataset for this CA special analysis case was extracted from the SWITS database on December 14, 2021, by the SWITS Administrator using a SQL query (Appendix A provides the details). This query focused on extracting both activated and nonactivated inventories of C-14 and Tc-99 associated with 218-E-12B, 218-W-3A, and 218-W-3AE. The extracted data records were stored in a Microsoft® Excel® spreadsheet “MEHTA_S_C-14_TC-99_20211214_REV 1 (5).xlsx.” Because of its size, the extracted data file will be presented as a separate file attached to this report in a Word® table format.

As additional information was further needed regarding uranium isotopes inventories associated with Tc-99 in N Reactor wastes disposed in 218-W-3AE over the course of this study, an additional SQL query (also provided in Appendix A) was performed on June 8, 2022, for including uranium isotopes in this extraction. The extracted data records using the additional SQL were saved in a separate Excel spreadsheet file (MEHTA_S_C-14_TC-99_URANIUM_20220608.xlsx).

The following steps were taken for evaluating and analyzing SWITS based inventories for 218-E-12B, 218-W-3A, and 218-W-3A:

1. Parse the SWITS inventory data for C-14 and Tc-99 based on the waste sites.
2. Evaluate the data quality for individual units in the individual waste sites.
3. Perform decay calculations using the first-order decay equations and Hanford-approved parameters (e.g., half-life); decay the inventories from release times to 2070.
4. Compare the SWITS based inventories with the inventories in the CA data package and calculate the difference.
5. Compare the C-14 inventories in 218-E-12B with or without consideration of the inventory in Trench 94; make decision to exclude inventories in Trench 94 based on the fact that the C-14 inventory in Trench 94 is associated with activated metals in the naval reactor compartment vessel and will not be released to the site during the compliance period.
6. Summarize the inventories across the units for C-14 and Tc-99 in each site.

The calculated inventories for C-14 and Tc-99 went through the following quality assurance/quality control steps to ensure the data quality:

1. Check the parsing process for inventory data from the original SWITS data file (see Section 4.1 for assumptions regarding SWITS data quality).
2. Check the calculation of decay years for individual package based on the treatment, storage, and disposal (TSD) accept year.

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3. Check the first-order decay equation and parameters.
4. Check the summarization calculation.
5. Check the comparison of the decayed SWITS inventories with that in CA data package.

3.3 Waste Form Assignment Approach

Waste forms have been assigned based on waste description, profile, and comments available for each waste package mentioned in SWITS for 218-E-12B, 218-W-3A, and 218-W3AE. These text fields have been analyzed for identifying the most commonly observed keywords among the 3,316 waste packages disposed in these waste sites. A lookup table (Table 3-1) built from these keywords has been used for differentiating the wastes whose release processes are most likely governed by diffusion to those governed by advection. To do so, the cement waste form was assigned when the waste description, profile or comments mentioned a keyword listed in Table 3-1 reflecting a stabilization process (e.g., stabilized, concreted, grouted, compacted, bulking) and/or the occurrence of a large fraction of concrete (e.g., slab, vault, concrete overpack), grout or very fine material (e.g., sludge, Table 3-1). If none of these keywords were found within the waste description or comments, then the soil-debris waste form was assigned to these remaining wastes. This methodology relies on the assumption that diffusion is most likely the most significant transport process once the waste has been stabilized or contains significant fractions of diffusion-dominated materials. One has to note however that the occurrence of a keyword listed in Table 3-1 in the waste descriptions, comments, or profiles does not quantify the actual fraction of the diffusion-dominated material within the waste package. This waste form assignment methodology remains therefore qualitative. As the development of a quantitative methodology similar to a performance assessment (PA) approach was beyond the scope of this study, the representativeness of the waste form assignment resulting from the qualitative methodology developed for this study has not been compared to a quantitative approach. This could be achieved in future work.

Additionally, care is taken to address the different waste form inventories received at the 218-W-3AE waste site. N Reactor wastes disposed in 218-W-3AE are described in SWITS as “N REACTOR < 1% ENRICHED UNIRRADIATED FINISHED AND UNFINISHED FUEL ASSEMBLY DISPOSAL.” It is assumed that this waste form is analogous to the uranium billet disposed in Trench 34. According to 218-W-3AE uranium waste descriptions mentioned in FH-0105097, *Performance Assessment Review Report, 2000-2001 Annual Review of the 200 West and 200 East Area Performance Assessments*, N Reactor waste have been disposed in a concrete monolithic structure in Trench 08, which constitutes a commonality with Trench 34 conceptual model. As N Reactor wastes disposed in 218-W-3AE have a very different nature than the other wastes considered as soil-debris, their inventory has been separated in order to consider solubility-limited release processes similar to that of uranium billet waste model, which was previously developed for Trench 34 uranium billet (CP-62766). This particular waste form is described as metallic uranium with trace metal impurities (e.g., Tc-99) included within the uranium matrix whose release is congruent to uranium dissolution controlled by uranium solubility. The inventory of all uranium isotopes was thus determined for the N Reactor waste packages using SWITS for implementing a solubility limit for Tc-99 based on congruent dissolution of uranium.

Table 3-1. Keywords Considered for Waste Form Assignment in this CA Maintenance Special Analysis

Keyword	Waste Form in CASWR[a]
GROUTED	Cement
CONCRETED	Cement
BULKING	Cement
SLUDGE	Cement
STABILIZED	Cement
COMPACTED	Cement
CONCRETE OVERPACK	Cement
SLAB	Cement
VAULT	Cement
N REACTOR	Solubility-limited U billet[b]
Any other than the above	Soil-debris

a. UCAQ-2022-01, 2022, *Inventory Discrepancies for 218-E-12B, 218-W-3A and 218-W-3AE in the Hanford Site Composite Analysis*, .

b. Solubility limit for Tc-99 based on congruent dissolution of technetium with uranium waste matrix representing N Reactor unirradiated fuel disposed in 218-W-3AE.

CASWR = Composite Analysis Solid Waste Release

3.4 Release Calculation Approach

Release calculations have been performed with the same methodology as the one developed for the CA Update (DOE/RL-2019-52) and described in detail in CP-62766 and ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*. However, as three different waste forms (cement, soil-debris, and uranium (U) billet) have been considered for each waste site, only cement and soil-debris submodels have been implemented. The soil-debris submodel allow not only advection-controlled release simulations (soil-debris waste form) but also solubility-limited advection-controlled release simulations (U billet waste form). The main calculation steps are described as follows:

1. Request site specific recharge time series data (designated as a waste site centroid) as extracted from ECF-HANFORD-15-0019, *Hanford Site-Wide Natural Recharge Boundary Condition for Groundwater Models* and outlined by ECF-HANFORD-18-0074, *Application of the Recharge Evolution Tool (RET) to Prepare Spatially and Temporally Variable Recharge Boundary Conditions for Hanford Site Composite Analysis Vadose Zone Models*.

    a. The same Excel file "Solid_Waste_Release_RET.xlsx" as the one considered in ECF-HANFORD-19-0112 has been considered as no modification of the recharge rates has been implemented.

2. Determine which recharge rates impact the soil-debris during years simulated.

    a. The same moisture content values abstracted from steady-state Subsurface Transport Over Multiple Phases (STOMP[7]) simulations have been considered for each relevant recharge rate using the representative 200 East and 200 West Area one-dimensional vadose zone column models developed for CP-62766: one-dimensional STOMP results for each recharge scenario are included in their respective submodel hydrostratigraphic moisture content elements.

3. Check data linkages in GoldSim for each soil-debris submodel waste site to the Solid_Waste_Release_RET.xlsx file (path: Soil_Debris\Soil_Inputs\Recharge).

4. Define the sites for which a calculation is run: The spreadsheet “Parameters.xlsx” has been modified for running calculations only for 218-E-12B, 218-W-3A, and 218-W-3AE with both cement and soil-debris submodels considering SWITS inventory implemented in “Inventory.xlsx” for each waste form. N Reactor inventory has been separated out from the other soil-debris inventory of 218-W-3AE and has been implemented in a data element within the U billet container renamed “NReac_U_Billet” (Figure 3-1).

5. Close all Excel files before running the GoldSim model.

6. Run GoldSim CASWR model.

7. Once the runs are complete, copy the PostProcess_Input.txt and SWR_Output_Postprocess.R files in the folder. The original R Script has been modified for adding up the results of each waste form (cement and soil-debris) and computing the total release rate of each waste site. Appendix B provides the updated script.

8. Appendix E includes the final postprocessed results.

[7] STOMP is a copyright of Battelle Memorial Institute, Columbus, Ohio, and used under the Limited Government License.

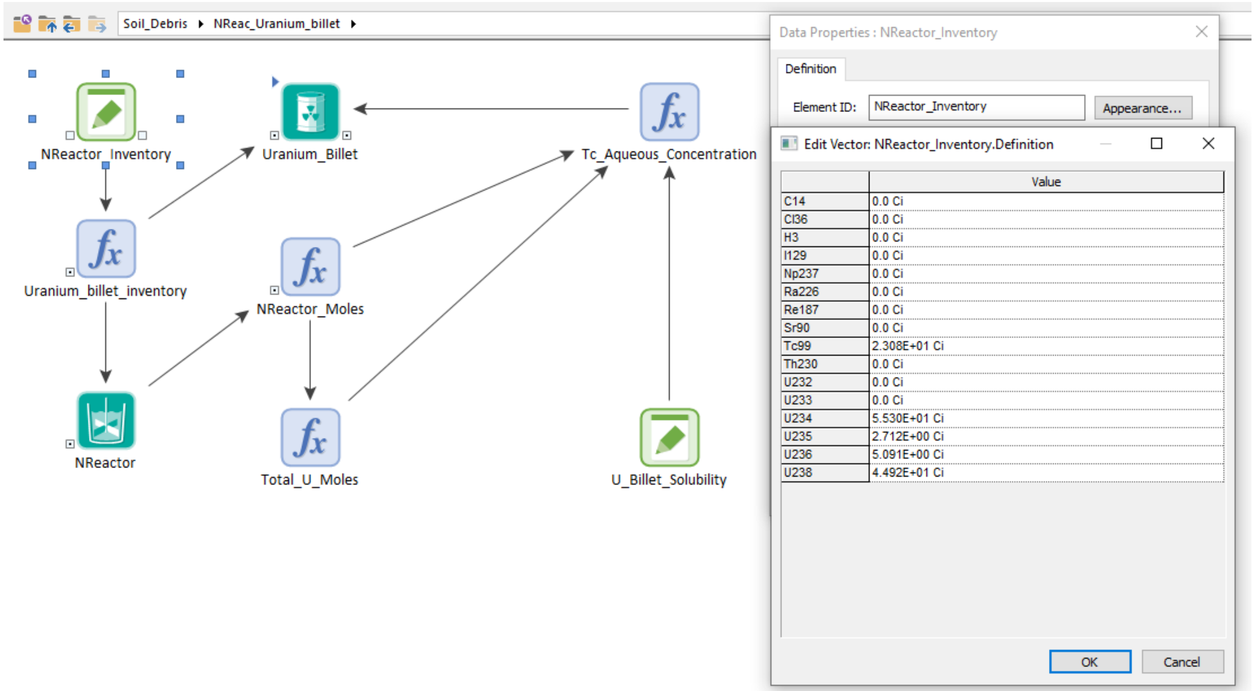

Figure 3-1. Implementation of N Reactor Waste Packages Inventory Within the Soil-Debris Submodel

3.5 Data Reduction Approach

Once release rates are computed with GoldSim and postprocessed with R using the methodology previously described in Section 3.4, data reduction is performed for decreasing the number of data pairs (i.e., [Time, Release Rate]). This step is required for not exceeding the limitations imposed by the STOMP modeling software package used to simulate contaminant transport through the vadose zone. The methodology considered here for data reduction is exactly the same as the one developed in ECF-HANFORD-20-0006, *Composite Analysis Solid Waste Release Data Reduction of Activity Flux from Waste Sites to the Vadose Zone for Baseline Assessment* and can be summarized as follows:

1. Create the user-defined configuration file (JSON-formatted file given in Appendix F) used as input for the calculations
2. Run the Python® script developed for the CA Update (DOE/RL-2019-52) based on the Ramer-Douglas-Peucker algorithm
3. Check the errors and corresponding reduced results. Appendix F includes the final postprocessed results.

® Python is a trademark of the Python Software Foundation, Wilmington, Delaware.

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4 Assumptions and Inputs

This chapter provides key assumptions and inputs used to calculate radionuclide inventory and radionuclide release rates for the four sensitivity cases.

4.1 Assumptions and Inputs for Radionuclide Inventory

Wastes disposed in trenches in the LLBGs of the Hanford Site after 1998 must meet the requirements specified in HNF-EP-0063, Rev. 5, *Hanford Site Solid Waste Acceptance Criteria*.[8] The inventory concentration of each major radionuclide must be established with sufficient sensitivity and accuracy to classify and manage the waste properly in accordance with unit-specific radiological limits (DOE M 435.1-1, *Radioactive Waste Management Manual*). Major radionuclides are defined as those that meet any of the conditions identified in Appendix A of HNF-EP-0063.

The inventory and solid waste container types disposed in the LLBGs of the Hanford Site are controlled and tracked in SWITS[9]. SWITS assists Hanford Site waste generators by providing a tool for tracking regulated wastes from cradle to grave. Its use is required for Hanford Site waste generators that generate dangerous and polychlorinated biphenyl wastes. The general structure and content of SWITS are presented in HNF-58315, *Solid Waste Information and Tracking System (SWITS) User's Manual – Waste Generation*.

From an inventory and waste container perspective, the key information contained in SWITS includes the following:

- Disposal facility identification (e.g., 218-E-12B, 218-W-3A, or 218-W-3AE)
- Disposal Unit identification (e.g., Trench 94 in 218-E-12B)
- Disposal date
- Container identification number
- Container description
- Container volume
- Container weight (gross, tare, packaging, and waste)
- Waste categorization (Cat1, Cat3, Greater Than Category 3)
- Waste component descriptions and weight
- Packaging component descriptions and weight
- Radioisotope activity (Ci) and mass (gm)
- Waste acceptance date

[8] Following the completion of the initial PAs for the 200 West Area and 200 East Area LLBGs (WHC-EP-0645, *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds* and WHC-SD-WM-TI-730, *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Burial Grounds*), the initial version of Hanford Site waste acceptance criteria (WAC) was developed (HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev. 5, dated May 1998). The WAC has undergone revisions since it was initially developed, but the key requirement related to radiological characterization are unchanged.

[9] SWITS contains radiological concentration of solid wastes disposed prior to the completion of the WAC in 1998.

There is a well-defined and audited process to TSD wastes at the Hanford Site. The TSD process includes development of the waste profile, which is required to be submitted and approved before the submittal of waste packages for acceptance prior to receipt and disposal. The waste profile is identified in SWITS. Part of the waste profile is the radiological characterization of the waste, which includes a description of the analysis and characterization methods used to determine the radionuclide inventory of the waste stream. As detailed in HNF-EP-0063, Rev. 5, the characterization methods include one or more of the following methods:

- Radionuclide material accountability performed by summing the radionuclide content from each originating waste package being processed and ensuring mass balance
- Radiochemical analysis including description of the type and frequency of sampling and analysis
- Nondestructive assay including description of the type and frequency of the assay performed
- Field measurement including description of the type of instruments and how they are used to help establish the radionuclide inventory
- Scaling factors including description of how the scaling factors were derived and how they are used
- Computer models including description of the computer model and how it is used to establish the radionuclide inventory
- Other methods

It is beyond the scope of this inventory evaluation to review the details behind the technical basis of the inventory information provided in SWITS. It is assumed that the audited waste acceptance processes ensure the wastes received and disposed in the LLBGs are adequately characterized and that therefore, the SWITS information is appropriate for use in the CA Update (DOE/RL-2019-52).

It is further assumed that the data records provided in the Excel spreadsheet files "MEHTA_S_C-14_TC-99_20211214_REV 1 (5).xlsx" and "MEHTA_S_C-14_TC-99_URANIUM_20220608.xlsx" adequately reflect the quantities of the radionuclide inventories disposed in waste sites 218-E-12B, 218-W-3A, and 218-W-3AE, which are the focus of this CA special analysis.

The radionuclide activity reported in SWITS is by container. Each container has an identified disposal unit and an identified waste categorization (i.e., Cat1 or Cat3[10]). As has been demonstrated in the original 200 West LLBG PA (WHC-EP-0645, *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds*) used as the basis for the disposal authorization and the WAC (HNF-EP-0063) the release of radionuclide activity from the waste forms are dependent on the radionuclide and the waste container configuration. Cat3 wastes need to be segregated from Cat1

[10] The distinction between Cat1 and Cat3 is based on the radionuclide concentration in the waste container. The different concentration categories are based on concentration limits derived from the inadvertent intruder assumptions used for the waste trenches analyzed in the 200 West LLBG PA (WHC-EP-0645). The burial grounds with Cat1 waste containers were assumed to allow waste exhumation during excavation of residential basements immediately following the institutional control period while the burial grounds with Cat3 waste containers were assumed to only allow inadvertent drilling through waste containers 500 years after the wastes were disposed. The Cat3 containers also require stabilization to meet the groundwater performance objective and land disposal restrictions. Because the Cat1 containers do not require stabilization, radionuclides may be released by advection from these containers and therefore it is relevant to determine the radionuclide inventory in the Cat1 containers separately form the Cat3 containers.

wastes because the Cat1 wastes do not require stabilization and therefore can release radionuclides by advection through the degraded container.

The waste category was not however directly available for each waste package disposed in 218-E-12B, 218-W-3A, and 218-W-3AE in the extraction of the SWITS database performed for this study. Among the 3,316 waste packages listed in the spreadsheet derived from SWITS for these three solid waste sites, only 88 were found to have a category information (Table 4-1). This may be because 77% of these waste packages have been accepted for disposal in these waste sites before the definition and publication of the WAC in 1998 (HNF-EP-0063) as detailed in Table 4-1.

Table 4-1. Number of Waste Packages, TSD Acceptance Date, and Category Information

Waste Site	Number of Waste Packages	TSD Acceptance Date Range	Number of Waste Packages Accepted Before 01/01/1998	Number of Waste Packages for which a Category is Mentioned in SWITS
218-E-12B	675*	04/08/1986 – 10/06/2003	594 (88%)	8 (1%)
218-W-3A	420	11/24/1980 – 07/21/1998	419 (99%)	2 (0%)
218-W-3AE	2,221	05/16/1988 – 01/14/2010	1,537 (69%)	78 (4%)
Total	3,316	11/24/1980 – 01/14/2010	2,550 (77%)	88 (3%)

*Trench 94 packages included.

SWITS = Solid Waste Information System

TSD = treatment, storage, and disposal

As the category information was mostly missing in this study for the three waste sites (Table 4-1), the assumption was made that any keyword reflecting a stabilization process and/or the occurrence of a large fraction of concrete, grout or very fine material (e.g., sludge, Table 3-1) in waste description and comments available in SWITS can be used for differentiating the wastes whose release processes are most likely governed by diffusion to those governed by advection (see waste form assignment methodology presented in Section 3.3).

All SWITS inventories have been decay corrected to January 1, 2070, considering the TSD Acceptance Date indicated in SWITS and radionuclide half-lives given by ICRP Publication 107, *Nuclear Decay Data for Dosimetric Calculations*.

4.2 Assumptions and Inputs for Waste Release

The following sections describe the assumptions (Section 4.2.1) and inputs (Section 4.2.2) considered for waste release calculations and next the assumptions and inputs for data reduction (Section 4.2.3).

4.2.1 Waste Release Assumptions

CP-62766 provides an in-depth discussion of CASWR model limitations. A brief discussion of the assumptions that apply to the CASWR cement and soil-debris submodels considered in the CA Update and in this study in a base case approach is included below together with a description of an additional assumption differing from the CA Update (DOE/RL-2019-52) approach and tested in an additional sensitivity case:

1. C-14 and Tc-99 inventories provided by SWITS for a given waste site are available for release at a single start date defined by EMDT-MO-0032. Simulations last 10,000 years after the assumed Hanford Site closure in 2070.

2. One of two waste forms, including cement and soil-debris, are assigned to each waste disposal for limiting the conservatism related to a single soil-debris waste form assignment for these particular sites. The release process is governed by diffusion in the cement waste form and by advection in the soil-debris waste form. The respective assumptions related to each of their corresponding waste release submodels are detailed in Section 4.2.1 for cement and Section 4.2.2 for soil-debris.

3. The respective inventory assigned to each waste form is assumed to be homogenously distributed over the whole waste site footprint and thickness in a base case approach consistent with the CA Update approach. When additional information was available regarding the distribution of the inventory through the waste site footprint, another inventory distribution was considered in an additional sensitivity case. Due to the lack of information regarding the spatial distribution of the different waste forms in each disposal site, such a sensitivity case was only conducted for the cement waste form disposed in 218-W-3AE. For this particular case, most of the cement waste form inventory was found to be associated with a very limited number of waste packages (Section 7.2). It was therefore assumed in a sensitivity case that the cement waste form footprint within 218-W-3AE was like that of a B-25 container (PNNL-15965, *Release Data Package for Hanford Site Assessments*). A corresponding area-to-volume ratio for the cement waste form disposed in 218-W-3AE was derived from this assumption (Table C-1 in this ECF).

4. Tc-99 inventory associated with N Reactor waste packages is considered as impurities within the uranium mineral matrix of unirradiated fuel. This hypothesis is consistent with the source release model developed for Trenches 31 and 34 in Section 3.2.4 of ECF-HANFORD-20-0011, *Waste Release Calculations for the Active Trenches of the Low-Level Burial Grounds*. The release of Tc-99 associated with N Reactor waste packages is assumed to be controlled by a solubility limit resulting from congruent dissolution of technetium with uranium matrix. The molar technetium/uranium ratio within N Reactor waste packages at closure is deduced from SWITS.

5. The total release rate is assumed to be the sum of each waste form contribution. This sum is computed with the modified postprocessing R script (given in Appendix B).

4.2.2 Waste Release Calculation Inputs

Table 4-2 lists the main transport and release processes considered in each waste form submodel with their corresponding parameter requirements in Table 4-3. Section 4.2.3 details the mathematical description of the transport and release processes. Table 4-4 summarizes the parameter tables supporting each solid waste form model.

Table 4-2. Transport and Release Processes Considered in the Solid Waste Form Submodels

Transport and Release Processes	Release Submodel	
	Cement	Soil-Debris
Advection in the source zone		X
Diffusion in the source zone	X	
Solubility-controlled release		X[a]
Reversible sorption in the source zone	X[b]	X[c]

a. Only for N Reactor waste packages disposed in 218-W-3AE where a solubility limit for technetium is applied based on congruent dissolution of technetium with uranium in waste matrix.

b. Process included implicitly through the effective diffusion coefficient values considered in the CA Update approach (DOE-RL-2019-52, *Composite Analysis for Low-Level Waste Disposal in the Hanford Site Central Plateau (FY 2020))* (see Appendix C).

c. Process included in the CA Update approach for radionuclides other than C-14 and Tc-99 that have a K_d equal to 0 mL/g (see Appendix D).

CA = composite analysis

K_d = distribution coefficient

Table 4-3. Summary of Input Parameter Requirements for the Solid Waste Form Submodels

Model Parameter (Units)	Release Submodel	
	Cement	Soil-Debris
Source zone cross-sectional area or waste surface area (L^2)		X
Thickness of waste or distance from soil surface to bottom of contaminant source zone (L)	X	X
Distribution coefficient (K_d, L^3/M)		X
Contaminant solubility (M/L^3)		X*
Bulk density of waste matrix (M/L^3)		X
Volumetric moisture content (-)		X
Recharge or Darcy velocity (L/T)		X
Effective diffusion coefficient (L^2/T)	X	
Contaminant activity (Ci)	X	X

*For technetium only in N Reactor waste packages disposed in 218-W-3AE.

Table 4-4. Summary of Parameter Tables Supporting Solid Waste Release Submodels

Release Submodel	Model Parameter	Data Package (in this report)
Cement	Area-to-volume ratio	Table C-1
Cement	Effective diffusion coefficient	Table C-2
Soil-Debris	Source zone cross-sectional area	Table D-1
Soil-Debris	Source zone thickness	Table D-1
Soil-Debris	Distribution coefficient (K_d) for very high salt/very basic source zone (Category 4)	Table D-2
Soil-Debris	Contaminant solubility	Table D-3
Soil-Debris	Source zone volumetric moisture content	Table D-4
Soil-Debris	Source zone bulk density	Table D-4

Special care is given to implementing a solubility-limited release for Tc-99 associated with N Reactor waste packages disposed in 218-W-3AE based on congruent dissolution of uranium waste matrix. The following inputs have been considered for computing the technetium solubility limit into the soil-debris submodel:

- A solubility limit of 1E-6 mol/L is considered for uranium constituting the waste matrix (CP-62766), this assumption is supported by the existence of concrete monolith in Trench 08 for the disposal of N Reactor wastes (per FH-0105097).
- N Reactor waste packages contain 567,125.5 mol of uranium prior to leaching according to SWITS (Table 4-5). Uranium is thus in excess through the whole leaching process over 10,000 years. This inventory leads to a Tc-99/uranium ratio equal to 2.4E-5 mol/mol at the beginning of the simulation (January 1 , 2014; Table 2-3). This ratio evolves slightly over time due to differing radioactive decay rates between Tc-99 and uranium.
- The solubility limit for Tc-99 in N Reactor waste packages can be estimated using Equation 4-1, which leads to a technetium solubility limit of 2.4E-11 mol/L at the beginning of the simulation.

Table 4-5. Inventory of N Reactor Waste Packages Disposed in 218-W-3AE According to SWITS at the Beginning of the Simulation

Radionuclide	Inventory (01/01/2014)	
	Ci	Mol
Tc-99	2.308E+01	13.63
U-232	0	0
U-233	0	0
U-234	5.530E+01	37.98
U-235	2.712E+00	5341.00
U-236	5.091E+00	333.50
U-238	4.492E+01	561413.00

Note: Release date equal to 01/01/2014.

$$S_{Tc} = \frac{Tc}{U} \times S_U \quad \textbf{(Eq. 4-1)}$$

where:

S_{Tc} = Solubility limit of technetium due to congruent dissolution with uranium waste matrix (mol/L)

$\frac{Tc}{U}$ = Molar ratio of technetium and uranium within N Reactor Wastes (-)

S_U = Solubility limit of uranium in waste matrix (1E-6 mol/L).

4.2.3 GoldSim Transport and Release Equations

This section provides mathematical descriptions of the transport and release processes considered for each CASWR submodel identified in Table 4-2 as implemented in GoldSim using its Contaminant Transport Module expansion GoldSim RT. As mentioned in RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington* from which the text below is extracted, the Contaminant Transport Module allows the user to dynamically model mass transport using an element-based model of the system including the following key features (GoldSim, 2021, *GoldSim Contaminant Transport Module User's Guide, Version 14.0*). Both diffusive and advective transport mechanisms can be explicitly represented using the "Cell" pathway element, by specifying the diffusion coefficient and geometric factors for diffusive transport as well as the flow rates for advective transport. Media properties through which diffusion and advection occur also need to be specified.

> When multiple cells are linked together via advective and diffusive mechanisms, the behavior of the Cell network is mathematically described using a coupled system of ordinary differential equations in time. A network of cells is mathematically equivalent to a finite difference network of nodes. GoldSim numerically solves the coupled system of equations to compute the contaminant mass present in each Cell and the mass fluxes between cells as a function of time. The solution technique uses backwards-difference (fully implicit) algorithm for each cell net and each species decay chain family.

The basic mass balance equation for Cell *I* is as follows (Appendix B in GoldSim, 2021):

$$m'_{is} = -m_{is}\lambda_s + \sum_{p=1}^{NP_s} m_{ip}\lambda_p f_{ps} R_{sp}\left(\frac{A_s}{A_p}\right) + \sum_{c=1}^{NF_i} f_{cs} + S_{is} \quad \textbf{(Eq. 4-2)}$$

where:

m'_{is} = rate of increase of mass of species *s* in Cell *i* (M/T)

m_{is} = mass of species *s* in Cell *i* (M)

λ_s = decay rate of species *s* (1/T)

NP_s = number of direct parents for species *s*

m_{ip} = mass of species *p* in Cell *i* (M)

λ_p = decay rate of species *p* (1/T)

f_{ps} = fraction of parent p which decays into species s

R_{sp} = stoichiometric ratio of moles of species s produced per mole of species p decayed

A_s = molecular (or atomic) weight of species s (M/N)

A_p = molecular (or atomic) weight of species p (M/N)

NF_i = number of mass flux links from/to Cell i

f_{cs} = influx rate of species s (into Cell i) through mass flux link c (M/T)

S_{is} = rate of direct input of species s to Cell i from external source (M/T).

The first term on the right-hand side in Equation 4-1 represents decay (or chemical reaction), the second term represents ingrowth, the third term represents mass transfer in or out of the Cell via mass flux links, and the fourth term represents the rate of direct input to the Cell from other sources.

Equation 4-1 couples in two ways to other mass balance equations: through the ingrowth terms, which couple all species in a decay chain; and through the mass flux terms, which couple all cells that are connected by mass flux links. Representation of the mass flux terms (f_{cs}) is described below in terms of diffusive mass flux and advective mass flux.

Diffusive mass flux links are used to transport mass through a stagnant or slowly moving fluid via the process of molecular diffusion. Diffusive mass transport is proportional to a concentration difference, with mass diffusing from high concentration to low concentration. The constant of proportionality is referred to as the diffusive conductance:

$$\text{Diffusive Mass Rate} = (\text{Diffusive Conductance}) \times (\text{Concentration Difference}) \quad \textbf{(Eq. 4-3)}$$

In Equation 4-2, the Diffusive Mass Rate has dimensions of Ci/yr or kg/yr, the Diffusive Conductance has dimensions of L/yr, and the Concentration Difference has dimensions of Ci/L or kg/L. Diffusive Conductance is a function of the properties of the species and fluids involved and the geometry of the diffusive process. For diffusion through a single fluid, the Diffusive Conductance for species s (D_s) is computed as:

$$D_s = \frac{(A\ d\ \tau\ \theta\ )}{L} \quad \textbf{(Eq. 4-4)}$$

wher e:

D_s = diffusive conductance (L^3/T)

A = mean cross-sectional area of the connection (L^2)

d = free-water diffusivity of species s (L^2/T)

τ = tortuosity of continuous liquid film in the porous medium

θ = moisture content (porosity times saturation)

L = diffusive length (L).

The diffusive flux, f_s, from pathway *i* to pathway *j* is computed as follows:

$$f_{s,i\rightarrow j} = D_s(C_{ims} - C_{jms}) \quad \textbf{(Eq. 4-5)}$$

where:

C_{ims} = concentration of species *s* in medium *m* in Cell *i* (M/L^3 for fluids, M/M for solids)

C_{jms} = concentration of species *s* in medium *m* in Cell *j* (M/L^3 for fluids, M/M for solids).

The diffusion can occur in either direction, so the flux can be positive or negative.

When media properties are changing for diffusive release calculation, such as when diffusion occurs between cement layer and the vadose zone as described in the cement submodel or grout to the vadose zone in the Grouted Residual Waste submodel, the diffusive conductance is calculated using a harmonic average of the physical properties of the two cell pathways as follows:

$$D_s = \frac{A}{\frac{L_i}{d_{msi}\theta_i\tau_{Pi}} + \frac{L_j}{d_{msj}\theta_j\tau_{Pj}}} \quad \textbf{(Eq. 4-6)}$$

where:

A = the area of the diffusive mass flux link (L^2)

L_i = diffusive length for the diffusive mass flux link in Cell *i* (L)

L_j = diffusive length for the diffusive mass flux link in Cell *j* (L)

d_{msi} = free-water diffusivity of species *s* for fluid *m* in Cell *i* (L^2/T)

d_{msj} = free-water diffusivity of species *s* for fluid *m* in Cell *j* (L^2/T)

τ_{Pi} = tortuosity for the porous medium for Cell *i*

τ_{Pj} = tortuosity for the porous medium for Cell *j*

θ_i = moisture content of porous media in Cell *i*

θ_j = moisture content of porous media in Cell *j*.

The second representation of the mass flux term (f_{cs}) presented in Equation 4-1 is advective mass flux. Equation 4-6 describes advective mass flux from Cell *i* to Cell *j* for species *s* as follows:

$$f_{s,i\rightarrow j} = c_{ims}\, q \quad \textbf{(Eq. 4-7)}$$

where:

q = the rate of advection of water for the mass flux link *i* to *j* (L^3/T)

c_{ims} = the total dissolved concentration of species *s* in medium *m* within Cell *i* (M/L^3).

When mass enters a Cell, it is instantaneously partitioned among the media present in the Cell. The partitioning is controlled by the partition coefficients defined for each species in each medium, and the quantity of each medium present. In the absence of solubility limits (e.g., all contaminants with the exception of uranium in the CASWR), the concentration of the species *s* in medium m in Cell *i* is computed by GoldSim as follows:

$$C_{ims} = \left(\frac{K_{mrs}}{\sum_{g=1}^{NM_i} K_{grs} \cdot VM_{ig}} \right) m_{is} \quad \textbf{(Eq. 4-8)}$$

where:

K_{mrs} = partition coefficient between medium *m* and reference fluid *r* for species *s* (L^3/ L^3) for fluids or (L^3/M) for solids

K_{grs} = partition coefficient between medium *g* and reference fluid *r* for species *s* (L^3) for fluids or (L^3/M) for solids

VM_{ig} = quantity (volume or mass) of medium *g* in Cell *i* (L^3 for fluids, M for solids)

NM_i = the number of media in Cell *i*

m_{is} = mass of species *s* in Cell *i* (M).

When a solubility constraint is applied for a species in a Cell, the Cell has a saturation capacity with respect to that species, which represents the maximum amount of species mass the Cell can contain before the species will start to precipitate out of solution. It is calculated as:

$$msat_{is} = sol_{sr} \sum_{g=1}^{NM_i} K_{grs} \cdot VM_{ig} \quad \textbf{(Eq. 4-9)}$$

where:

$msat_{is}$ = saturation capacity for species *s* in Cell *i* (M)

sol_{sr} = solubility of species *s* in the reference fluid *r* (M/L^3).

All or a portion of the mass within a source can be specified to exist within the waste matrix, such that species that are bound in such a matrix are not released until the matrix itself degraded in some manner. These species are referred to as a “bound” inventory. Release of mass from the matrix is assumed to be congruent with the degradation of the matrix. Degradation rates are specified by the user. The rate at which the waste is exposed for release is calculated as:

$$e_s(n,t) = M_s(t) \cdot k_s(t) \cdot I_s(n,t) \quad \textbf{(Eq. 4-10)}$$

where:

$e_s(n,t)$ = the exposure rate for species *n* in bound inventory *s* for the Source at time *t* (M/T)

$M_s(t)$ = fraction of unprotected but undegraded matrix (unitless)

$k_s(t)$ = fractional degradation rate of waste matrix for bound inventory *s* (1/T)

$I_s(n,t)$ = mass of species *n* in bound inventory *s* at time (M).

When applying a fractional degradation rate to the matrix (such as for release of Tc-99 in the grouted residual waste form), the fraction of undegraded matrix $M_s(t)$ can be determined by solving the following differential equation:

$$\frac{dM_s(t)}{dt} = h(t) - M_s(0) \cdot k_s(t) \qquad \textbf{(Eq. 4-11)}$$

where:

$h(t)$ = rate at which matrix is being unprotected (1/T)

$k_s(t)$ = rate at which unprotected matrix is being degraded (1/T).

If $h(t)$ and $k_s(t)$ are constant, the solution to the above equation is:

$$M_s(t) = \frac{h}{k_s}\left(1 - e^{-k_s t}\right) + M_s(0)e^{-k_s t} \qquad \textbf{(Eq. 4-12)}$$

4.2.1 Cement Submodel Assumptions

The source zone contaminant release behavior of the cement submodel is driven by diffusive flux through cement material (CP-62766). Calculations in GoldSim are conducted using Equations 4-2 through 4-6 as described above. Initial activities are provided by SWITS considering the waste form assignment methodology based on waste descriptions and comments (Section 3.3). Each waste site’s source thickness is outlined in Table C-1 in this ECF. To be consistent with the approach applied to all the cement waste sites in the CA Update (DOE/RL-2019-52), the source thickness was first considered to be equal to the waste site thickness in a base case approach. When additional information was available regarding the distribution of the inventory through the waste site footprint, the area-to-volume ratio was modified accordingly in a sensitivity case. The binary diffusion coefficient of the analyte of concern is calculated in GoldSim from the effective diffusion coefficient through the tortuous water pathway of cement. For simplification purposes, the cement tortuosity and porosity are set to 1 such that the effective diffusivity is applied in the calculations. This allows for the diffusivity input be equivalent to the effective diffusivity values assigned). The effective diffusion coefficient values detailed in Table C-2 in this ECF include implicitly sorption processes for both C-14 and Tc-99 (PNNL-15965). Additional model calculation details are available in CP-62766.[11]

4.2.2 Soil-Debris Submodel Assumptions

Advection (Equation 4-7) is the sole release mechanism driving contaminant mass flux (Equation 4-2) from the source zone in the soil-debris submodel. Waste site cross-sectional areas are compiled in Table D-1 of this ECF. Both contaminant sorption (Equation 4-8) and solubility (Equation 4-9) values are provided in Tables D-2 and D-3, respectively. Representative soil properties (e.g., dry bulk density, porosity, and moisture content) for respective Darcy velocity values in 200 East and 200 West Operational Areas are presented in Table D-4 in order to calculate the mass flux rate of advection (Equation 4-7). Initial activities are provided by SWITS considering the waste form assignment methodology based on waste descriptions and comments (Section 3.3). Additional model calculation details are available in CP-62766.

[11] CP-62766 incorrectly mentions that sorption is not considered in the cement submodel while it was implicitly included through the values of effective diffusion coefficients considered in the CA Update. This mistake has been corrected here in Table 4-2.

4.2.3 Data Reduction Assumptions and Inputs

An in-depth discussion of CASWR data reduction approach including its limitations and input requirements is outlined in ECF-HANFORD-20-0006. The user-defined configuration files used as input for the calculations documented by this ECF are provided in Appendix F. Brief descriptions of the Ramer-Douglas-Peucker algorithm parameters contained in these configuration files are listed below and values are given in Table 4-6:

- Mass threshold: threshold value for total mass; used to determine which error threshold value is used for data reduction acceptance criteria [numeric]. If total mass is less than or equal to mass threshold, then acceptance criteria is less than or equal to upper error threshold. If total mass is greater than mass threshold, then acceptance criteria is less than or equal to lower error threshold.
- Output lower error threshold: the acceptance criteria to be applied to the relative error of a reduced dataset if the total mass is greater than the mass threshold [numeric]
- Output upper error threshold: the acceptance criteria to be applied to the relative error of a reduced datasets if the total mass is less than or equal to the mass threshold [numeric]
- Lower reduced datapoint limit: the minimum number of data pairs in the reduced dataset [numeric]
- Upper reduced datapoint limit: the maximum number of data pairs in the reduced dataset (may be exceeded if additional error corrections are required) [numeric]
- Maximum iterations: maximum number of reduction iterations to be performed if acceptance criteria are not met [numeric]
- Maximum error iterations: maximum number of error iterations to be performed if acceptance criteria are not met [numeric]
- Epsilon: the initial distance tolerance value used in the Ramer-Douglas-Peucker algorithm [numeric]
- Close gaps: flag to add additional data points to close large time gaps in reduced datasets [True or False]
- Gap delta: minimum value of time gap to reduce [numeric]
- Gap steps: number of additional time steps to add when reducing gaps between time steps [numeric]
- Diff mass correction: flag to correct differences in accumulated mass greater than acceptance criteria in reduced dataset [True or False]

Table 4-6. Parameters of the Ramer-Douglas-Peucker Algorithm Considered for C-14 and Tc-99 Data Reduction of the CASWR Model Results

Parameter	C-14	Tc-99
Mass Threshold	0.1	0.1
Output Lower Error Threshold	0.001	0.001
Output Upper Error Threshold	0.01	0.01
Lower Reduced Datapoint Limit	25	25
Upper Reduced Datapoint Limit	50	50
Maximum Iterations	25	25
Maximum Error Iterations	15	15
Epsilon	1	1
Close Gaps	False	True
Gap Delta	2,000	3,000
Gap Steps	3	1
Diff Mass Correction	True	True

Source: ECF-HANFORD-20-0006, *Composite Analysis Solid Waste Release Data Reduction of Activity Flux from Waste Sites to the Vadose Zone for Baseline Assessment*.

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5 Software Applications

The following sections document the utility calculation software tool used in this ECF that complies with requirements of Central Plateau Cleanup Company's (CPCCo) controlled software management procedure.

5.1 Approved Software

5.1.1 Description

The following information identifies the approved utility calculation software used for the calculation of release rates documented in this ECF for each of the sensitivity cases.

5.1.1.1 Waste Release Calculations

Microsoft Excel and GoldSim software programs were used for inventory and solid waste release calculations. STOMP was not rerun for solid waste release calculations (ECF-HANFORD-19-0112) and has no modification of the original flow fields used as inputs in GoldSim for the CA Update. These are CPCCo-approved software, managed and used in compliance with the requirements of their controlled software management procedure. GoldSim is approved calculation software; approval is documented in CHPRC-00262, *GoldSim Pro Acceptance Test Report: Version 12.1*. Microsoft Excel was used as spreadsheet software for this calculation. The following information identifies the approved utility calculation software used for waste release calculations documented in this ECF:

- **Software Title:** GoldSim Pro RT
- **Software Version:** 12.1
- **Hanford Information Systems Inventory Identification Number:** 2461
- **Workstation type and property number:** Dell® Precision 7720 INTERA SAS (Service Tag: 9XNP0G2)

The reduction of the CASWR model-generated datasets used a utility code included in CHRPC-04032, *Composite Analysis/Cumulative Impact Evaluation (CACIE) Utility Codes Integrated Software Management Plan*. The utility code was tested and qualified for use in compliance with the requirements specified in CHPRC-04032 and documented in the consolidated tool package attachment for the tool. The following information identifies the approved utility calculation software used for waste release data reduction documented in this ECF:

- **Software Title:** Solid Waste Release Reduction Tool (vzreducer.py) from CACIE Utility Codes
- **Software Version:** v5.21
- **Hanford Information Systems Inventory Identification Number:** 4503
- **Software Git SHA-1 Hash:** 79b4125e3b7bbef2b4b5d061771d2efb03d3a57e
- **Git Repository SHA-1 Hash:** 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b

® Dell is a registered trademark of the Dell Corporation, Round Rock, Texas.

5.1.2 Software Installation and Checkout

Verification that the utility calculation software specified in Section 5.1.1 is qualified for use is documented in the log files maintained as output in the Integrated Computational Framework for each work product generated as documented in this ECF. The software installation and checkout form can be found in Appendix G of this ECF. The log files (Appendix H) document the tool used, software and repository versioning, quality assurance status of the code, and software user, workstation, and operating platform.

5.1.3 Statement of Valid Software Application

The preparers of this calculation attest that the software identified and used for this calculation is appropriate for the application and has been used within the range of intended uses for which it was tested and accepted.

6 Calculation

This chapter details the inventory and waste release calculation processes performed in GoldSim and common to the four sensitivity cases.

The SWITS inventories were updated in the dedicated Excel spreadsheet for replacing the former TC & WM EIS (DOE/EIS-0391) values considered for each solid waste site in the CA Update (DOE/RL-2019-52). This updated inventory spreadsheet was next used as input for GoldSim in the CA Solid Waste Release Model.

The output data produced by the GoldSim release model for solid waste sites correspond to solute annual rates released over time from the corresponding waste form for each site. Cumulative contaminant release is calculated annually with the previous year's cumulative release subtracted. This provides the activity released over a given year as a timeseries. These timeseries are saved in each inner submodel into an Excel spreadsheet (Figure 6-1). As only two submodels are considered for this study, two column-formatted spreadsheets are populated once a run is completed: "Soil_results.xlsx," "Cmnt_results.xlsx" (corresponding respectively to the soil-debris and cement submodel results). Each file is formatted as follows: The opening sheet, "Results," includes the site name in the first column. Site names are populated using the same site indexing list included in the "Parameters.xlsx" file ("Site_Index" sheet). The following two columns contains the site index and the time (calendar year over which the annual release rate is cumulated). Each subsequent column contains the cumulative activity released for a given species calculated by the corresponding submodel at a certain year. A row offset has been defined so that each line corresponds to a different year of release since the beginning of the simulation and to a different site once the results of the previous site are completely exported. Both spreadsheets, "Soil_results.xlsx," "Cmnt_results.xlsx," are next postprocessed in R for adding up the respective contribution of the soil and cement waste forms to the total release emanating from each waste site. This dataset is next reduced using the CACIE reduction tool for subsequent transport simulations through the vadose zone.

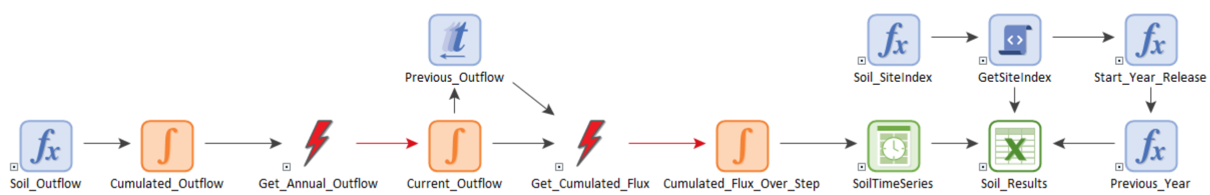

Figure 6-1. Example Output Structure for Exporting Results Data

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7 Results/Conclusions

This chapter details the results of the inventory (Section 7.1) and waste form assignment revisions (Section 7.2) that were performed for the three waste sites concerned by this CA Maintenance Special Analysis. The results of each sensitivity case are next presented (Sections 7.3 to 7.5) considering the updated inventories and waste form assignments as inputs of the subsequent waste release calculations.

7.1 Inventory

Figure 7-1 presents the comparison of SWITS based inventories for C-14 and Tc-99 at site 218-E-12B with and without including the inventories in Trench 94. The inventory calculations showed that almost 100% of C-14 and 99.95% of Tc-99 in site 218-E-12B are contributed by Trench 94.

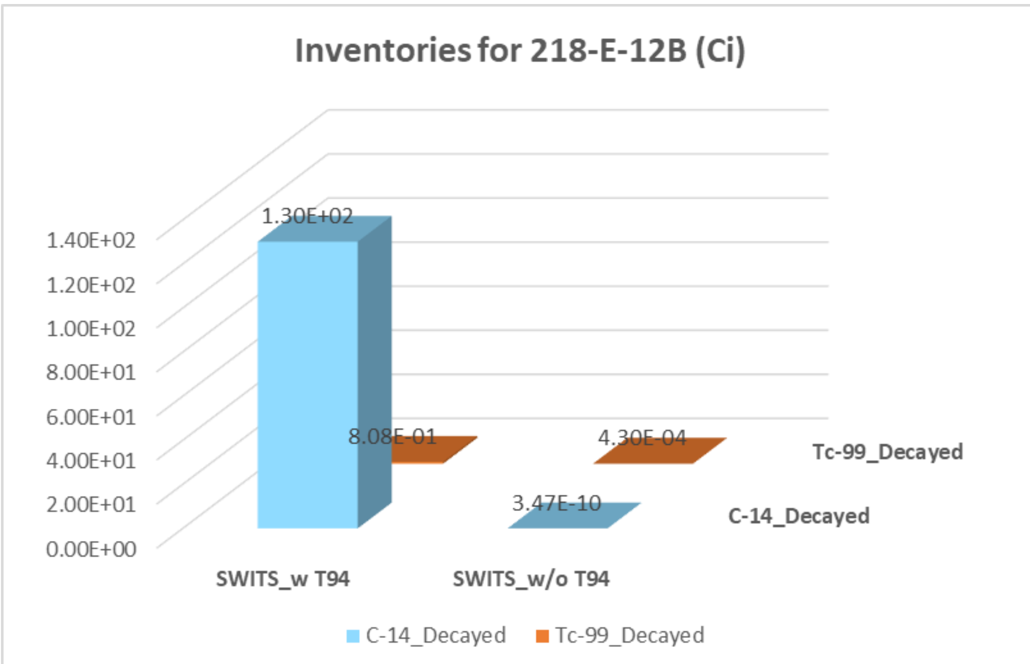


Figure 7-1. Comparison of SWITS Based C-14 and Tc-99 Inventories Decayed to 2070 with and Without Including Inventories in Trench 94 at Site 218-E-12B

Figure 7-2 shows the comparison of SWITS based inventories for C-14 and Tc-99 (excluding the inventories in Trench 94) with the inventories in the CA inventory data package (CP-61786) for site 218-E-12B. It can be observed that without the consideration of inventories in Trench 94, the SWITS based inventories for C-14 and Tc-99 are consistent with that of the CA inventory data package.

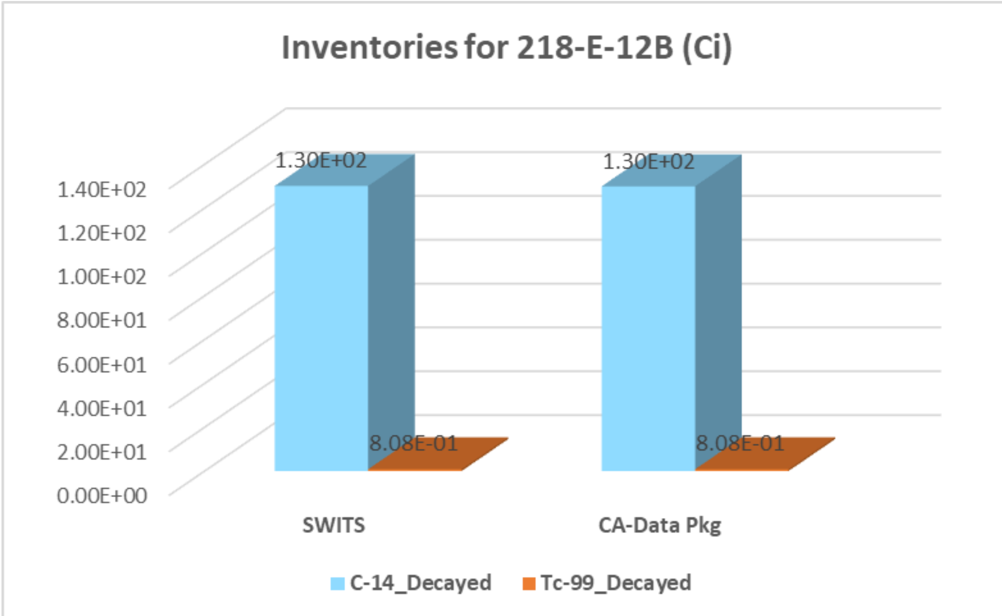


Figure 7-2. Comparison of SWITS Based C-14 and Tc-99 Inventories Decayed to 2070 with Inventories in the CA Data Package for Site 218-E-12B

Figure 7-3 compares the C-14 and Tc-99 inventories from the SWITS database with that presented in the CA inventory data package (CP-61786) for site 216-W-3A. The inventory comparison calculations showed that the C-14 inventory in 218-W-3A used in the CA Update (DOE/RL-2019-52) is about 167 times higher than the SWITS based inventory, while the Tc-99 inventories from both sources are comparable.

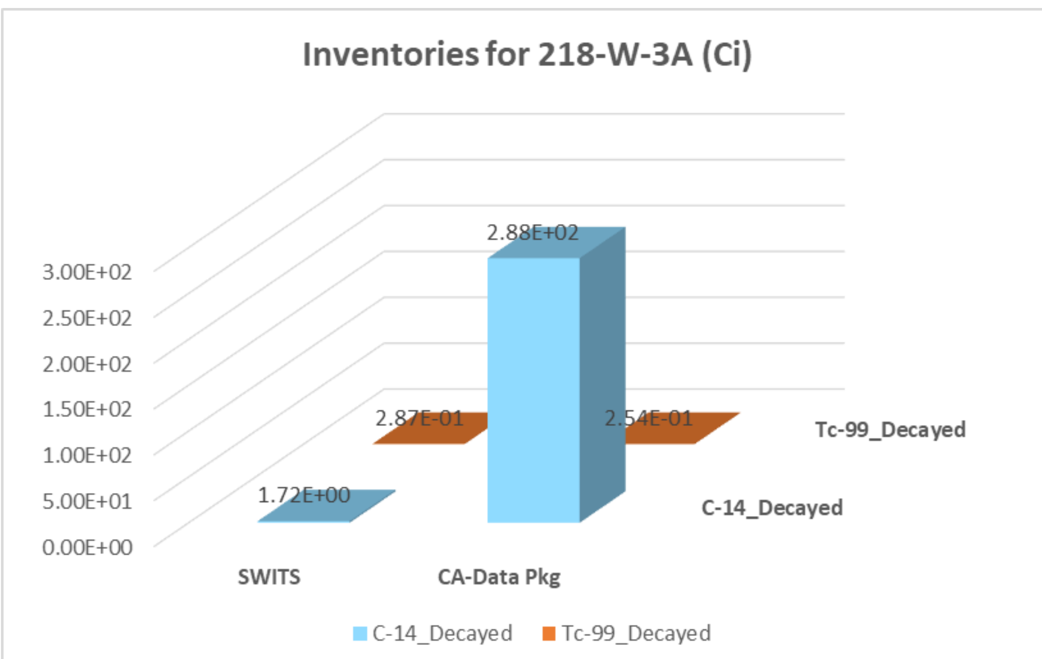


Figure 7-3. Comparison of SWITS Based C-14 and Tc-99 Inventories Decayed to 2070 with Inventories in the CA Data Package for Site 216-W-3A

Figure 7-4 compares the C-14 and Tc-99 inventories from the SWITS database with those from the CA inventory data package (CP-61786) for site 216-W-3AE. The inventory comparison calculations demonstrated that the C-14 and Tc-99 inventories in the CA inventory data package for 218-W-3A are consistent with the SWITS based inventories.

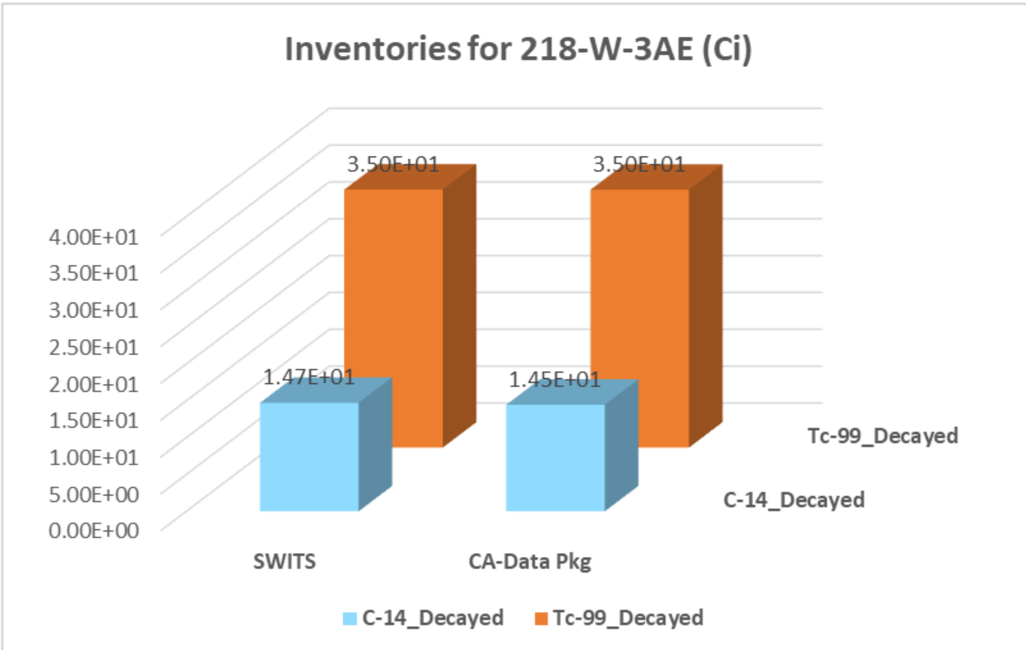


Figure 7-4. Comparison of SWITS Based C-14 and Tc-99 Inventories Decayed to 2070 with Inventories in the CA Data Package for Site 216-W-3AE

Tc-99, and nonactivated and activated C-14 inventories decayed to 2070 (following the methodology described in Section 3.2) are further compared in Table 7-1 to the TC & WM EIS inventory considered in the CA Update (ECF-HANFORD-19-0112):

- TC & WM EIS C-14 inventory for 218-E-12B (also considered in Rev. 0 and Rev. 1 of the CA Update, DOE/RL-2019-52) was found to be very close to Trench 94 inventory indicated in SWITS. This suggests that the C-14 TC & WM EIS inventory was based on nonactivated C-14 inventory disposed in Trench 94. As stated in DOE/RL-2020-50, *Annual Status Report (FY 2020): Performance Assessment for the Disposal of Low Level Waste in the 200 East Area Burial Grounds*, it is anticipated that no release from the naval reactor compartments disposed in Trench 94 of 218-E-12B will occur after the compliance period and no aquifer contamination is envisioned for several thousands of years. The ongoing PA for Trench 94 will especially review the EA performed by the US Navy (USN, 2012, *Final Environmental Assessment on the Disposal of Decommissioned, Defueled Naval Reactor Plants from USS Enterprise*) before developing the basis to exclude the possibility of release of radionuclides from Trench 94 over the timescales evaluated in DOE/RL-2020-50. In the CA Maintenance special study, Trench 94 waste inventories are discarded for the 218-E-12B sensitivity case assuming that the metal reactor compartments of the naval reactors provide a robust engineered barrier to the release of radionuclides included both activated and nonactivated inventories (consistently with DOE/RL-2020-50).

- Additionally, it can be seen in Table 7-1 that C-14 inventory given by SWITS is very close to that of TC & WM EIS which does not seem to have included activated C-14 inventory. It is also assumed here that activated C-14 associated with 218-W-3AE can be discarded from the CA Maintenance release calculations as corrosion of activated metals should not lead to relevant releases to the vadose zone. Table 7-2 details 218-W-3AE activated C-14 inventory by disposal unit and waste profile. It can be seen that among the 62.5 Ci of activated C-14 disposed in 218-W-3AE, 69% of this inventory (Table 7-2) corresponds to activated metals from core structures (thermal shield/core basket), the remainder 31% being activated metals in stabilized containers.

Discarding Trench 94 waste from the remaining wastes disposed in 218-E-12B will lead to an inventory decrease of 11 orders of magnitude for C-14 (and 3 orders of magnitude for Tc-99) in 218-E-12B sensitivity case. C-14 inventory given by SWITS is also 2 orders of magnitude lower than that of TC & WM EIS (DOE/EIS-0391) for 218-W-3A. These results confirm therefore the following sources of unrepresentativeness presumed in the CA Update (DOE/RL-2019-52) analysis:

- C-14 and Tc-99 inventories in 218-E-12B are mainly associated with Trench 94 waste, which should not be taken into account as no releases from the naval reactor compartments will occur within the compliance period (DOE/RL-2020-50).
- C-14 inventory in 218-W-3A was overestimated by 2 orders of magnitude in the TC & WM EIS. No reason for explaining this discrepancy in C-14 inventory between TC & WM EIS and SWITS was found in DOE/EIS-0391, which mentioned a C-14 inventory decayed to 1994 equal to 2.91E+02 Ci.

7.2 Waste Form Assignment

As the category information was not available for all the waste packages mentioned in the extraction of the SWITS database available for this study (Section 3.3), waste forms have been assigned using keywords mentioned in waste description, profile and comments for differentiating the cement waste form (diffusion-dominated) from the soil-debris (advection-dominated) and solubility-limited release U billet waste forms. The number of waste packages associated with each waste form using the methodology developed in this study (Section 3.3) is reported in Table 7-3. For 218-E-12B, the 103 waste packages disposed in Trench 94 have been discarded as they represent naval reactor compartments from which no release is expected for several thousands of years (consistently with DOE/RL-2020-50, see discussion in Section 7.1). The number of waste packages associated with the cement waste form was found to be lower than 1% of the total number of waste packages (Table 7-3) disposed in each waste site. However, the associated inventory corresponding to the cement waste form was found to be relevant for the Tc-99 inventory in 218-W-3A and 218-W-3AE despite the low number of packages associated with these inventories.

Table 7-1. Comparison of SWITS Inventory to TC & WM EIS Inventory Considered in the CA Update

Solid Waste Disposal Site	Radionuclide[a]	Inventory (decayed to 01/01/2070) SWITS (Ci)	Inventory (decayed to 01/01/2070) TC & WM EIS[b] (Ci)
218-E-12B	C-14	Total: 1.301E+02 Without T94: 3.466E-10	1.299E+02
	Activated C-14	Total: 2.178E+02 Without T94: 0.000E+0	N/A
	Tc-99	Total: 8.081E-01 Without T94: 4.301E-04	8.078E-01

Table 7-1. Comparison of SWITS Inventory to TC & WM EIS Inventory Considered in the CA Update

Solid Waste Disposal Site	Radionuclide[a]	Inventory (decayed to 01/01/2070) SWITS (Ci)	Inventory (decayed to 01/01/2070) TC & WM EIS[b] (Ci)
218-W-3A	C-14	1.722E+00	2.884E+02
	Activated C-14	0.000E+00	N/A
	Tc-99	2.875E-01	2.539E-01
218-W-3AE	C-14	1.473E+01	1.447E+01
	Activated C-14	6.255E+01	N/A
	Tc-99	3.501E+01	3.499E+01

Source: ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*.

Reference: DOE/EIS-0391, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

a. No relevant inventory was found to be associated with activated Tc-99 for these three waste sites in SWITS (only 1E-07 Ci decay corrected to 2070 was found in a waste package disposed in Trench 08 of 218-W-3AE and was considered to be irrelevant here).

b. Used in ECF-HANFORD-19-0112.

N/A = not applicable

SWITS = Solid Waste Information and Tracking System

TC & WM EIS = Tank Closure and Waste Management Environmental Impact Statement

Table 7-2. Activated C-14 Inventory in 218-W-3AE From SWITS

Solid Waste Disposal Unit	Activated C-14 Inventory (Ci) in SWITS (decay corrected to 01/01/2070)	Inventory (Ci) by Waste Profile
CB1	3.059E+01	Core basket/thermal shield: 1.121E+01 Stabilized container: 1.938E+01
T08	3.181E+01	Core basket/thermal shield: 3.181E+01
T16	1.494E-01	CP-5 Reactor parts and Hardware from 105N Fuel Basin: 1.494E-01
Total in 218-W-3AE	6.255E+01	Core basket/thermal shield/Reactor parts/ Hardware: 4.317E+01 Stabilized container: 1.938E+01

SWITS = Solid Waste Information and Tracking System

Table 7-3. Number of Waste Packages by Waste Form Deduced from SWITS Analysis

Solid Waste Disposal Site	Number of Waste Packages	Number of Waste Packages Associated with the Cement Waste Form	Number of Waste Packages Associated with the Soil-Debris Waste Form	Number of Waste Packages Associated with the Solubility-Limited Release U Billet Waste Form
218-E-12B[a]	572	3	569	0
218-W-3A	420	13	407	0
218-W-3AE	2221	437[b]	1,605	179[c]

a. Without Trench 94 wastes corresponding to naval reactor compartments as no release from these wastes will occur after the compliance period according to DOE/RL-2020-50, *Annual Status Report (FY 2020): Performance Assessment for the Disposal of Low Level Waste in the 200 East Area Burial Grounds*.

b. Among these 437 waste packages associated with the cement waste form in 218-W-3AE, only 415 were found to contain Tc-99 and only 4 contain more than 95% of the total 218-W-3AE Tc-99 inventory. These 4 waste packages are disposed in Trench 08.

c. These 179 waste packages corresponding to N Reactor unirradiated fuel wastes are all disposed in Trench 08.

Table 7-4 details the inventory associated with the cement, soil-debris, and solubility-limited release U billet waste forms that were differentiated in SWITS using the methodology described in Section 3.3. The soil-debris submodel is more conservative than the cement one as it releases more quickly the inventory leading to greater downstream concentrations and doses in contrast to more slowly releasing diffusive release mechanisms associated with the cement model. The less conservative cement waste form is a relevant component of the Tc-99 inventory in 218-W-3A (Figure 7-2) and 218-W-3AE (Figure 7-3). Additionally, a large fraction (about 66%, Figure 7-3) of Tc-99 inventory is associated with N Reactor U billet wastes disposed in 218-W-3AE. These results confirm that the waste form assignment considered in the CA Update for 218-W-3AE (which consisted in considering the most conservative soil-debris waste form) was a relevant source of nonrepresentativeness in the CA Update as N Reactor waste strongly differ in nature from soil-debris. The cement waste form is however a small component of Tc-99 inventory in 218-E-12B (Figure 7-1), C-14 in 218-W-3A (Figure 7-5), and C-14 in 218-W-3AE (Figure 7-6). No cement waste form was found to be associated with C-14 inventory in 218-E-12B (Figure 7-4).

Table 7-4. Inventory by Waste Form Deduced from SWITS Analysis

Solid Waste Disposal Site	Radionuclide	Inventory (Decay corrected to 01/01/2070)		
		Cement Waste Form (Ci)	Soil-Debris Waste Form (Ci)	Solubility-Limited Release U Billet Waste Form (Ci)
218-E-12B[a]	C-14	0.00E+00	3.47E-10	0.00E+00
	Tc-99	9.14E-05	3.39E-04	0.00E+00
218-W-3A	C-14	5.51E-05	1.72E+00	0.00E+00
	Tc-99	1.97E-01	9.03E-02	0.00E+00

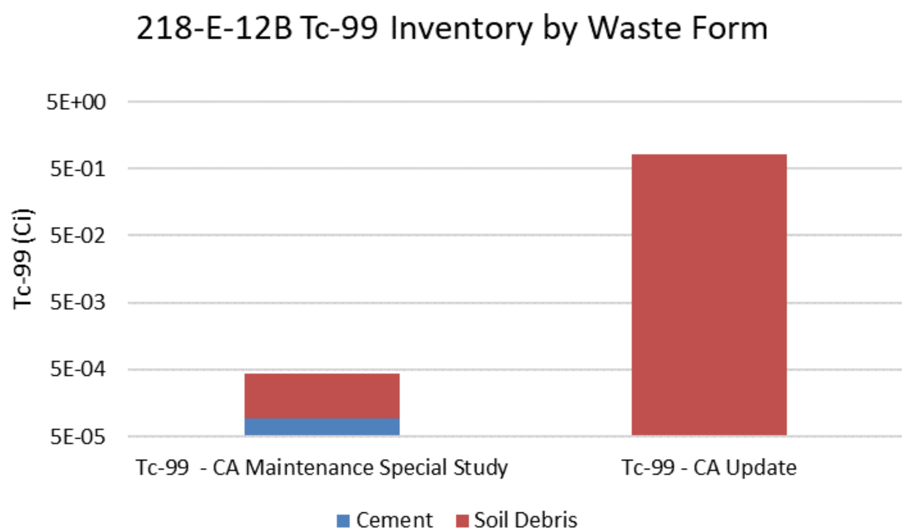
Table 7-4. Inventory by Waste Form Deduced from SWITS Analysis

Solid Waste Disposal Site	Radionuclide	Inventory (Decay corrected to 01/01/2070)		
		Cement Waste Form (Ci)	Soil-Debris Waste Form (Ci)	Solubility-Limited Release U Billet Waste Form (Ci)
218-W-3AE	C-14	4.88E-01	1.42E+01	0.00E+00
	Tc-99	8.45E+00[c]	3.48E+00	2.31E+01[b]

a. 218-E-12B inventory does not include Trench 94 wastes corresponding to naval reactor compartments, representing 1.301E+02 Ci of C-14 (decay corrected to 2070), as no release is expected from these wastes after the compliance period and no groundwater contamination is expected for several thousands of years (DOE/RL-2020-50, *Annual Status Report (FY 2020): Performance Assessment for the Disposal of Low Level Waste in the 200 East Area Burial Grounds*).

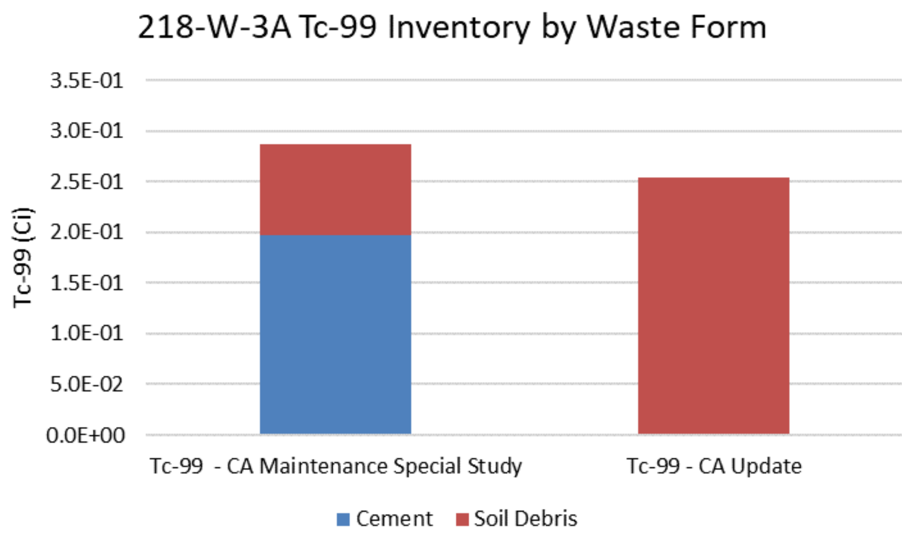
b. This inventory corresponds to 179 N Reactor unirradiated fuel waste packages disposed in 218-W-3AE Trench 08 which significantly differ in nature from soil-debris because of their solubility-limited release process.

c. This cement waste form inventory is associated with 415 waste packages disposed in 218-W-3AE but 95% of this inventory is associated with 4 waste packages disposed in Trench 08.



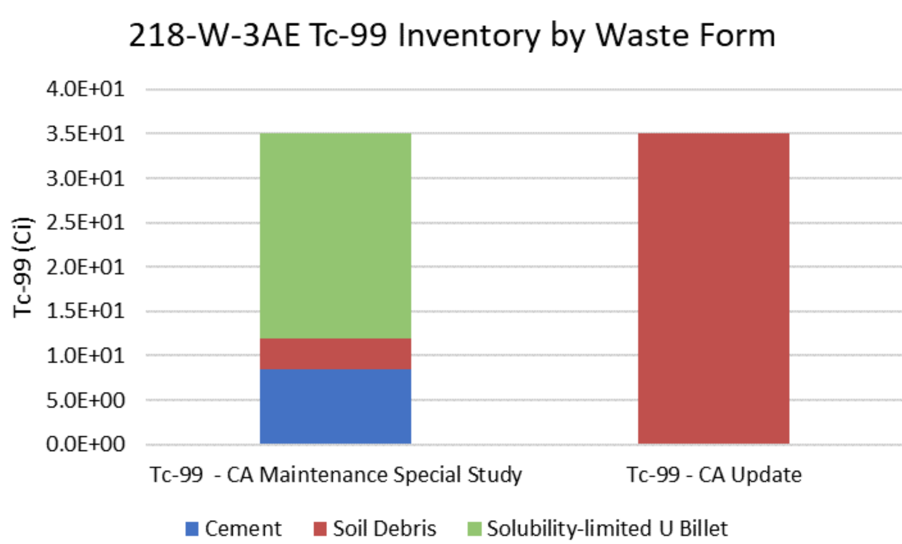
Source: ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*.

Figure 7-5. Tc-99 Inventory in 218-E-12B Associated with the Cement and Soil-Debris Waste Forms in SWITS and Comparison with the CA Update



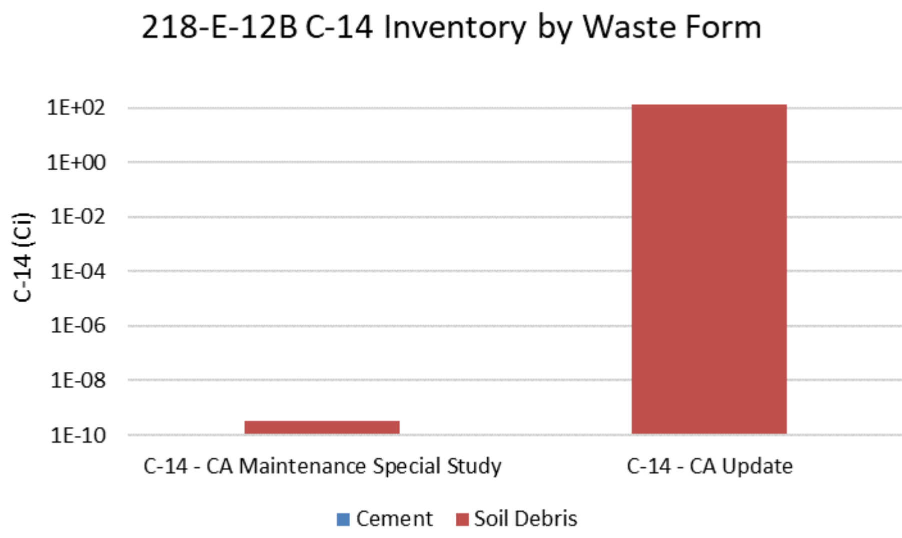
Source: ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*.

Figure 7-6. Tc-99 Inventory in 218-W-3A Associated with the Cement and Soil-Debris Waste Forms in SWITS and Comparison with the CA Update



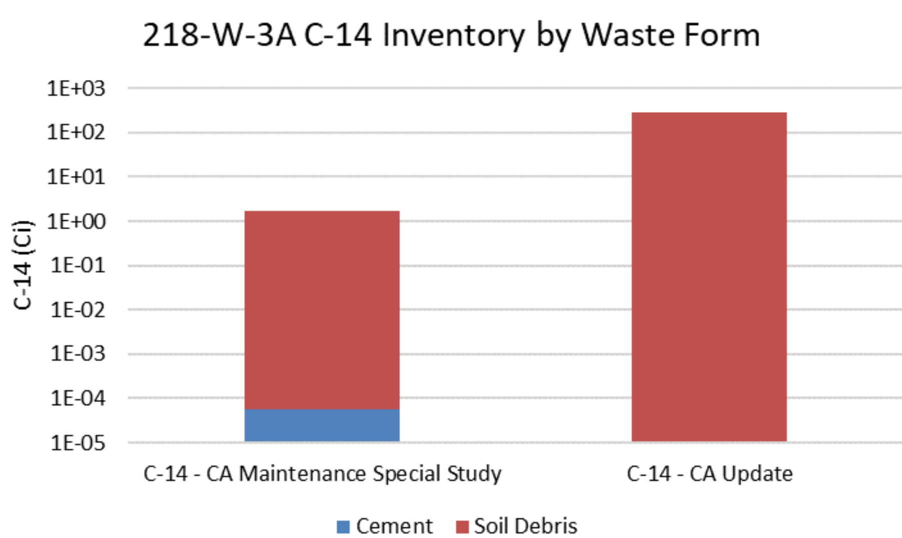
Source: ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*.

Figure 7-7. Tc-99 Inventory in 218-W-3AE Associated with the Cement, Soil-Debris and Solubility-Limited U Billet Waste Forms in SWITS and Comparison with the CA Update



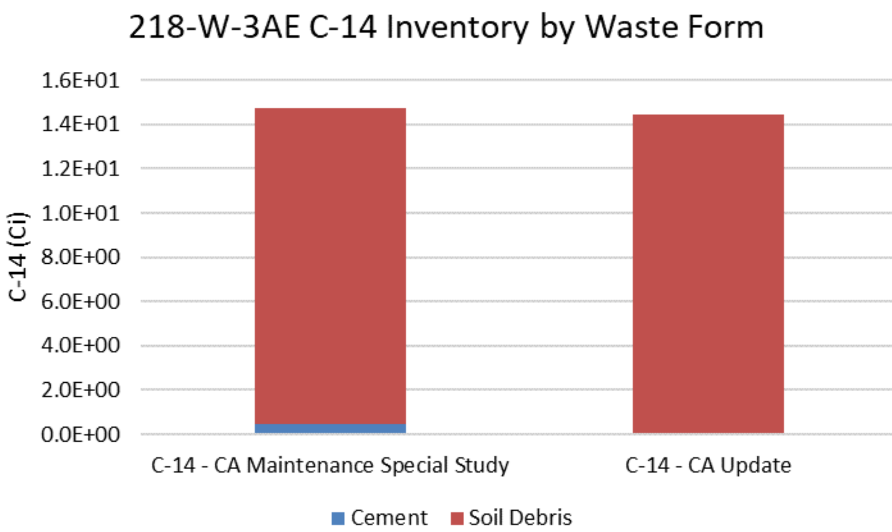
Source: ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*.

Figure 7-8. C-14 Inventory in 218-E-12B Associated with the Cement and Soil-Debris Waste Forms in SWITS When T94 Waste are Discarded and Comparison with the CA Update



Source: ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*.

Figure 7-9. C-14 Inventory in 218-W-3A Associated with the Cement and Soil-Debris Waste Forms in SWITS and Comparison with the CA Update



Source: ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*.

Figure 7-10. C-14 Inventory in 218-W-3AE Associated with the Cement and Soil-Debris Waste Forms in SWITS and Comparison with the CA Update

7.3 218-E-12B C-14 Inventory Sensitivity Case

The 218-E-12B C-14 Inventory Sensitivity Case was performed considering 218-E-12B SWITS inventory (Table 7-4) from which Trench 94 inventory has been excluded (Section 7.1) and the revised waste form assignment considering the cement and soil-debris waste forms (Section 7.2). Both waste forms have been assumed to be homogenously distributed over the whole waste site footprint to be consistent with the CA Update (DOE/RL-2019-52) approach. Note that this spatial distribution is not expected to be representative of the actual inventory distribution in 218-E-12B as the cement waste form is associated with only a few waste packages (Table 7-3). However, a more realistic waste form footprint within 218-E-12B extent would require a sounder technical basis regarding the spatial distribution of waste within 218-E-12B as in a PA approach. Additionally, including information about the distribution of waste forms within the waste site footprints should be consistently performed for all the CA waste sites and radionuclides as it could lead to relevant modifications of release estimates.

In line with expectations due to the substantial decrease of inventory for this waste site without modifying the spatial footprint of each waste form uniformly distributed within 218-E-12B extent, both C-14 and Tc-99 release rates from 218-E-12B have significantly decreased in this sensitivity case compared to the CA Update results (Figure 7-11, inset a). The resulting cumulative activity released over the simulation is lowered by 11 orders of magnitude for C-14 and by 3 orders of magnitude for Tc-99 (Figure 7-11, inset b). The sharp changes in the annual release rate and cumulative activity are similar to that of the CA Update results because of changes in recharge rate and subsequent Darcy velocity through time applied to the soil-debris submodel. Additionally, Tc-99 release rates after 3,000 years (Figure 7-11, inset a) are governed by the cement waste form, which reaches near steady state because of diffusive release. This is not observed for C-14 as no C-14 inventory was assigned to the cement waste form for this waste site (Table 7-4).

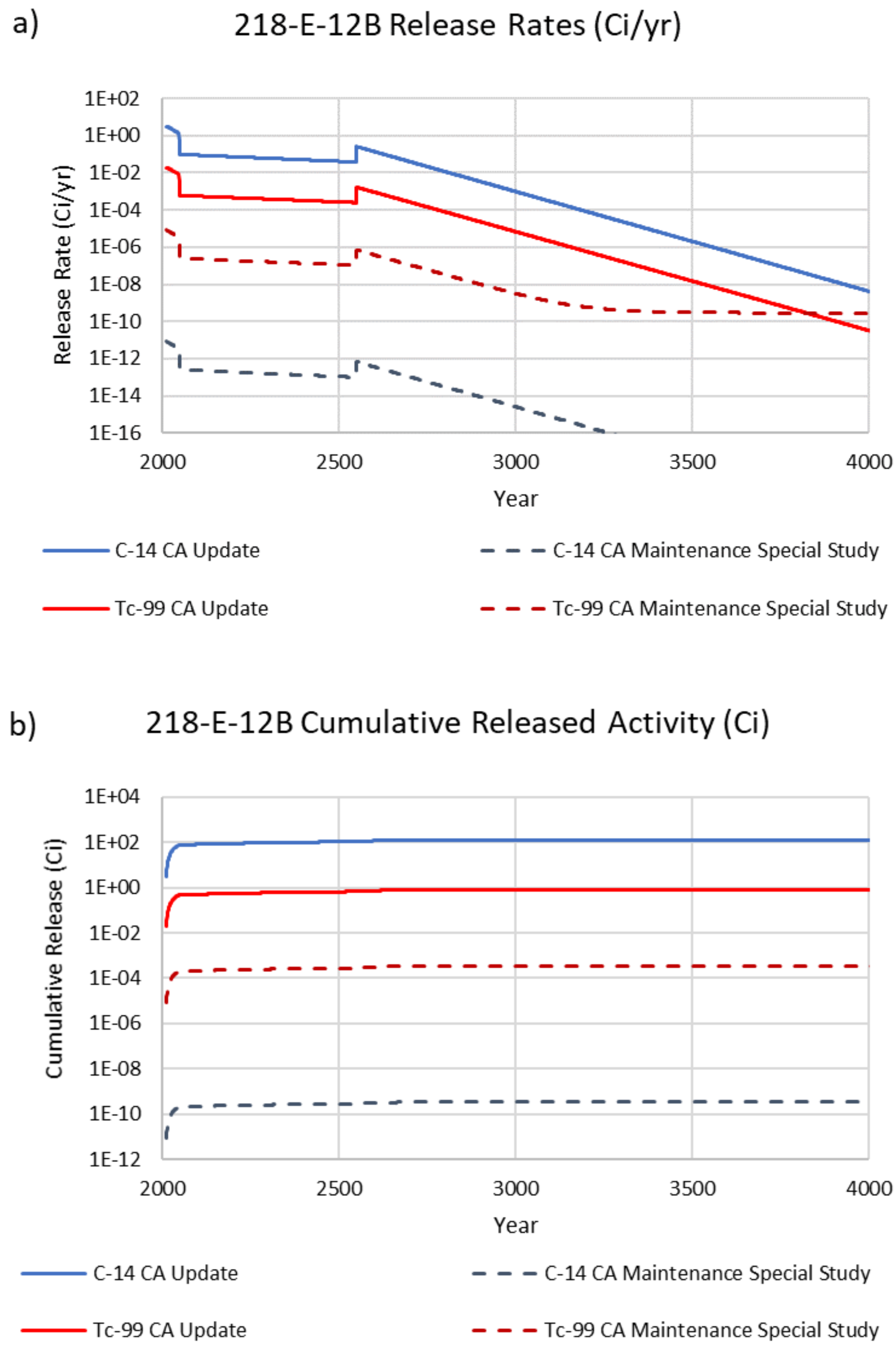


Figure 7-11. 218-E-12B a) Annual Release Rate and b) Cumulative Activity Released Over the First 4,000 Years

7.4 218-W-3A C-14 Inventory Sensitivity Case

218-W-3A C-14 Inventory Sensitivity Case was performed considering 218-W-3A revised inventory using SWITS and revised waste form assignment considering the cement and soil-debris waste forms. Both waste forms have been assumed to be homogenously distributed over the whole waste site footprint to be consistent with the CA Update approach. This spatial distribution is not expected to be representative of the actual inventory distribution in 218-W-3A as the cement waste form is associated with only a few waste packages (Table 7-3). However, a more realistic waste form footprint within 218-W-3A extent would require a sounder technical basis regarding the spatial distribution of waste within 218-W-3A as in a PA approach. Additionally, including information about the distribution of waste forms within the waste site footprints should be consistently performed for all the CA waste sites and radionuclides as it could lead to relevant modifications of release estimates.

Similarly to 218-E-12B, substantial decrease in C-14 release rates (Figure 7-12, inset a) can be observed for 218-W-3A because of the C-14 inventory reduction resulting from its revision with SWITS (Table 7-1). Such a large decrease is not observed for Tc-99 (Figure 7-12, inset a) because 218-W-3A Tc-99 inventory has not been reduced in this sensitivity case compared to the CA Update (see Table 7-1). The small decrease in Tc-99 release rate and resulting cumulative activity (Figure 7-12, inset b) is nonetheless attributable to the assignment of Tc-99 inventory to the cement waste form (Table 7-4), which dominates the release rate shortly before 3,000 once a decreasing asymptotic change in release rates is observed (Figure 7-12, inset a).

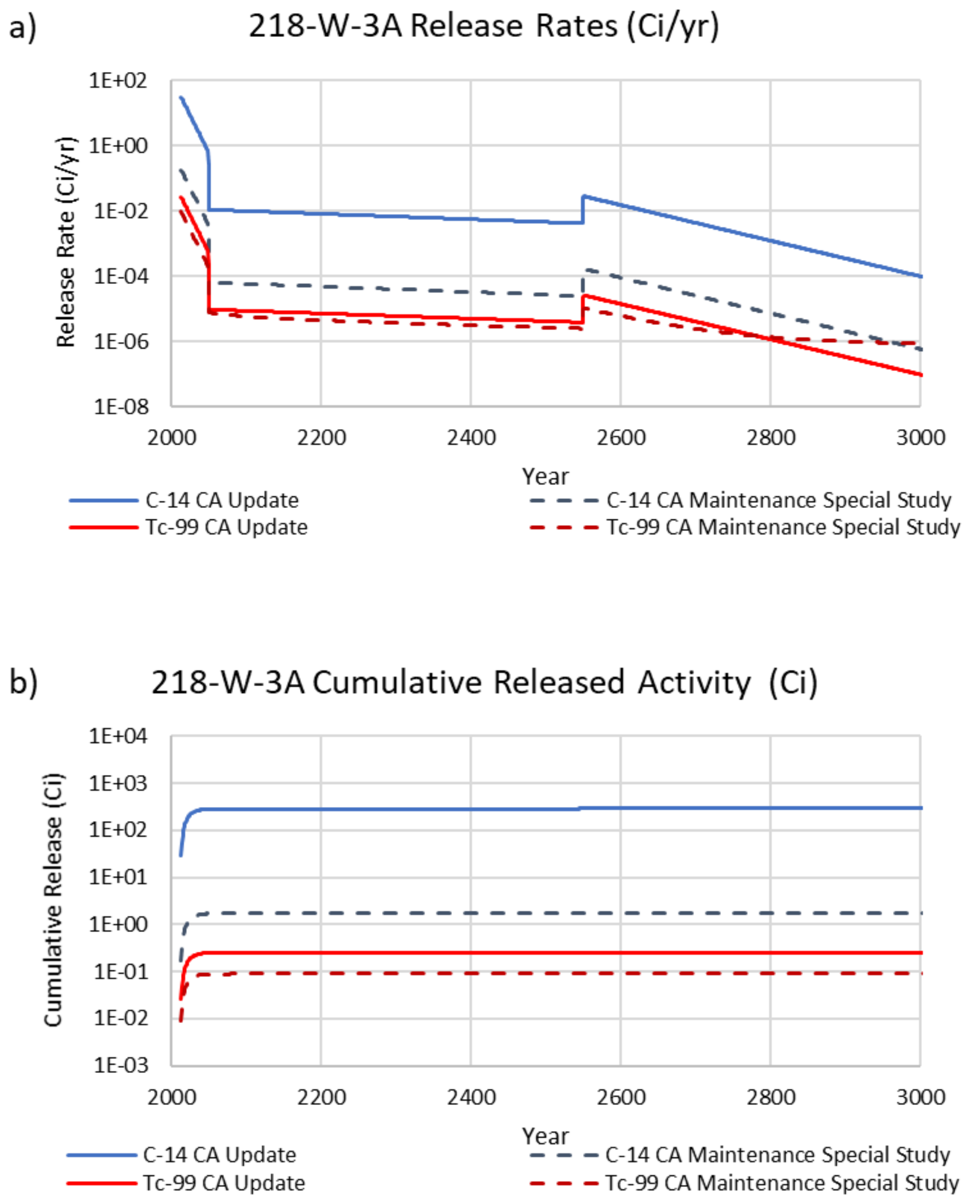


Figure 7-12. 218-W-3A a) Annual Release Rate and b) Cumulative Activity Released over the First 1,000 Years

7.5 218-W-3AE Tc-99 Release Sensitivity Cases

Two sensitivity cases have been undertaken for 218-W-3AE in this study. Even if the cement Tc-99 inventory is mainly associated with a few waste packages as demonstrated in Section 7.2, a base case is first performed (Section 7.5.1) assuming that the inventory associated with the cement waste form in 218-W-3AE is homogeneously distributed within 218-W-3AE volume to be consistent with the original CA Update approach (CP-62766 and ECF-HANFORD-19-0112). A more realistic area-to-volume ratio requires more technical basis regarding the spatial distribution of waste within 218-W-3AE as in a PA approach. A sensitivity case assuming cement waste form disposal within a B-25 container (same assumption as in PNNL-15965) is nevertheless presented in Section 7.5.2 to illustrate the importance of this assumption for this particular site. Including information about the distribution of waste forms within the waste site footprints should be consistently performed for all the CA waste sites and radionuclides as it could lead to significantly different estimates.

7.5.1 Tc-99 Inventory Sensitivity Case

218-W-3AE Tc-99 Inventory Sensitivity Case was performed considering the revised waste form assignment including the cement and soil-debris waste forms and the revised inventory given by SWITS from which N Reactor inventory was separated out in order to consider a solubility-limited release process for Tc-99. The base case consisted of the three different waste forms (i.e., cement, soil-debris, and solubility-limited release U billet) homogenously distributed within the whole 218-W-3AE footprint. This assumption is not representative of the actual distribution of the corresponding waste forms within the waste disposal site as both the cement and the solubility-limited release U billet waste forms were found to be associated with a limited number of waste packages and disposal units (see Section 7.2 and Table 7-3). However, this assumption is consistent with the original CA Update approach (CP-62766 and ECF-HANFORD-19-0112).

No relevant decrease in C-14 release rate and cumulative released activity can be observed for 218-W-3AE base case (Figure 7-13) as its inventory has not been substantially modified and only a small fraction was found to be associated with the cement waste form (see Table 7-4).

Contrary to C-14, the cumulative released activity of Tc-99 is reduced by a factor 9 (Figure 7-13, inset b) in this base case. This is the result of the waste form assignment revision which has led to distributing 218-W-3AE Tc-99 inventory among the cement waste form where Tc release is controlled by diffusion, and the U billet waste form where technetium release is controlled by a solubility limit resulting from congruent dissolution of technetium with uranium waste matrix. Figure 7-14 shows the respective contribution of each waste form considered in 218-W-3AE to Tc-99 release rates (Figure 7-14, inset a) and cumulative released activity (Figure 7-14, inert b). Even if the soil-debris waste form is still the highest contributor to the total Tc-99 release at early times (first 1,000 years), the long-term release rate trend after year 8,000 is governed by Tc-99 releases from N Reactor wastes which indicates that technetium is still in excess within the uranium waste matrix over the simulated period. The changes over time of Tc-99 release rate emanating from this waste form (Figure 7-14, inset a) result from changes in recharge rate and subsequent Darcy velocity through time which also simultaneously impact the releases from the soil-debris waste form. The cement waste form contributes to Tc-99 release with a magnitude higher to that of N Reactor wastes over the first 1,000 years (Figure 7-14, inset a). The resulting cumulative released activity from the cement waste form has however the same order of magnitude to that of the N Reactor wastes in this sensitivity case. These two waste forms contribute however to a cumulative activity lower by one order of magnitude to that of the soil-debris waste form which is still responsible for the majority of the Tc-99 release (Figure 7-14, inset b), despite this waste form assignment revision. However, the assumption was made that the three waste forms are homogeneously distributed within the whole 218-W-3AE footprint whereas:

- The cement waste form is mainly localized into four waste packages disposed in Trench 08 and containing more than 95% of the 218-W-3AE cement inventory: these four containers were disposed in May 1999, but their inventory was not reported in the fiscal 1999 annual review detailed in HNF-7561, *1998 - 1999 Annual Review of the 200 West and 200 East Area Performance Assessments* (which questions this information).
- The U billet waste form is associated with 179 waste packages (among 2,221 packages disposed in 218-W-3AE) also disposed in Trench 08.

The actual release area of these waste forms should therefore correspond only to a fraction of Trench 08 within 218-W-3AE footprint. The cross-sectional release area of these waste forms is thus considerably overestimated in this base case, which was conducted for keeping the same distribution hypothesis as in the CA Update. The impact of this hypothesis is tested in the following alternative sensitivity case (Section 7.5.2).

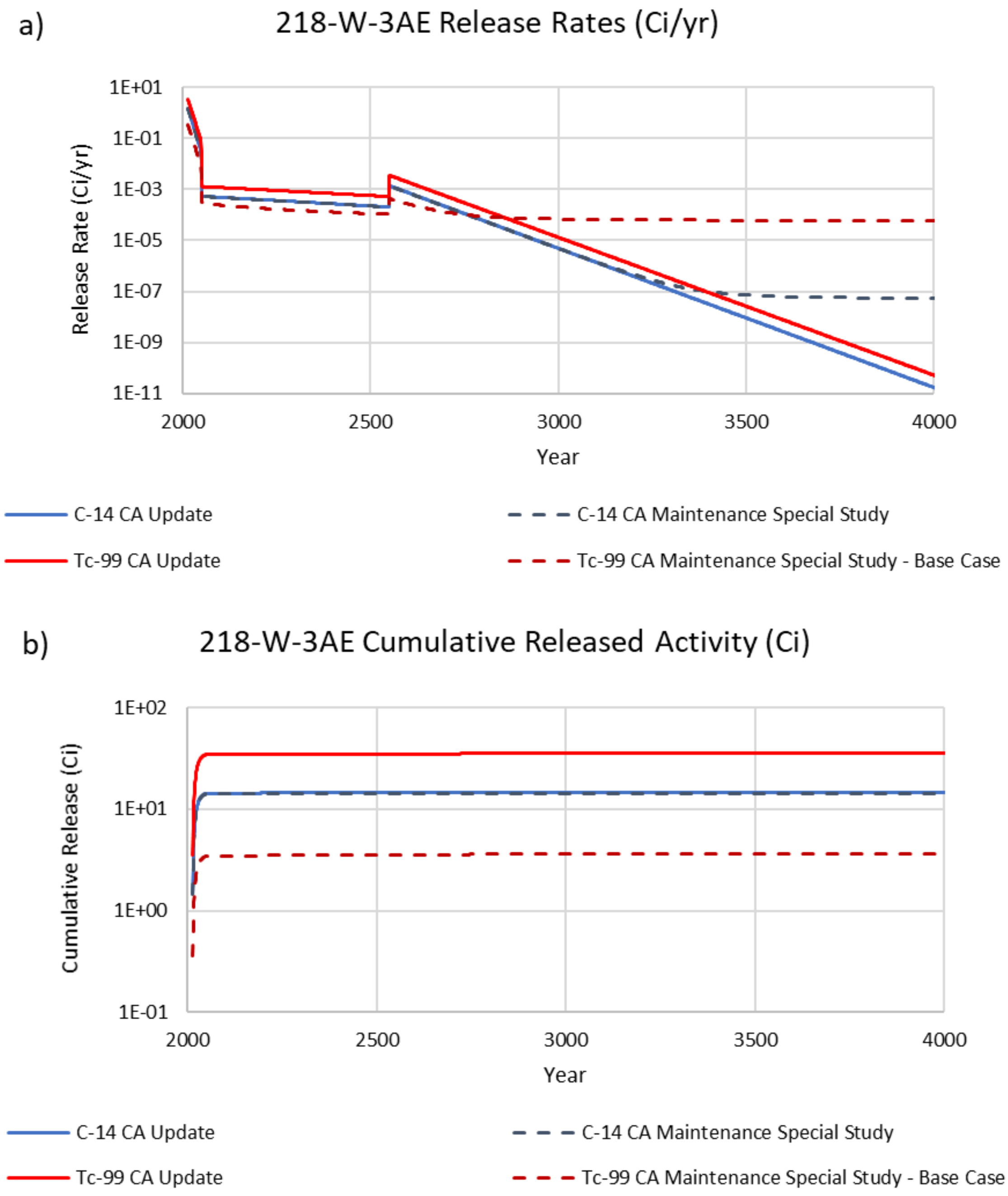


Figure 7-13. 218-W-3AE a) Annual Release Rate and b) Cumulative Activity Released for the Base Case over the first 2,000 Years

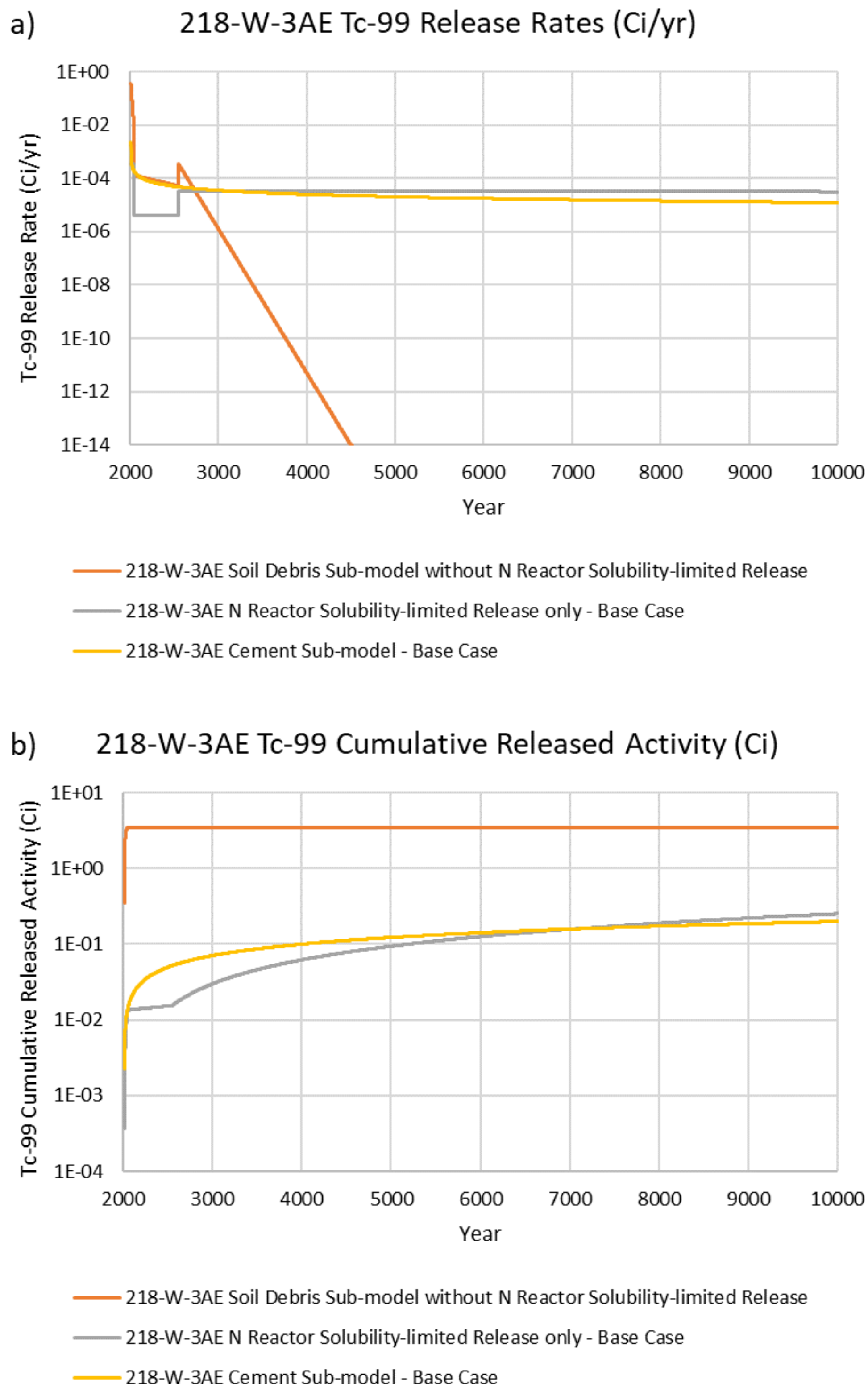


Figure 7-14. 218-W-3AE Tc-99 a) Annual Release Rate and b) Cumulative Activity Released by Waste Form

7.5.2 Tc-99 Release Footprint Sensitivity Case

In this 218-W-3AE additional sensitivity case, an alternative distribution of the cement waste form is tested while keeping the same base case inventory and waste form assignment as previously. It is assumed here that the cement waste form footprint is similar to that of a B-25 container as stated in PNNL-15965. The corresponding area-to-volume ratio (4.1 m^{-1}, see Appendix C) was applied to the cement submodel for simulating diffusive releases from such a configuration which should lead to higher releases as the cement inventory is not diluted over an unrealistic release area in that case. The soil-debris and solubility-limited release U billet waste forms were still assumed to be homogenously distributed through the whole 218-W-3AE footprint due to the lack of information regarding a more representative spatial distribution. The Tc-99 cumulative activity released by the cement submodel at 12,000 years with the B-25 area-to-volume ratio was found to be 20 times higher than that of the base case (Figure 7-15) as expected. The contribution of the cement submodel (Figure 7-15) becomes higher than that of the soil-debris submodel in the long run. The total Tc-99 cumulative activity is thus two times higher than that of the base case at 12,000 years with a B-25 disposal configuration for the cement waste form. This result illustrates the importance of addressing the lack of information related to the spatial distribution of wastes within the waste site footprint for taking into account more representative inventories and waste form assignments in the CA Update.

Even if a more appropriate footprint could be envisioned for the cement waste form in 218-W-3AE, the spatial distribution of inventories should be revised consistently when multiple waste forms need to be considered as it could change the order of magnitude of the simulated releases. Moreover, one has to note that the release rates of multiple waste forms for subsequent vadose zone transport calculations should not be added up if the waste form footprint do not match anymore the same area. This would require applying each source term to its appropriate surface area in the corresponding vadose zone model. In the case of 218-W-3AE where three different waste forms are required to consider a more representative inventory for two radionuclides in the CA Update, improving the representativeness of each waste form footprint should have required to compute independently six release rate time series that should have been applied to the corresponding surface area in the vadose zone model. One has to note that such a procedure would significantly increase the complexity of CA workflow between source release modeling and vadose zone modeling. As information was lacking for defining more representative waste form footprints, it was not deemed appropriate to perform vadose zone calculations with multiple source terms corresponding to several waste forms. Total release rates computed with homogenously distributed inventories through each waste site footprint were thus considered as the base case calculations for subsequent vadose zone modeling.

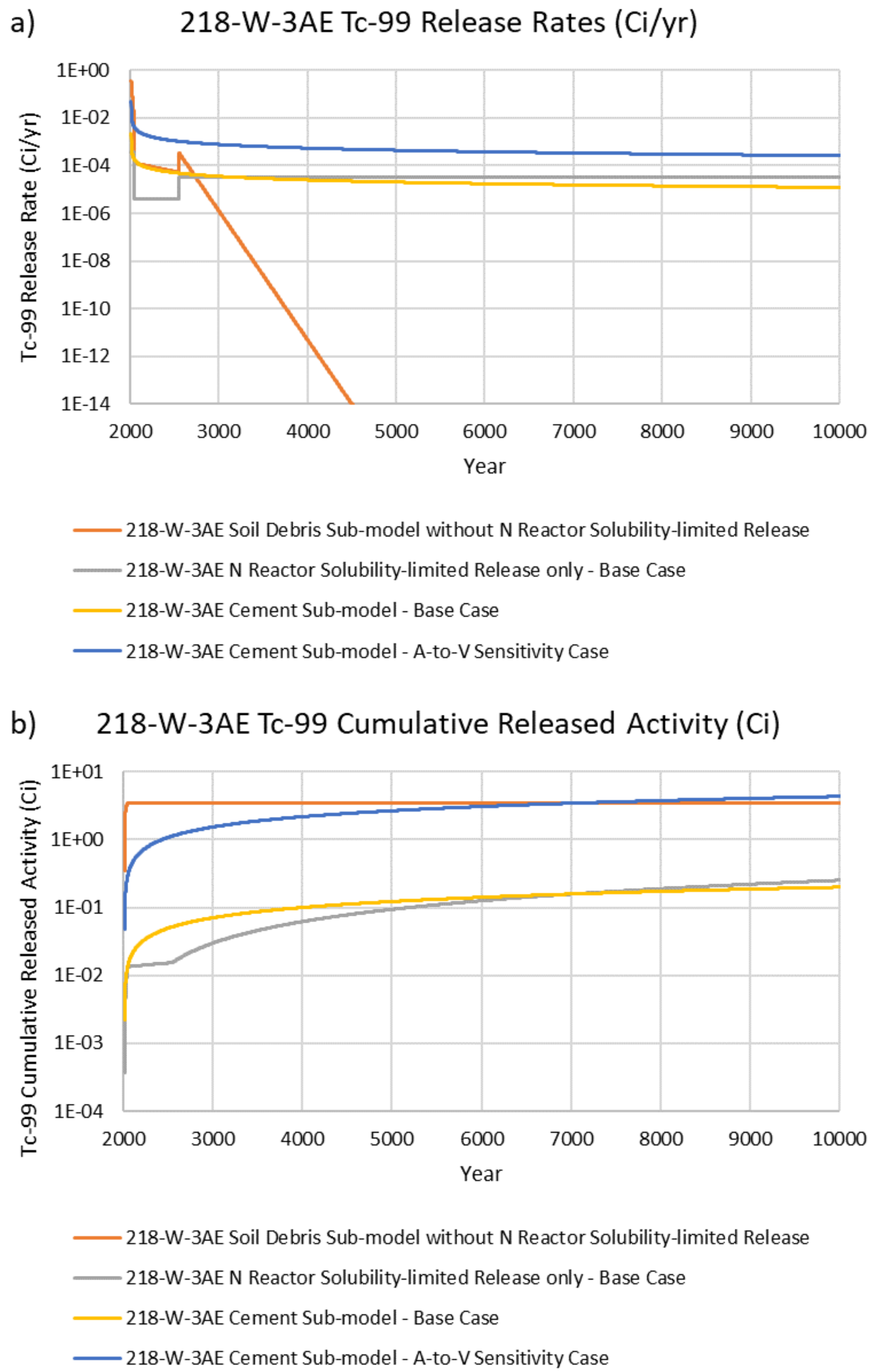


Figure 7-15. 218-W-3AE Tc-99 a) Annual Release Rate and b) Cumulative Activity Released by Waste Form for the Area-to-Volume Ratio Sensitivity Case

7.6 Summary and Conclusions

7.6.1 Inventory Revision

Through the preparation and review of CA Update (DOE/RL-2019-52, Rev. 1), it is identified that the assumed inventory and release rate of C-14 and Tc-99 from three DOE O 435.1 waste sites 218-E-12B, 218-W-3A, and 218-W-3AE as not to be representative of the expected inventory and release rate. A specific analysis was conducted to address the representativeness issue of the C-14 and Tc-99 inventories at these sites by calculating the C-14 and Tc-99 inventories using the original disposal records from the SWITS database. The results of the specific analysis showed the following:

- Nearly 100% of C-14 and 99.95% of Tc-99 in site 218-E-12B are contributed by Trench 94.
- The C-14 inventory in 218-W-3A used in the CA Update is about 167 times higher than the SWITS-based inventory, while the Tc-99 inventories from both sources are comparable.
- The C-14 and Tc-99 inventories in the CA inventory data package (CP-61786) for 218-W-3A are consistent with the SWITS-based inventories.

7.6.2 Waste Release

In this CA Maintenance sensitivity analysis, the cumulative activity released over the simulation period has decreased by several orders of magnitude for 218-E-12B and 218-W-3A C-14, and a factor nine for 218-W-3AE Tc-99 when compared to the CA Update results (Table 7-5). This decrease mainly results from the following:

- The inventory revision based on the SWITS database for 218-E-12B and 218-W-3A. In the case of 218-E-12B, this revision has mainly consisted in discarding Trench 94 waste inventory to be consistent with DOE/RL-2020-50 which anticipated that no release from these naval reactor compartments will occur during the compliance period and no significant aquifer contamination is envisioned for the next 1,000 years.
- The waste form assignment revision for 218-W-3AE. The inventory associated with N Reactor waste packages corresponding to unirradiated fuel has been assigned to a more representative waste form corresponding to U billet, which differs significantly in nature from soil-debris. For this alternative waste form, technetium release is controlled by a solubility limit deduced from congruent dissolution of technetium with uranium from the solid waste matrix. This submodel was similar to that of developed for Trench 34 U billet in the CA Update approach, which was found to be analogous to N Reactor fuel disposed in 218-W-3AE according to waste descriptions available in FH-0105097.

However, as information was lacking for defining representative waste form footprints, total release rates computed with homogenously distributed inventories through each waste site footprint were considered as the base case calculations for subsequent vadose zone modeling. However, this hypothesis of homogenous waste form inventory distribution within the whole waste site footprint (as formulated in the CA Update) can lead to nonrepresentative release rates. This study demonstrates that assigning a more representative waste form footprint for cement disposed in a few waste packages of Trench 08 in 218-W-3AE can lead to Tc-99 cumulative released activity two times higher than that of the base case at 12,000 years. More work is therefore needed to improve the representativeness of waste form footprints in the CA approach. As this reevaluation using information from SWITS identifies moreover significant differences from the assumptions used in the CA regarding Tc-99 and C-14, it tends to suggest that reevaluating the releases for other radionuclides in separate ECF(s)/special analyses could also be relevant in future work.

Table 7-5. Cumulative Activity Released per Waste Site Over the Simulation Period and Comparison to the CA Update Results

Solid Waste Disposal Site	Radionuclide	Cumulative Released Activity (Ci)				% Change
		Cement Waste Form	Soil-Debris Waste Form	Total	CA Update[b]	
218-E-12B[a]	C-14	0.0E+00	3.4E-10	3.4E-10	1.3E+02	-100
	Tc-99	2.4E-06	3.4E-04	3.4E-04	8.1E-01	-100
218-W-3A	C-14	4.7E-08	1.7E+00	1.7E+00	2.9E+02	-99
	Tc-99	5.2E-03	9.1E-02	9.6E-02	2.5E-01	-62
218-W-3AE	C-14	4.1E-04	Without N Reactor: 1.4E+01 N Reactor only: 0.0E+00	1.4E+01	1.5E+01	-7
	Tc-99	2.2E-01	Without N Reactor: 3.5E+00 N Reactor only: 3.2E-01	4.0E+00	3.5E+01	-89

Source: ECF-HANFORD-19-0112, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*.

a. Without Trench 94 naval reactor compartment wastes.

b. According to ECF-HANFORD-19-0112 where only the soil-debris waste form was considered.

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Appendix A

SQL Queries Considered for Extracting Information from the SWITS Database Regarding C-14, Tc-99, and Uranium Isotope Inventories Disposed in 218-E-12B, 218-W-3A, and 218-W-3AE

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A.1 SQL Query for Extracting C-14 and Tc-99 Inventories from 218-E-12B, 218-W-3A, 218-W-3AE Performed on 12/14/2021

```
WITH “C-14” AS
 (SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
   SWIADM.PKG_ISOTOPE.PISO_CI_QTY
 FROM SWIADM.ISOTOPE
 INNER JOIN SWIADM.PKG_ISOTOPE
 ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
 WHERE SWIADM.ISOTOPE.ISO_NAME IN ('C-14')
 ),
 “Tc-99” AS
 (SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
   SWIADM.PKG_ISOTOPE.PISO_CI_QTY
 FROM SWIADM.ISOTOPE
 INNER JOIN SWIADM.PKG_ISOTOPE
 ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
 WHERE SWIADM.ISOTOPE.ISO_NAME IN ('Tc-99')
 ),
 “C-14_AM” AS
 (SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
   SWIADM.PKG_ISOTOPE.PISO_CI_QTY
 FROM SWIADM.ISOTOPE
 INNER JOIN SWIADM.PKG_ISOTOPE
 ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
 WHERE SWIADM.ISOTOPE.ISO_NAME IN ('C-14 ACTIV. METAL')
 ),
 “Tc-99_AM” AS
 (SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
   SWIADM.PKG_ISOTOPE.PISO_CI_QTY
```

```
  FROM SWIADM.ISOTOPE
  INNER JOIN SWIADM.PKG_ISOTOPE
  ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
  WHERE SWIADM.ISOTOPE.ISO_NAME IN ('Tc-99 ACTIV. METAL')
  )
SELECT SWIADM.EXTWASTE_VW.CON_LOCN_FACIL_ID AS “Facility ID”,
  SWIADM.EXTWASTE_VW.CON_LOCN_UNIT         AS “Unit”,
  SWIADM.EXTWASTE_VW.CON_PKG_ID            AS “Package ID”,
  SWIADM.EXTWASTE_VW.CON_TSD_RECEIPT_DT    AS “TSD Received Date”,
  SWIADM.EXTWASTE_VW.CON_TSD_ACCEPT_DT     AS “TSD Accept Date”,
  SWIADM.EXTWASTE_VW.CON_DISPOSAL_DT       AS “TSD Disposal Date”,
  “C-14”.PISO_CI_QTY                AS “C-14 Ci”,
  “C-14_AM”.PISO_CI_QTY              AS “C-14 Activated Metal Ci”,
  “Tc-99”.PISO_CI_QTY               AS “Tc-99 Ci”,
  “Tc-99_AM”.PISO_CI_QTY             AS “Tc-99 Activated Metal Ci”,
  EXTWASTE_VW.CON_DNGR_FLAG        AS “Danger Flag”,
  EXTWASTE_VW.CON_CERCLA_FLAG      AS “CERCLA Flag”,
  EXTWASTE_VW.CON_RAD_CD           AS “Rad Code”,
  EXTWASTE_VW.CON_TSCA_FLAG        AS “TSCA Flag”,
  EXTWASTE_VW.CON_GENER_COMMENT    AS “Comments”,
  EXTWASTE_VW.CON_GENER_WASTE_DESCR AS “Waste Description”,
  EXTWASTE_VW.CON_PROF_NUM         AS “Profile Number”,
  EXTWASTE_VW.CON_PROF_REV_NUM     AS “Profile Rev.”,
  SWIADM.PROFILE.PROF_NAME         AS “Profile Name”,
  SWIADM.PROFILE.PROF_COMMENTS     AS “Profile Comments”

FROM SWIADM.EXTWASTE_VW
LEFT JOIN “C-14”
ON SWIADM.EXTWASTE_VW.CON_PKG_ID = “C-14”.PISO_PKG_ID
LEFT JOIN “Tc-99”
```

```
ON SWIADM.EXTWASTE_VW.CON_PKG_ID          = “Tc-99”.PISO_PKG_ID
LEFT JOIN “C-14_AM”
ON SWIADM.EXTWASTE_VW.CON_PKG_ID = “C-14_AM”.PISO_PKG_ID
LEFT JOIN “Tc-99_AM”
ON SWIADM.EXTWASTE_VW.CON_PKG_ID          = “Tc-99_AM”.PISO_PKG_ID
LEFT JOIN SWIADM.PROFILE
ON EXTWASTE_VW.CON_PROF_NUM   = SWIADM.PROFILE.PROF_NUM
WHERE SWIADM.EXTWASTE_VW.CON_LOCN_FACIL_ID IN ('218E12B', '218W3A', '218W3AE')
AND (“C-14”.PISO_CI_QTY                  IS NOT NULL
OR “Tc-99”.PISO_CI_QTY                  IS NOT NULL
OR “C-14_AM”.PISO_CI_QTY                    IS NOT NULL
OR “Tc-99_AM”.PISO_CI_QTY                   IS NOT NULL)
ORDER BY “Facility ID”,
  “Unit”,
  “Package ID”
```

A.2 Additional SQL Query for Extracting Uranium Isotope Inventories from 218-E-12B, 218-W-3A, 218-W-3AE Performed on 06/08/2022

```
“WITH ““C-14”“ AS
  (SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
    SWIADM.PKG_ISOTOPE.PISO_CI_QTY
  FROM SWIADM.ISOTOPE
  INNER JOIN SWIADM.PKG_ISOTOPE
  ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
  WHERE SWIADM.ISOTOPE.ISO_NAME IN ('C-14')
  ),
  ““Tc-99”“ AS
  (SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
    SWIADM.PKG_ISOTOPE.PISO_CI_QTY
```

```
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('Tc-99')
),
""“C-14_AM”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('C-14 ACTIV. METAL')
),
""“Tc-99_AM”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('Tc-99 ACTIV. METAL')
),
""“U-232”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('U-232')
),
""“U-233”“ AS
```

```
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('U-233')
),
"“U-234”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('U-234')
),
"“U-235”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('U-235')
),
"“U-236”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('U-236')
```

```
),
"“U-237”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('U-237')
),
"“U-238”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('U-238')
),
"“URANIUM-DEPLETED”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
WHERE SWIADM.ISOTOPE.ISO_NAME IN ('URANIUM-DEPLETED')
),
"“URANIUM-ENRICHED”“ AS
(SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
  SWIADM.PKG_ISOTOPE.PISO_CI_QTY
FROM SWIADM.ISOTOPE
INNER JOIN SWIADM.PKG_ISOTOPE
```

```
 ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
 WHERE SWIADM.ISOTOPE.ISO_NAME IN ('URANIUM-ENRICHED')
 ),
 "“URANIUM-NATURAL”“ AS
 (SELECT SWIADM.PKG_ISOTOPE.PISO_PKG_ID,
   SWIADM.PKG_ISOTOPE.PISO_CI_QTY
 FROM SWIADM.ISOTOPE
 INNER JOIN SWIADM.PKG_ISOTOPE
 ON SWIADM.ISOTOPE.ISO_NUM     = SWIADM.PKG_ISOTOPE.PISO_ISO_NUM
 WHERE SWIADM.ISOTOPE.ISO_NAME IN ('URANIUM-NATURAL')
 )
SELECT SWIADM.EXTWASTE_VW.CON_LOCN_FACIL_ID AS "“Facility ID”“,
 SWIADM.EXTWASTE_VW.CON_LOCN_UNIT         AS "“Unit”“,
 SWIADM.EXTWASTE_VW.CON_PKG_ID            AS "“Package ID”“,
 SWIADM.EXTWASTE_VW.CON_TSD_RECEIPT_DT    AS "“TSD Received Date”“,
 SWIADM.EXTWASTE_VW.CON_TSD_ACCEPT_DT     AS "“TSD Accept Date”“,
 SWIADM.EXTWASTE_VW.CON_DISPOSAL_DT       AS "“TSD Disposal Date”“,
 "“C-14”“.PISO_CI_QTY                     AS "“C-14 Ci”“,
 "“C-14_AM”“.PISO_CI_QTY                  AS "“C-14 Activated Metal Ci”“,
 "“Tc-99”“.PISO_CI_QTY                    AS "“Tc-99 Ci”“,
 "“Tc-99_AM”“.PISO_CI_QTY                 AS "“Tc-99 Activated Metal Ci”“,
 "“U-232”“.PISO_CI_QTY                    AS "“U-232 Ci”“,
 "“U-233”“.PISO_CI_QTY                    AS "“U-233 Ci”“,
 "“U-234”“.PISO_CI_QTY                    AS "“U-234 Ci”“,
 "“U-235”“.PISO_CI_QTY                    AS "“U-235 Ci”“,
 "“U-236”“.PISO_CI_QTY                    AS "“U-236 Ci”“,
 "“U-237”“.PISO_CI_QTY                    AS "“U-237 Ci”“,
 "“U-238”“.PISO_CI_QTY                    AS "“U-238 Ci”“,
 "“URANIUM-DEPLETED”“.PISO_CI_QTY         AS "“URANIUM-DEPLETED Ci”“,
 "“URANIUM-ENRICHED”“.PISO_CI_QTY         AS "“URANIUM-ENRICHED Ci”“,
```

```
""URANIUM-NATURAL"".PISO_CI_QTY        AS ""URANIUM-NATURAL Ci"",
EXTWASTE_VW.CON_DNGR_FLAG        AS ""Danger Flag"",
EXTWASTE_VW.CON_CERCLA_FLAG      AS ""CERCLA Flag"",
EXTWASTE_VW.CON_RAD_CD           AS ""Rad Code"",
EXTWASTE_VW.CON_TSCA_FLAG        AS ""TSCA Flag"",
EXTWASTE_VW.CON_GENER_COMMENT    AS ""Comments"",
EXTWASTE_VW.CON_GENER_WASTE_DESCR AS ""Waste Description"",
EXTWASTE_VW.CON_PROF_NUM         AS ""Profile Number"",
EXTWASTE_VW.CON_PROF_REV_NUM     AS ""Profile Rev."",
SWIADM.PROFILE.PROF_NAME         AS ""Profile Name"",
SWIADM.PROFILE.PROF_COMMENTS     AS ""Profile Comments""

FROM SWIADM.EXTWASTE_VW
LEFT JOIN ""C-14""
ON SWIADM.EXTWASTE_VW.CON_PKG_ID = ""C-14"".PISO_PKG_ID
LEFT JOIN ""Tc-99""
ON SWIADM.EXTWASTE_VW.CON_PKG_ID       = ""Tc-99"".PISO_PKG_ID
LEFT JOIN ""C-14_AM""
ON SWIADM.EXTWASTE_VW.CON_PKG_ID = ""C-14_AM"".PISO_PKG_ID
LEFT JOIN ""Tc-99_AM""
ON SWIADM.EXTWASTE_VW.CON_PKG_ID       = ""Tc-99_AM"".PISO_PKG_ID
LEFT JOIN ""U-232""
ON SWIADM.EXTWASTE_VW.CON_PKG_ID       = ""U-232"".PISO_PKG_ID
LEFT JOIN ""U-233""
ON SWIADM.EXTWASTE_VW.CON_PKG_ID       = ""U-233"".PISO_PKG_ID
LEFT JOIN ""U-234""
ON SWIADM.EXTWASTE_VW.CON_PKG_ID       = ""U-234"".PISO_PKG_ID
LEFT JOIN ""U-235""
ON SWIADM.EXTWASTE_VW.CON_PKG_ID       = ""U-235"".PISO_PKG_ID
LEFT JOIN ""U-236""
```

```
ON SWIADM.EXTWASTE_VW.CON_PKG_ID          = "“U-236”“.PISO_PKG_ID
LEFT JOIN "“U-237”“
ON SWIADM.EXTWASTE_VW.CON_PKG_ID          = "“U-237”“.PISO_PKG_ID
LEFT JOIN "“U-238”“
ON SWIADM.EXTWASTE_VW.CON_PKG_ID          = "“U-238”“.PISO_PKG_ID
LEFT JOIN "“URANIUM-DEPLETED”“
ON SWIADM.EXTWASTE_VW.CON_PKG_ID          = "“URANIUM-DEPLETED”“.PISO_PKG_ID
LEFT JOIN "“URANIUM-ENRICHED”“
ON SWIADM.EXTWASTE_VW.CON_PKG_ID          = "“URANIUM-ENRICHED”“.PISO_PKG_ID
LEFT JOIN "“URANIUM-NATURAL”“
ON SWIADM.EXTWASTE_VW.CON_PKG_ID          = "“URANIUM-NATURAL”“.PISO_PKG_ID
LEFT JOIN SWIADM.PROFILE
ON EXTWASTE_VW.CON_PROF_NUM   = SWIADM.PROFILE.PROF_NUM
WHERE SWIADM.EXTWASTE_VW.CON_LOCN_FACIL_ID IN ('218E12B', '218W3A', '218W3AE')
AND ("“C-14”“.PISO_CI_QTY                 IS NOT NULL
OR "“Tc-99”“.PISO_CI_QTY                  IS NOT NULL
OR "“C-14_AM”“.PISO_CI_QTY                IS NOT NULL
OR "“Tc-99_AM”“.PISO_CI_QTY               IS NOT NULL
OR "“U-232”“.PISO_CI_QTY                  IS NOT NULL
OR "“U-233”“.PISO_CI_QTY                  IS NOT NULL
OR "“U-234”“.PISO_CI_QTY                  IS NOT NULL
OR "“U-235”“.PISO_CI_QTY                  IS NOT NULL
OR "“U-236”“.PISO_CI_QTY                  IS NOT NULL
OR "“U-237”“.PISO_CI_QTY                  IS NOT NULL
OR "“U-238”“.PISO_CI_QTY                  IS NOT NULL
OR "“URANIUM-DEPLETED”“.PISO_CI_QTY       IS NOT NULL
OR "“URANIUM-ENRICHED”“.PISO_CI_QTY       IS NOT NULL
OR "“URANIUM-NATURAL”“.PISO_CI_QTY        IS NOT NULL)
ORDER BY "“Facility ID”“,
  "“Unit”“,
  "“Package ID”"“
```

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Appendix B

CASWR Results Postprocess R Script

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B.1 Postprocess Input Information

UnitEnd_Year File_Output
Ci 12069 CA_Maintenance_Results.csv

B.2 Postprocess R Script

```
#File generated by Ryan Nell, INTERA (modified for CA Maintenance)

#06/17/2022

#Solid Waste Release GoldSim model generates 2 outputs, corresponding with each submodel

#Vadose Zone facet modelers prefer a single, continuous .csv output compiling each waste site's analyte release per year

#Update the PostProcess_Input.txt file prior to running script. Designate the desired output file name.


library(readxl)

library(scales)

library(dplyr)

library(data.table)


###########

#reads “PostProcess_Input.txt” file which designates units, end year, and file output title

df<-read.table(“PostProcess_Input.txt”,header=T)

Unit<-as.character(df$Unit)

End_Year<-as.numeric(df$End_Year)

File_Output<-as.character(df$File_Output)


#imports all result sheets from each .xlsx file

#Only Cement_Results  & Soil_Results, add up results for computing total release

cmnt<-read_excel(“Cmnt_results.xlsx”,col_types = c(“text”, rep(“numeric”,18)))

cmnt<-data.frame(cmnt)

SD<-read_excel(“Soil_results.xlsx”,col_types = c(“text”, rep(“numeric”,18)))

SD<-data.frame(SD)

CASWR_data<-data.frame(cmnt$Site_Name,cmnt$Year)

CASWR_data$C14<-cmnt$C.14+SD$C.14
```

```
CASWR_data$Tc99<-cmnt$Tc.99+SD$Tc.99
colnames(CASWR_data)<-c(“Site_Name”,”Year”,”C14”,”Tc99”)

#removes blank values
combinedresult<-na.omit(CASWR_data)

#removes the site_index column from the data table. This is an artifact of the CA SWR.
# Not needed here
# cleanedresult=subset(combinedresult,select=-c(Site_Index))

#keeps years < the designated end year for assigned release
cleanedresult_yr=subset(combinedresult,Year<=End_Year)

#add row defining units
cleanedresult_yr$Site_Name <- as.character(cleanedresult_yr$Site_Name)
ci<- c(““,”“,rep(Unit,ncol(cleanedresult_yr)-2))
cleanedresults_ci<-rbind(ci,cleanedresult_yr)
cleanedresults_ci$Site_Name<-as.factor(cleanedresults_ci$Site_Name)
#writes final combined result output
write.csv(cleanedresults_ci,file=File_Output,row.names=FALSE)
```

Appendix C

Cement Submodel Parameter Inputs

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Table C-1. Source Zone Area-to-Volume Ratio Used in the Cement Submodel

Site	Thickness or Height (m)	Surface Area (m^2)	A/V (m^{-1})	Reference
218-E-12B[a]	5.4	231688.0	0.185	ECF-HANFORD-19-0112[a]
218-W-3A[a]	5.3	210959.2	0.189	ECF-HANFORD-19-0112[a]
218-W-3AE[a]	5.3 2.4[b]	197489.6 14.9 [b]	0.189 4.1 [b]	ECF-HANFORD-19-0112[a] PNNL-15965 - Table 5.7[b]

References:

EMDT-GR-0035, 2019, *Waste Site and Structure Footprint Shapefiles for Inclusion in Updated Composite Analysis*, CH2M HILL Plateau Remediation Company, Richland, Washington.

PNNL-15965, 2006, *Release Data Package for Hanford Site Assessments,* Pacific Northwest National Laboratory, Richland, Washington.

ECF-HANFORD-19-0112, 2022, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*, Rev. 1, Central Plateau Cleanup Company, Richland, Washington.

a. Thickness assumed to be equal to that of the soil-debris submodel (i.e., cement waste forms homogenously distributed through the whole waste site) in a base case approach consistent with the CA Update approach (ECF-HANFORD-19-0112) where the site footprints have been derived from EMDT-GR-0035.

b. Area-to-volume ratio assumed to be equal to that of a B-25 grouted container (PNNL-15965) in an alternative sensitivity case (i.e., cement waste form footprint assumed to be limited to that of a grouted container for taking into account that the cement waste form inventory is associated with only a few waste packages supposed to be gathered within the same macro-encapsulation box in Trench 08 of 218-W-3AE).

A/V = area-to-volume

CA = composite analysis

Table C-2. Effective Diffusion Coefficients Used in the Cement Submodel

Species	Effective Diffusion Coefficient in Cement (cm^2/yr)	References
C-14	3.15E-05	HANFORD-19-0112 (from PNNL-15965 - Table 5.8)
Tc-99	1.58E-02	HANFORD-19-0112 (from PNNL-15965 - Table 5.8)

References:

ECF-HANFORD-19-0112, 2022, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*, Rev. 1, Central Plateau Cleanup Company, Richland, Washington.

PNNL-15965, 2006, *Release Data Package for Hanford Site Assessments*, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-15965.pdf.

Appendix D

Soil-Debris Submodel Parameter Inputs

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Table D-1. Source Zone Geometry and Chemistry Category Used in the Soil-Debris Submodel

Site	Height or Thickness (m)	Cross-Sectional Area (m^2)	Chemistry Category	Reference
218-E-12B	5.4	231688.0	4	HANFORD-19-0112*
218-W-3A	5.3	210959.2	4	HANFORD-19-0112*
218-W-3AE	5.3	197489.6	4	HANFORD-19-0112*

Reference: ECF-HANFORD-19-0112, 2022, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*, Rev. 1, Central Plateau Cleanup Company, Richland, Washington.

*Thickness and cross-sectional area assumed to be equal to that of the disposal site (i.e., soil waste form assumed to be homogeneously distributed over the whole site footprint).

Table D-2. K_d Values Used in the Soil-Debris Submodel for the Sites Having a Chemistry Category Equal to 4 (i.e., near neutral pH)

Element	K_d (mL/g)	Document
C	0	HANFORD-19-0112
Tc	0	HANFORD-19-0112

Reference: ECF-HANFORD-19-0112, 2022, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*, Rev. 1, Central Plateau Cleanup Company, Richland, Washington.

K_d = distribution coefficient

Table D-3. Solubilities Used in the Soil-Debris Submodel

Element	Solubility Limit	Reference
C	No solubility constraint	ECF-HANFORD-19-0112
Tc	No solubility constraint except for N Reactor waste packages: 2.4E-11 mol/L at the beginning of the simulation (see Section 4.2.2 in the main text of this document)	ECF-HANFORD-19-0112 except for N Reactor waste packages where Tc solubility is computed from Tc/U ratio (see Section 4.2.2)

Reference: ECF-HANFORD-19-0112, 2022, *Solid Waste Release Calculations for the Composite Analysis Baseline Assessment*, Rev. 1, Central Plateau Cleanup Company, Richland, Washington.

Table D-4. Soil Physical Properties Used in the Soil-Debris Submodel

Area	Dry Bulk Density (g/cm^3)*	Porosity (-)*	0.5 mm/yr Volumetric Moisture Content (-)	4 mm/yr Volumetric Moisture Content (-)	8.5 mm/yr Volumetric Moisture Content (-)	26 mm/yr Volumetric Moisture Content (-)	46 mm/yr Volumetric Moisture Content (-)	63 mm/yr Volumetric Moisture Content (-)
200-E	2.15	0.1740	0.0522	0.0605	0.0647	0.0721	0.0765	0.0789
200-W	2.03	0.1917	0.0520	0.0606	--	0.0749	0.0805	0.0838

Reference: DOE/RL-2011-50, 2012, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093361.

*ECF-HANFORD-19-0121, 2020, *Selection of Vadose Zone Flow and Transport Properties with Gravel Fraction Corrections for the Hanford Site Composite Analysis and Cumulative Impact Evaluation*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://www.osti.gov/servlets/purl/1605425.

Appendix E

CASWR Model Electronic Content Outputs

These files are too large to include in a Word Table format and will be included as separate .csv files attached to this report.

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Appendix F

CASWR Data Reduction Configuration Files and Outputs

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F.1 C-14 Configuration Input File

{

“Source Files”:{

“200 E”:”input/CA_Maintenance_Results.csv”,

“200 W”:”input/CA_Maintenance_Results.csv”

},

“Zero Below”:”0”,

“SUMMARY_FILE_NAME”: “CACIE-reducer_CA-Maintenance_C-14_summary.csv”,

“SUMMARY_TEMPLATE”:”{copc},{site},{N},{ix},{used_eps:.2g},{orig_total_mass:.7e},{reduced_total_mass:.7e},{unbal_mass_err:.2g},{unbal_rel_err:.2g},{bal_mass_err:.2g},{bal_rel_err:.2g}”,

“SUMMARY_HEADER”:[“COPC”,”SITE”,”N reduced”,”N Iterations”,”Epsilon”,”Original Total Mass (Ci)”,”Reduced/Rebalanced Total Mass (Ci)”,”Unbalanced Total Mass Error (Ci) (Original-Reduced)”,”Total Mass Relative Percent Error [before rebalance]”,”Rebalanced Total Mass Error(Ci) (Original-Reduced)”,”Total Mass Relative Percent Error [after rebalance]”

],

“SUMMARY_MODE”:”a”,

“COPCs”: [“C-14”],

“Waste Sites”: [“218-E-12B”,”218-W-3A”,”218-W-3AE”],

“Mass Threshold”:”0.1”,

“Output Lower Error Threshold”:”0.001”,

“Output Upper Error Threshold”:”0.01”,

“Lower Reduced Datapoint Limit”:”25”,

“Upper Reduced Datapoint Limit”:”50”,

“Maximum Iterations”:”25”,

“Maximum Error Iterations”:”15”,

“Epsilon”:”1”,

“Close Gaps”:”False”,

“Gap Delta”: “2000”,

“Gap Steps”:”3”,

“Diff Mass Correction”:”True”

}

F.2 Tc-99 Configuration Input File

{

“Source Files”:{

“200 E”:”input/CA_Maintenance_Results.csv”,

“200 W”:”input/CA_Maintenance_Results.csv”

},

“Zero Below”:”0”,

“SUMMARY_FILE_NAME”: “CACIE-reducer_CA-Maintenance_Tc-99_summary.csv”,

“SUMMARY_TEMPLATE”:”{copc},{site},{N},{ix},{used_eps:.2g},{orig_total_mass:.7e},{reduced_total_mass:.7e},{unbal_mass_err:.2g},{unbal_rel_err:.2g},{bal_mass_err:.2g},{bal_rel_err:.2g}”,

“SUMMARY_HEADER”:[“COPC”,”SITE”,”N reduced”,”N Iterations”,”Epsilon”,”Original Total Mass (Ci)”,”Reduced/Rebalanced Total Mass (Ci)”,”Unbalanced Total Mass Error (Ci) (Original-Reduced)”,”Total Mass Relative Percent Error [before rebalance]”,”Rebalanced Total Mass Error(Ci) (Original-Reduced)”,”Total Mass Relative Percent Error [after rebalance]”

],

“SUMMARY_MODE”:”a”,

“COPCs”: [“Tc-99”],

“Waste Sites”: [“218-E-12B”,”218-W-3A”,”218-W-3AE”],

“Mass Threshold”:”0.1”,

“Output Lower Error Threshold”:”0.001”,

“Output Upper Error Threshold”:”0.01”,

“Lower Reduced Datapoint Limit”:”25”,

“Upper Reduced Datapoint Limit”:”50”,

“Maximum Iterations”:”25”,

“Maximum Error Iterations”:”15”,

“Epsilon”:”1”,

“Close Gaps”:”True”,

“Gap Delta”: “3000”,

“Gap Steps”:”1”,

“Diff Mass Correction”:”True”

}

F.3 218-E-12B C-14 Output

Site Name: 218-E-12B

Date Created: 2022/07/07

Script Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b

COPC: C-14

Reduced Year,Reduced Activity Release Rate (Ci/year)

2013,0.0

2014,8.30350772313415e-12

2015,8.18580050893202e-12

2017,7.795142429049899e-12

2019,7.423128064612659e-12

2021,7.06886766536687e-12

2023,6.73151394338456e-12

2025,6.41026004659672e-12

2027,6.1043376290376795e-12

2029,5.81301501318476e-12

2031,5.5355954399984e-12

2033,5.27141540247666e-12

2034,5.17248680330203e-12

2037,4.8077899272036895e-12

2040,4.46786540197002e-12

2042,4.2536815616997595e-12

2045,3.9529340857805695e-12

2049,3.58561680778998e-12

2050,1.38406020119521e-12

2051,2.55841881109951e-13

2162,2.0730157717361998e-13

2282,1.65129730805696e-13

2411,1.2931224141639e-13

2549,9.95510181739709e-14

2550,6.2439276627782e-13

2551,6.75906679611569e-13

2564,5.7525802501582e-13

2576,4.95942855008803e-13

2591,4.11995836946171e-13

2606,3.4225832260039e-13

2621,2.84325104490156e-13

2639,2.27598101593016e-13

2657,1.82188962672243e-13

2678,1.40529573735427e-13

2721,8.259298508310211e-14

2774,4.28863755275117e-14

2843,1.82743028306072e-14

2936,5.787622478039421e-15

3318,5.14634052130126e-17

12069,0.0

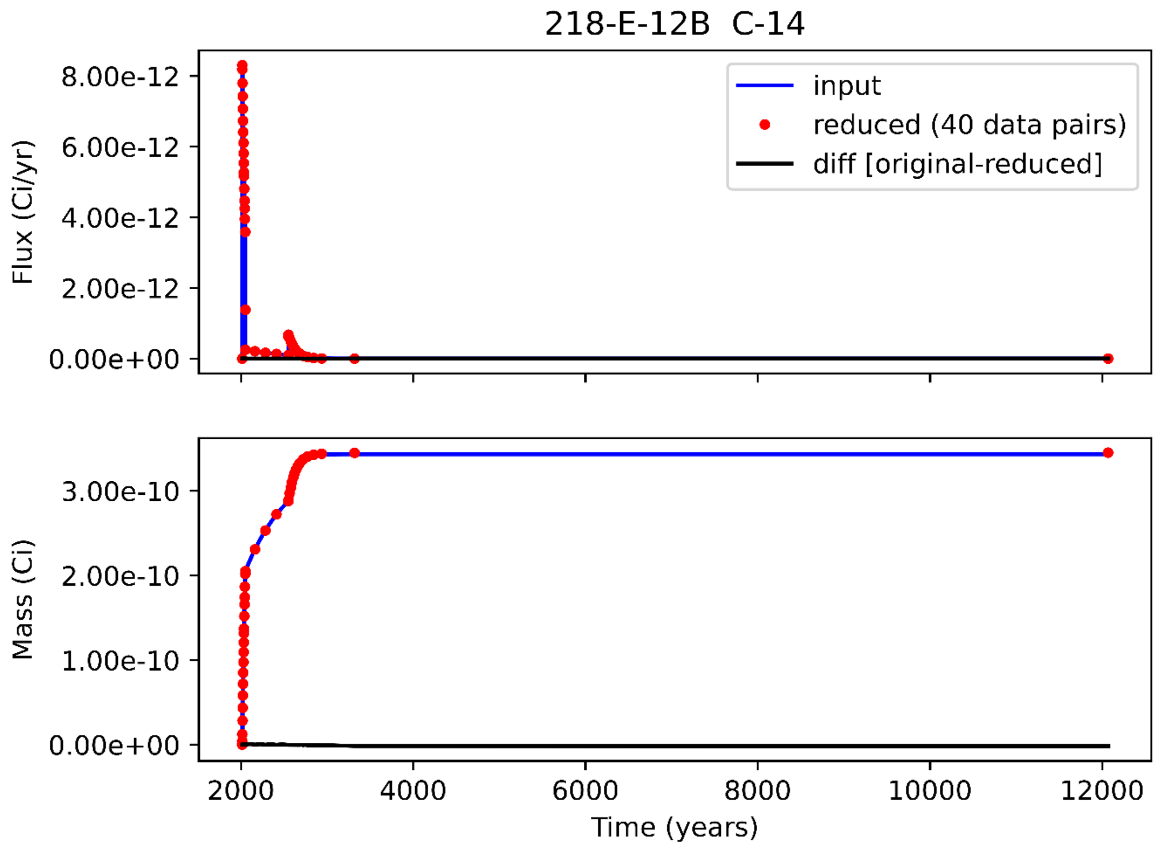

Figure F-1. Comparison of 218-E-12B C-14 CASWR Model-Generated Release Rates (Ci/yr) given by GoldSim (blue line) to the Reduced Dataset (red dots) Produced with the CACIE Reduction Tool for Subsequent Vadose Zone Transport Calculations

F.4 218-E-12B Tc-99 Output

Site Name: 218-E-12B

Date Created: 2022/07/07

Script Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b

COPC: Tc-99

Reduced Year,Reduced Activity Release Rate (Ci/year)

2013,0.0

2014,8.08539811193891e-06

2015,7.95829725475941e-06

2017,7.57725009159572e-06

2019,7.21634224465719e-06

2021,6.873084407416e-06

2023,6.54634326445691e-06

2025,6.23523242805849e-06

2027,5.93896399095056e-06

2029,5.65680940341106e-06

2031,5.38808479994232e-06

2033,5.13214397706275e-06

2034,5.03628921322777e-06

2037,4.68286100912322e-06

2040,4.35334173581942e-06

2042,4.14565980207466e-06

2045,3.85396406525653e-06

2049,3.49756595368236e-06

2050,1.35138458456718e-06

2051,2.51426161364831e-07

2159,2.06897708768981e-07

2279,1.67097228408825e-07

2549,1.03479132261098e-07

2550,6.46399121437731e-07

2551,6.99763125001384e-07

2564,5.96551015361178e-07

2576,5.15094312127367e-07

2591,4.28742975309856e-07

2606,3.56879875915937e-07

2621,2.97074025695259e-07

2639,2.38398639889321e-07

2657,1.91328650328957e-07

2678,1.48045141383747e-07

2699,1.14574469361007e-07

2723,8.55079346506499e-08

2777,4.43405052873439e-08

2846,1.9275690218751e-08

2939,6.4307681563222e-09

3338,3.71431505526719e-10

7703,1.54948607723093e-10

12068,1.14899158326365e-10

12069,1.148931281531e-10

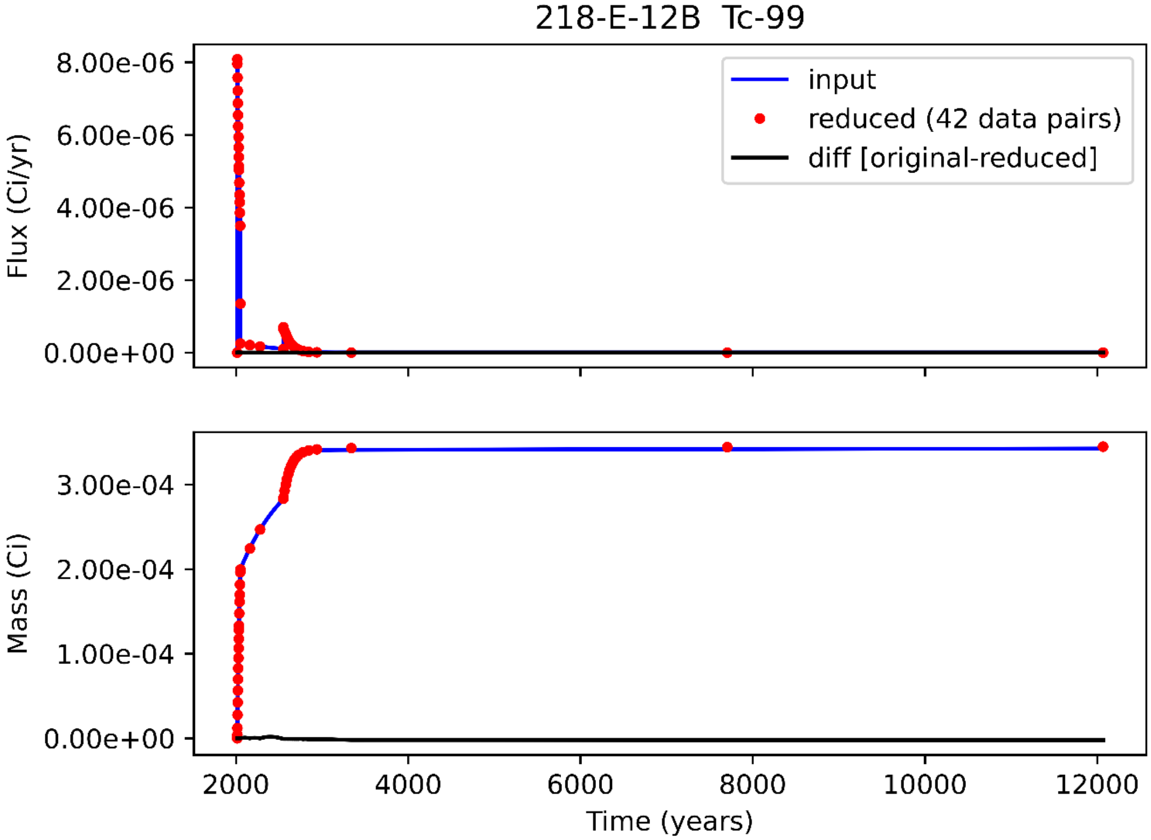

Figure F-2. Comparison of 218-E-12B Tc-99 CASWR Model-generated Release Rates (Ci/yr) given by GoldSim (blue line) to the Reduced Dataset (red dots) Produced with the CACIE Reduction Tool for Subsequent Vadose Zone Transport Calculations

F.5 218-W-3A C-14 Output

Site Name: 218-W-3A

Date Created: 2022/07/07

Script Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b

COPC: C-14

Reduced Year,Reduced Activity Release Rate (Ci/year)

2013,0.0

2014,0.175471216904758

2015,0.15792328063259742

2016,0.14176586486153428

2017,0.12726154347273716

2018,0.11424118537982682

2019,0.10255296361600413

2020,0.0920605849082813

2021,0.0833082210939388

2022,0.0747848067127141

2023,0.0671334382333273

2024,0.0602648950662354

2025,0.0540990849414279

2026,0.0485641099735604

2027,0.0435954282796637

2028,0.0391351013732646

2029,0.035131118558968

2030,0.0315367904494632

2031,0.0283102045328847

2032,0.0254137364420672

2033,0.0228136112267284

2034,0.0209808643564652

2035,0.0189234424593335

2036,0.0169113840822248

2037,0.0151989628319428

2038,0.0136954443257766

2039,0.012239259304687

2040,0.0109999303652981

2041,0.0099117904024727

2042,0.0088579070560159

2043,0.0079609687472794

2044,0.0071734502871497

2045,0.0064107243341235

2046,0.0057615840581619

2047,0.0051916341011087

2048,0.0046396272007137

2049,0.0041698255501446

2050,0.0015413572414328

2051,6.39937973033283e-05

2279,4.11584242370301e-05

2549,2.44045328776418e-05

2550,0.0001522198499574

2551,0.0001647415227012

2576,0.0001202431266124

2606,8.24597427077973e-05

2639,5.444891147371217e-05

2675,3.462639566392962e-05

2771,1.035592798618582e-05

2931,1.3853140593293192e-06

12069,9.64944967741709e-13

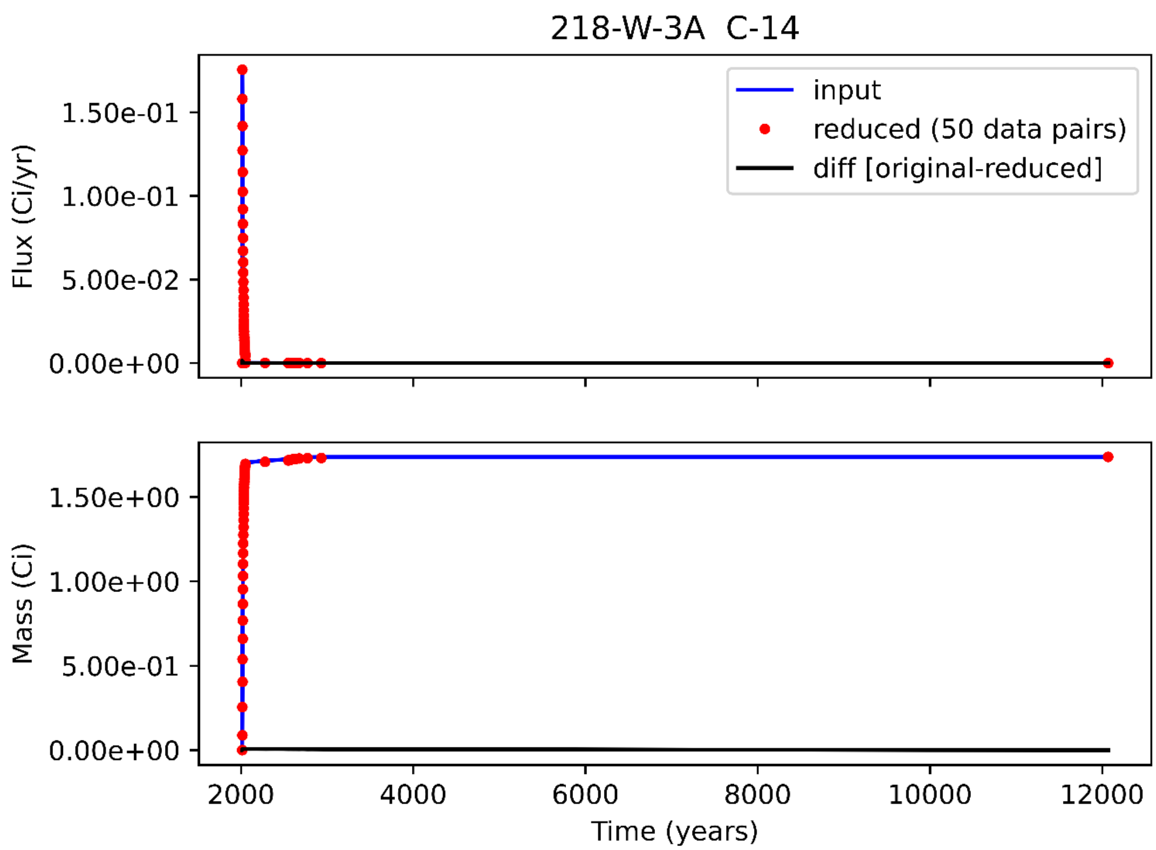

Figure F-3. Comparison of 218-W-3A C-14 CASWR Model-generated Release Rates (Ci/yr) given by GoldSim (blue line) to the Reduced Dataset (red dots) Produced with the CACIE Reduction Tool for Subsequent Vadose Zone Transport Calculations

F.6 218-W-3A Tc-99 Output

Site Name: 218-W-3A

Date Created: 2022/07/07

Script Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b

COPC: Tc-99

Reduced Year,Reduced Activity Release Rate (Ci/year)

2013,0.0

2014,0.0091926475925357

2015,0.0083156163096433

2016,0.0074628471398552

2017,0.0066991802974428

2018,0.0060142465543179

2019,0.0053996321949649

2020,0.0048480019243272

2021,0.004352847175867

2022,0.0039083576200784

2023,0.0035093328256743

2024,0.0031511124378114

2025,0.0028295173235925

2026,0.0025407984486826

2027,0.0022815918197819

2028,0.0020488784769317

2029,0.0018399488246872

2030,0.0016523707557362

2031,0.0014839611218173

2032,0.001332760176314

2033,0.0011970086646797

2034,0.0011013087509791

2035,0.0009938613666573

2036,0.0008887664003584

2037,0.0007993065774491

2038,0.0007207462519342

2039,0.000644645611195

2040,0.000579865288572

2042,0.0004678675640203

2043,0.0004209552909481

2045,0.0003398463473965

2046,0.0003058709720242

2047,0.0002760327856302

2048,0.000247126549734

2049,0.0002225180563154

2050,8.49792717849873e-05

2051,7.63740460648e-06

2189,4.58215992823465e-06

2549,2.48409374424231e-06

2550,9.57705906719835e-06

2551,1.02720112666852e-05

2612,5.34366622852836e-06

2693,2.5613074404406e-06

3020,8.49263133483763e-07

7544,3.45762053187635e-07

12068,2.52652878658997e-07

12069,2.52639618911453e-07

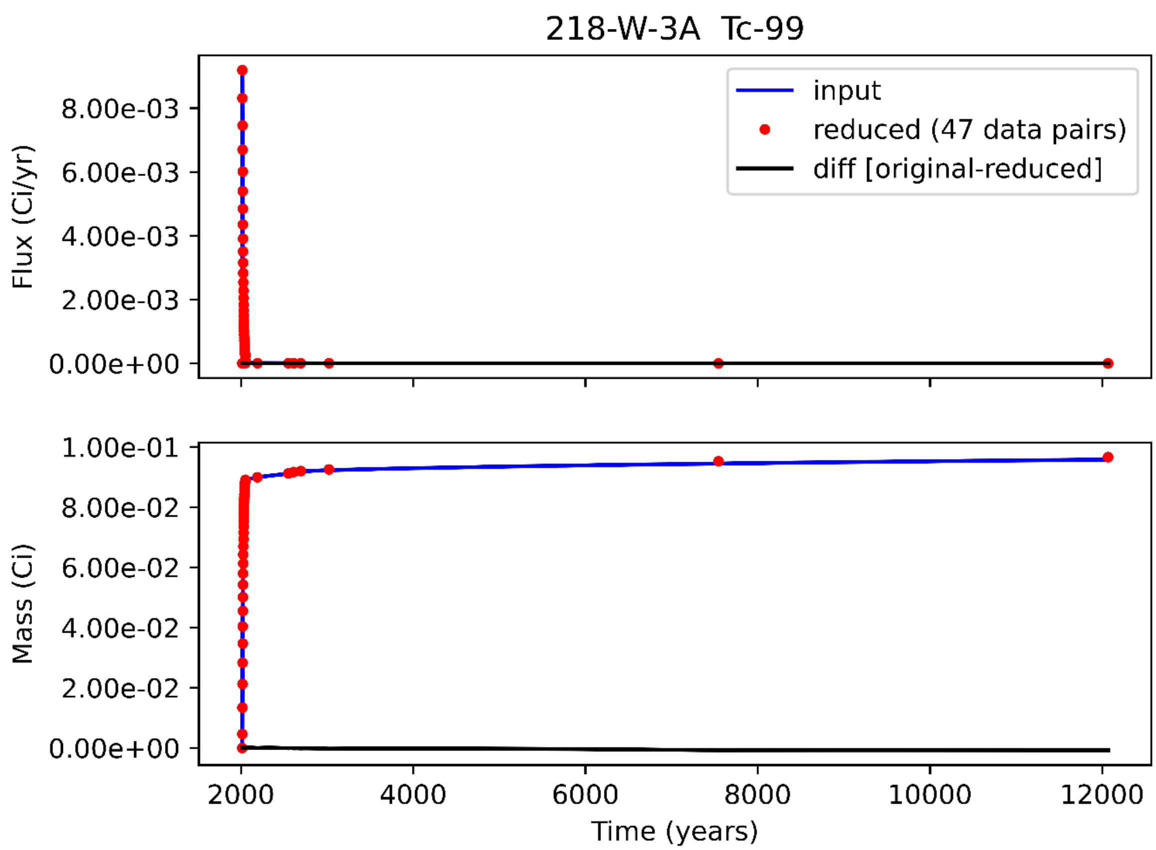

Figure F-4. Comparison of 218-W-3A Tc-99 CASWR Model-generated Release Rates (Ci/yr) given by GoldSim (blue line) to the Reduced Dataset (red dots) Produced with the CACIE Reduction Tool for Subsequent Vadose Zone Transport Calculations

F.7 218-W-3AE C-14 Output

Site Name: 218-W-3AE

Date Created: 2022/07/07

Script Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b

COPC: C-14

Reduced Year,Reduced Activity Release Rate (Ci/year)

2013,0.0

2014,1.45122687204574

2015,1.30605991094074

2016,1.1724342128025884

2017,1.0524802415562147

2018,0.9447990586770834

2019,0.8481349690236627

2020,0.7613607760407758

2021,0.68899544372703

2022,0.618503120517653

2023,0.555222998156407

2024,0.49841718180583

2025,0.447423272535198

2026,0.401646642981839

2027,0.360553503397367

2028,0.323664677167469

2029,0.290550013196983

2030,0.260823369990199

2031,0.234138112929253

2032,0.210183072240787

2033,0.188678914514564

2034,0.173521306560424

2035,0.156505538669746

2036,0.139864946157556

2037,0.125702481665186

2038,0.113267732713161

2039,0.101224451634167

2040,0.0909746637764653

2041,0.0819752738216734

2042,0.0732592004366296

2043,0.0658411302221567

2044,0.0593280092993773

2045,0.053019932723984

2046,0.0476512587971732

2047,0.0429375229824796

2048,0.0383721836456437

2049,0.0344867173531627

2050,0.0127481613216637

2051,0.0005297312460008

2279,0.0003405707763531

2549,0.000201953781413

2550,0.0012590406216406

2551,0.0013626000538587

2576,0.0009945764163909

2606,0.00068208843307

2639,0.00045042312073530986

2675,0.0002864792090810077

2771,8.57443368143359e-05

2931,1.1543108784326488e-05

12069,8.556664015544021e-09

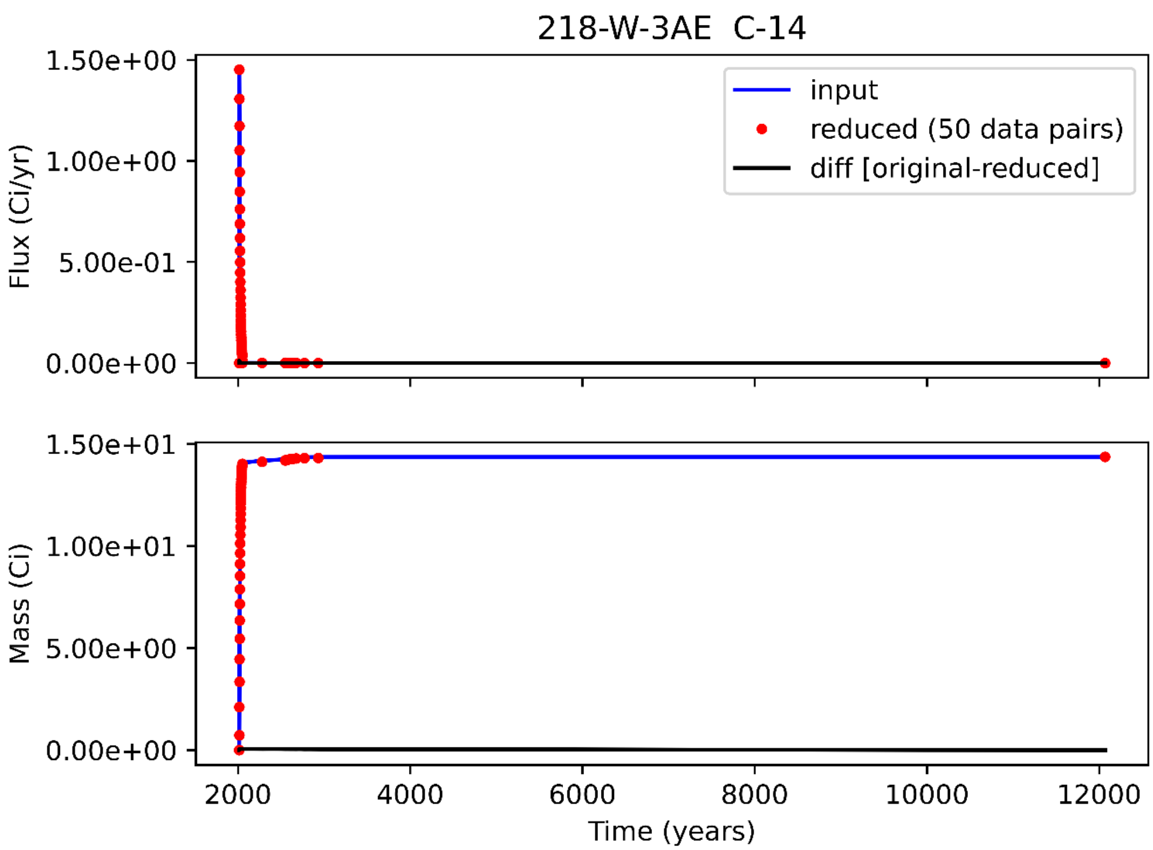

Figure F-5. Comparison of 218-W-3AE C-14 CASWR Model-generated Release Rates (Ci/yr) given by GoldSim (blue line) to the Reduced Dataset (red dots) Produced with the CACIE Reduction Tool for Subsequent Vadose Zone Transport Calculations

F.8 218-W-3AE Tc-99 Output

Site Name: 218-W-3AE

Date Created: 2022/07/07

Script Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b

COPC: Tc-99

Reduced Year,Reduced Activity Release Rate (Ci/year)

2013,0.0

2014,0.355222438899645

2015,0.3162055407775502

2016,0.28380383002929904

2017,0.25479578287988897

2018,0.2287812925812795

2019,0.2054389300192756

2020,0.18448933465310238

2021,0.16833471982728

2022,0.151184716032824

2023,0.135789057427439

2024,0.121967857168335

2025,0.109559824184878

2026,0.0984202794502432

2027,0.0884194110346046

2028,0.0794407265606646

2029,0.0713796745352241

2030,0.0641424128839404

2031,0.0576447071782459

2032,0.0518109438630812

2033,0.0465732458691113

2034,0.0428808448598135

2035,0.0387351723876644

2036,0.034680243653615

2037,0.0312285522287481

2038,0.0281973837725629

2039,0.0252610990083011

2040,0.0227615793797114

2041,0.0205665285819837

2042,0.0184401391288657

2043,0.0166299973576706

2045,0.0135002986551513

2046,0.0121892860050972

2047,0.0110378982993212

2048,0.0099224548745236

2049,0.0089728368711192

2050,0.0034106613817924

2051,0.0003170122463025

2099,0.0002438956278935

2189,0.0001892474696666

2549,0.0001046783703176

2550,0.0004035785655503

2551,0.0004331919900262

2612,0.000242806173535

2696,0.0001328764591638

2813,8.51455688639203e-05

3038,6.78057595150406e-05

7553,4.6270581695540744e-05

12068,4.183809019325078e-05

12069,4.19321229767155e-05

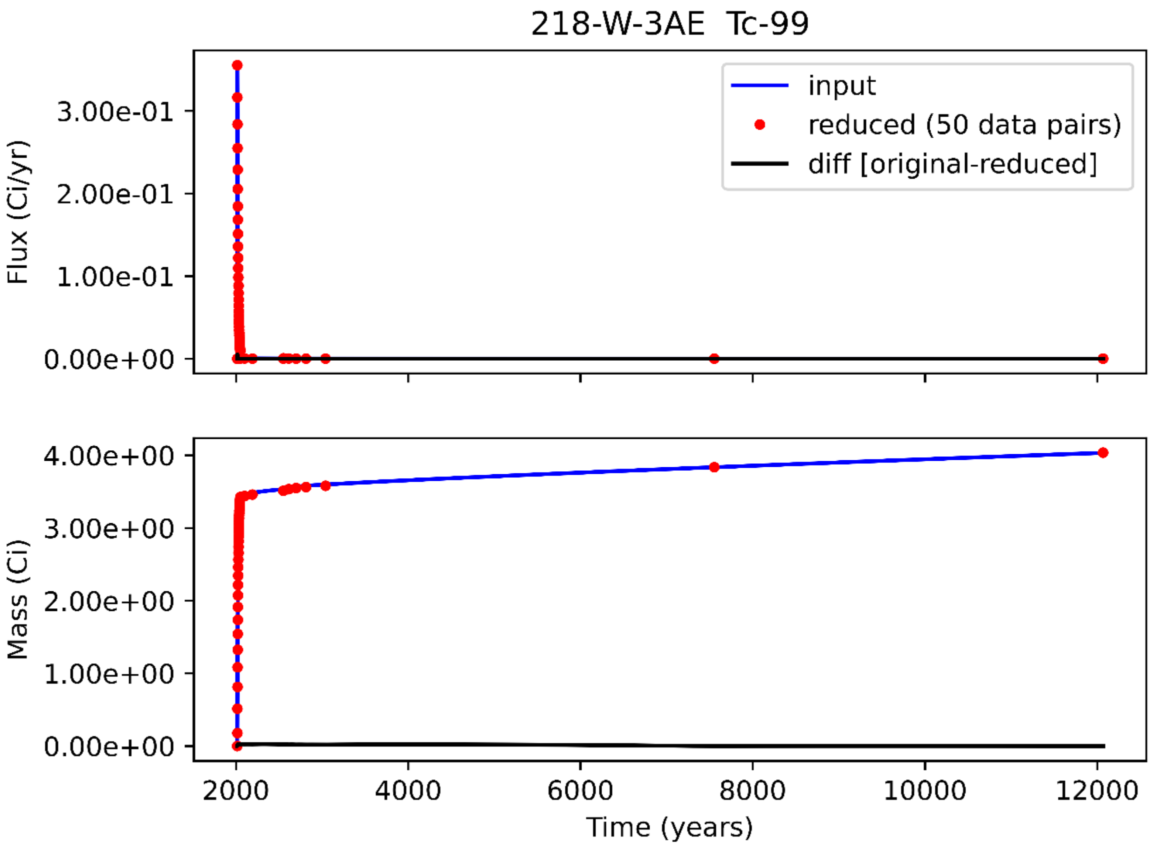

Figure F-6. Comparison of 218-W-3AE Tc-99 CASWR Model-generated Release Rates (Ci/yr) given by GoldSim (blue line) to the Reduced Dataset (red dots) Produced with the CACIE Reduction Tool for Subsequent Vadose Zone Transport Calculations

Appendix G

Software Installation and Checkout Forms

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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 Version No.: 12.1

EXECUTABLE INFORMATION

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

3. Executable Size *(bytes)*: 2,906,288 bytes

COMPILATION INFORMATION

4. Hardware System *(i.e., property number or ID)*:
Compiled by vendor

5. Operating System *(include version number)*:
Windows

INSTALLATION AND CHECKOUT INFORMATION

6. Hardware System *(i.e., property number or ID)*:
INTERA SAS PC-CCOURBET (SERVICE TAG: 9XNP0G2)

7. Operating System *(include version number)*:
Windows 10 (version 21H2)

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

TEST CASE INFORMATION

9. Directory/Path:
[redacted]General Examples

10. Procedures:
per CHPRC-00224 Rev 1, GoldSim Pro Software Test Plan

11. Libraries:
N/A

12. Input Files:
FirstModel.gsm

13. Output Files:
FirstModel.gsm

14. Test Cases:
GS-ITC-1

15. Test Case Results:
Match expected results as presented in CHPRC-00224, GoldSim Pro Software Test Plan

16. Test Performed By: Christelle Courbet

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

18. Disposition *(include HISI update)*:
Not applicable.

SOFTWARE INSTALLATION AND CHECKOUT FORM (Continued)

19. Prepared By *(Software Owner)*:

Christopher Farrow
Print First and Last Name

CHRISTOPHER FARROW (Affiliate)
Digitally signed by CHRISTOPHER FARROW (Affiliate)
DN: C=US, O=U.S. Government, OU=Department of Energy, OID.0.9.2342.19200300.100.1.1=89001003727219 + CN=CHRISTOPHER FARROW (Affiliate)
Reason: I have reviewed this document
Location: your signing location here
Date: 2022.06.17 09:50:00-05'00'
Foxit PhantomPDF Version: 10.1.7
Signature / Date

20. Test Personnel:

Title:

Christelle Courbet
Print First and Last Name

Christelle Courbet
Digitally signed by Christelle Courbet
Date: 2022.06.17 12:15:18 +02'00'
Signature / Date

Title:

Print First and Last Name

Signature / Date

Title:

Print First and Last Name

Signature / Date

21. Approved By *(Software SME)*:

N/R per SMP
Print First and Last Name

Signature / Date

Appendix H

Software Log Files

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H.1 C-14 Data Reduction Log File

INFO--07/07/2022 11:07:33 AM--Starting CA-CIE Tool Runner. Logging to “runner_CACIE_CA-Maintenance_logfile_C-14.txt”

INFO--07/07/2022 11:07:34 AM--Code Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b v5.21: D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/runner/runner.py<--1bcfd6779e9cbdb82673405873a8e5e81514ae27

INFO--07/07/2022 11:07:34 AM--Code Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b v5.21: D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/vzreducer/vzreducer.py<--79b4125e3b7bbef2b4b5d061771d2efb03d3a57e

INFO--07/07/2022 11:07:34 AM--QA Status: QUALIFIED : D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/runner/runner.py

INFO--07/07/2022 11:07:35 AM--QA Status: QUALIFIED : D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/vzreducer/vzreducer.py

INFO--07/07/2022 11:07:35 AM--Invoking Command:”python” with Arguments:”D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/vzreducer/vzreducer.py --logfile logfile_CACIE-reducer_CA-Maintenance_C-14.txt CACIE-reducer_CA-Maintenance_input_C-14.json output”

INFO--07/07/2022 11:07:35 AM--Username:ccourbet Computer:PC-CCOURBET Platform:Windows 10 10.0.19044

H.2 Tc-99 Data Reduction Log File

INFO--07/07/2022 10:59:33 AM--Starting CA-CIE Tool Runner. Logging to “runner_CACIE_CA-Maintenance_logfile_Tc-99.txt”

INFO--07/07/2022 10:59:33 AM--Code Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b v5.21: D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/runner/runner.py<--1bcfd6779e9cbdb82673405873a8e5e81514ae27

INFO--07/07/2022 10:59:33 AM--Code Version: 56869701bbe6826eb44753dcf5b9d32fd6ae7c4b v5.21: D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/vzreducer/vzreducer.py<--79b4125e3b7bbef2b4b5d061771d2efb03d3a57e

INFO--07/07/2022 10:59:33 AM--QA Status: QUALIFIED : D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/runner/runner.py

INFO--07/07/2022 10:59:34 AM--QA Status: QUALIFIED : D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/vzreducer/vzreducer.py

INFO--07/07/2022 10:59:34 AM--Invoking Command:”python” with Arguments:”D:/PC_Christelle/Training/CASWRS1/CA-CIE-Tools/pylib/vzreducer/vzreducer.py --logfile logfile_CACIE-reducer_CA-Maintenance_Tc-99.txt CACIE-reducer_CA-Maintenance_input_Tc-99.json output”

INFO--07/07/2022 10:59:34 AM--Username:ccourbet Computer:PC-CCOURBET Platform:Windows 10 10.0.19044