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ENVIRONMENTAL MODEL CALCULATION COVER PAGE

SECTION 1: COMPLETED BY RESPONSIBLE MANAGER OR DESIGNEE

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Project: Waste Management Area C Performance Assessment

Date: 12/09/2020

Calculation Title and Description: Special Analysis of Updated 2019 Tank Residual Waste Volumes and Inventories for Single-Shell Tanks in Waste Management Area C (UWMQ-WMA-C-2020-002-SA)

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Page **1** of **1**

A-6006-716 (REV 1)

RPP-CALC-64406, Rev. 0
UWMQ-WMA-C-2020-002-SA

EXECUTIVE SUMMARY

By January 1, 2019, waste had been retrieved from all 16 single-shell tanks in 241-C Tank Farm and post-retrieval sampling results were available for all tanks. Tanks retrieved to the limits of technology were sampled and analyzed and residual volumes estimated using the video/computer-aided design system. Because of lack of information, the residual inventory for ancillary equipment (241-C-301 catch tank, 244-CR vault tanks, and sump pits, diversion boxes, and waste transfer pipelines) was estimated based on the new average composition of waste for 241-C Tank Farm single-shell tanks.

To evaluate the impact of updated residual inventory and volumes on the Waste Management Area C performance assessment results, a Special Analysis has been performed as per the Unreviewed Waste Management Question Evaluation procedure developed per guidance provided in DOE-STD-5002-2017, *DOE Standard Disposal Authorization Statement and Tank Closure Documentation*.

The updated residual inventory estimates are lower than the estimates used in the Waste Management Area C performance assessment. As a result, the all-pathways dose and the intruder dose for the Special Analysis are lower than that calculated in the performance assessment (base case). The estimated technetium-99 inventory, the primary dose contributing radionuclide, has been reduced from about 14.7 Ci to 2.4 Ci. As a result, the peak groundwater pathway dose has been reduced by about an order of magnitude. The dose from inadvertent intruder scenarios is also lower compared to the Waste Management Area C performance assessment. The dose contribution from the air pathway in the performance assessment is negligible (peak of 4E-3 mrem/yr); consequently, no calculations were performed for the air pathway in this Special Analysis.

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LIST OF TERMS

AERMIC	American Meteorological Society/U.S. Environmental Protection Agency Regulatory Model Improvement Committee
AMS	American Meteorological Society
BCF	bio-concentration factor
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CHPRC	CH2M HILL Plateau Remediation Company
DCAL	Dose and Risk Calculation (software)
DOE	U.S. Department of Energy
DST	double-shell tank
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
IMBA	Integrated Modules for Bioassay Assessment
LFRG	Low-Level Waste Disposal Facility Federal Review Group
MCL	maximum contaminant level
NRC	U.S. Nuclear Regulatory Commission
PA	performance assessment
RESRAD	RESidual RADioactive (software)
ROD	record of decision
SA	Special Analysis
SST	single-shell tank
STOMP	Subsurface Transport Over Multiple Phases
UWMQE	Unreviewed Waste Management Question Evaluation
WMA	Waste Management Area

1.0 INTRODUCTION

A performance assessment (PA) towards closure of Waste Management Area (WMA) C was completed in 2016 to satisfy the requirements of U.S. Department of Energy (DOE) O 435.1, *Radioactive Waste Management*. The WMA C PA was documented in Revision 0 of RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington* following the review by the Low-Level Waste Disposal Facility Federal Review Group (LFRG) and approval by DOE-Headquarters. Subsequently, the PA was reviewed by U.S. Nuclear Regulatory Commission (NRC) as part of the Waste Incidental to Reprocessing Evaluation and was revised in 2020 in response to comments by NRC, without any changes to the underlying calculations (see Revision 1 of RPP-ENV-58782).

The WMA C PA calculations (for both Revision 0 and Revision 1) were based on residual inventory information from Revision 3 of RPP-RPT-42323, *Hanford C-Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*. At the time when PA calculations were conducted, only 13 out of 16 single-shell tanks (SSTs) in 241-C Tank Farm (C Farm) had been retrieved while retrieval was in progress for the remaining 3 tanks (241-C-102 [C-102], 241-C-105 [C-105], and 241-C-111 [C-111]). The post-retrieval samples were, however, only available for 10 SSTs (241-C-103, 241-C-104, 241-C-106 [C-106], 241-C-108, 241-C-109, 241-C-110, 241-C-201 [C-201], 241-C-202, 241-C-203, and 241-C-204) and were used to estimate the residual inventory for those tanks. The residual inventory for the remaining 6 tanks (241-C-101 [C-101], C-102, C-105, 241-C-107, C-111, and 241-C-112) was estimated based on indirect approaches, such as process knowledge, sample-based templates, etc. In addition, the inventory estimates for ancillary equipment—including 241-C-301 [C-301] catch tank, 244-CR vault tanks, sump pits, diversion boxes, and waste transfer pipelines—were based on average concentration of the retrieved tanks (as of September 2014).

By January 1, 2019, waste had been retrieved from all 16 SSTs in C Farm and post-retrieval sampling results were available for all tanks. Tanks retrieved to the limits of technology were sampled and analyzed and residual volumes estimated using the video/computer-aided design system. Residual inventory and volume estimates were updated for 2019 and are documented in Revision 4 of RPP-RPT-42323, *Post-Closure Hanford C-Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*. There remains no information regarding the residual inventory for ancillary equipment (C-301 catch tank, 244-CR vault tanks, and sump pits, diversion boxes, and waste transfer pipelines). Consequently, the ancillary equipment inventory was estimated based on average composition of waste for C Farm SSTs. While the latest residual inventory and residual volume information is documented in Revision 4 of RPP-RPT-42323, a more recent video assessment of tank C-106 obtained in November 2019 (RPP-RPT-62021, *2019 Camera/CAD Modeling System Waste Volume Estimate for Tank 241-C-106*) has resulted in a revised residual volume and consequently revised residual inventory estimate for tank C-106 (RPP-RPT-60124, *Derivation of Best-Basis Inventory for Tank 241-C-106 as of January 1, 2020*).

To evaluate the impact of updated residual inventory and volumes on the WMA C PA results, a Special Analysis (SA) has been performed as per the Unreviewed Waste Management Question

Evaluation (UWMQE) procedure developed per guidance provided in DOE-STD-5002-2017, *DOE Standard Disposal Authorization Statement and Tank Closure Documentation*.

Besides the changes to the inventory estimate, an update is also made to the waste layer thickness for the acute inadvertent intruder scenario for the waste transfer pipelines (excluding cascade lines). Instead of assuming contamination across the full pipeline diameter, the waste layer is assumed to occupy only 5% of the pipeline diameter to be consistent with the inventory estimates for these pipelines. This change was made as a response to comment resolution with NRC. Acute inadvertent intruder dose is known to scale linearly with the change in waste thickness, so that the update to dose was made in Revision 1 of the WMA C PA document without performing the calculations. For completeness, the update to waste layer thickness is included in this SA. In addition, a minor error (related to bio-concentration factor [BCF] for tritium) has been corrected that was identified recently, which does not have any impact on the calculated doses.

The updated residual inventory estimates have generally decreased for most analytes; it is therefore expected that the all-pathways dose and intruder dose will be lower than what was calculated in the WMA C PA. The air pathway is negligible in the PA (peak of 4E-3 mrem/yr), and consequently the focus of this calculation is on the groundwater pathway dose and on the inadvertent intruder dose.

2.0 BACKGROUND

Due to recent updates in estimates of the residual volume and residual inventory for the WMA C tanks following retrieval (see Revision 4 of RPP-RPT-42323 and RPP-RPT-62021), a UWMQE was conducted as per a Washington River Protection Solutions, LLC (WRPS) UWMQE procedure. The evaluation, documented in UWMQ-WMA-C-2020-002-S, Rev. 0 and UWMQ-WMA-C-2020-002-SE, Rev. 0 (see Attachment 3), assessed that an SA is required due to appreciable changes in residual inventory estimates.

During a recent review, the BCF values for tritium used in the WMA C PA were found to be too high and needed to be corrected for the milk, beef, poultry, and eggs. A UWMQE assessed that the change to the tritium BCF will have a negligible impact on dose (UWMQ-WMA-C-2020-003; see Attachment 4). However, as part of the SA, this change has been incorporated in the updated calculations.[1]

The focus of the SA is on evaluating the changes to the groundwater pathway dose and the inadvertent intruder dose. The air pathway dose and radon flux calculations have not been performed because their results are negligibly small in the WMA C PA, and will be even smaller due to the reduced residual inventory.

[1] Although the new BCF values recommended for use in the WMA C PA (RPP-ENV-58782) have been updated in the system model, they have no impact on current impact evaluation because hydrogen (i.e., tritium) in residual wastes in tanks and ancillary equipment decays to very low levels by the time it reaches groundwater and is not a dose driver in the groundwater pathway in the current WMA C PA evaluation.

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3.0 METHODOLOGY FOR ANALYSIS OF PERFORMANCE

The methodology adopted for analysis is the same as that presented in the WMA C PA. The calculations presented here were performed using the system model without any change to the calculation methodology from what is described in the WMA C PA.

The primary update is the new estimate for the residual inventory and volumes. Besides that, the correction to the tritium BCF (for milk, beef, poultry, and eggs) and the update waste layer thickness for the pipelines for the acute inadvertent scenario were made. Another correction was made to the grout K_d value for the chemical U_Total, which is not used in the dose calculations.

The focus of the calculations presented here is on the groundwater pathway and the inadvertent intruder dose, since other aspects of the PA are negligible.

3.1 SELECTION OF TECHNICAL STAFF

The following staff performed the identified functions on the basis of their expertise and experience.

3.1.1 Project Management

Marcel P. Bergeron, WRPS

M.A., Geology, Indiana University, Bloomington, Indiana
B.A., Geology, University of Vermont, Burlington, Vermont

Mr. Bergeron has more than 35 years of experience in a wide variety of subsurface investigations and studies at radioactive and hazardous waste facilities and contaminated sites. He is experienced in planning and implementation of environmental characterization and risk assessment investigations in a variety of roles including as a technical contributor, a project and task manager, and a line manager. He has performed quantitative analysis of subsurface systems using analytical and numerical models and visualization tools. He has significant technical project experience in managing technical teams, schedules, and budgets for multi-disciplinary projects and communication of project results with clients, regulators, and stakeholders.

3.1.2 Originators

Sunil Mehta, INTERA, Inc.

Ph.D., Earth Sciences (Hydrogeology specialization), University of Kentucky
M.S., Geosciences, University of Louisiana at Monroe
M.Sc., Geology, University of Poona, India
B.Sc., Chemistry, Zoology, and Geology, University of Jodhpur, India

Dr. Mehta has more than 18 years of experience related to groundwater flow and transport modeling, reactive transport modeling, total system performance assessment, uncertainty analysis, geophysical logging, and well testing. He has worked on projects involving geologic isolation of radioactive wastes, environmental restoration activities, and water resources exploration and evaluation. Dr. Mehta has over 10 years of experience in designing, developing, and applying probabilistic tools to assess the long-term performance of radioactive waste storage and disposal facilities. He has performed reactive transport modeling and groundwater flow modeling to study behavior of contaminants such as uranium and hexavalent chromium in periodically rewetted zones influenced by aquifer-river interactions.

David J. (DJ) Watson, Scientist, WRPS

M.S., Environmental Science, Washington State University
B.S., Geology, Washington State University

Mr. Watson has over 17 years of human health risk assessment and PA experience. He has over 14 years of environmental modeling experience, including: subsurface contaminant transport using STOMP[2], pflotran[3], and TOUGH2[4]; air dispersion with AERMOD[5]; internal and external radiological dosimetry using IMBA®[6], DCAL[7], OLINDA[8], and RESRAD[9]; and system modeling

[2] Subsurface Transport Over Multiple Phases (STOMP) has been developed and distributed by Battelle Memorial Institute, Richland, Washington.

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

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

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

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

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

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

using GoldSim©[10]. He has worked in the areas of underground tank waste retrieval and tank closure, radiation dosimetry of both internally-deposited radionuclides and external exposure, nuclear fuel fabrication and transport, and geologic carbon dioxide (CO_2) sequestration. His work has supported DOE, NRC, International Atomic Energy Agency, Joint Global Change Research Institute and other industrial and research organizations.

3.1.3 Checkers

David J. (DJ) Watson, Scientist, WRPS

M.S., Environmental Science, Washington State University
B.S., Geology, Washington State University

Mr. Watson verified that the groundwater pathway portion of this environmental model calculation file is clearly developed and that the calculation was performed as described and without error. He ensured that all the inputs are consistent with the original referenced material and documented the calculation review in the Checker Log. His biography and qualifications are in Section 3.1.2.

Kearn P. (Pat) Lee, ORANO Federal Services, LLC

M.CE, Civil and Environmental Engineering, University of Delaware
B.ChE., Chemical Engineering, University of Delaware

Mr. Lee has more than 12 years of PA development and analysis experience and has been supporting DOE nuclear waste programs for 17 years. He supported the development of the post-closure PA for the license application to dispose high-level waste at Yucca Mountain in Nevada. Following completion of the license application, Mr. Lee transitioned into technology development to develop and test different technologies to retrieve radioactive waste from underground tanks on the Hanford Site in Washington. Combining experience from both endeavors, Pat brings experience in model development and analysis and project management to the Technical Lead role.

Mr. Lee was responsible for checking of the inadvertent intruder analysis part of this environmental model calculation file.

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[9] The RESRAD (RESidual RADioactive) family of codes is developed at Argonne National Laboratory, Lemont, Illinois, managed by UChicago Argonne, LLC, for the U.S. Department of Energy's Office of Science.

[10] GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

3.1.4 Senior Reviewer

Matthew W. Kozak, INTERA, Inc.

Ph.D., Chemical Engineering, University of Washington
B.S., Chemical Engineering, Cleveland State University

Dr. Kozak has more than 30 years of experience in the areas of performance assessment of near-surface and geological radioactive waste repositories, regulatory development, dose assessment for residual contamination of soils and buildings, toxic materials risk assessment, and mixed waste issues. He is the author of over 100 publications on these topics. He has supported national programs in the U.S. and countries in Europe, Asia, and Africa to site, develop, construct, and analyze facilities for disposal of radioactive waste.

He has participated in a number of international research programs, including the International Atomic Energy Agency's Coordinated Research Program on Improvement of Safety Assessment Methodologies, and its successor programs: Application of Safety Assessment Methodologies, Practical Illustration and Use of the Safety Case Concept in the Management of Near-Surface Disposal, and most recently Modelling and Data for Radiological Impact Assessments.

4.0 ASSUMPTIONS AND INPUTS

The updated estimate of residual volume (in kiloliters) for various tanks and ancillary equipment is presented in Table 4-1. Table 4-2 provides the updated estimate of residual inventory for radionuclides that are decay corrected to January 1, 2020 to match the values presented in the WMA C PA. These estimates (except for tank C-106) are taken from RPP-RPT-42323, Revision 4 while that for tank C-106 are taken from RPP-RPT-60124.

Table 4-1. Updated Estimate of Residual Volume at Closure Used in the Special Analysis.

Tank/Equipment	Volume (kiloliters)
241-C-101	20.7
241-C-102	59
241-C-103	9.6
241-C-104	7.2
241-C-105	5.5
241-C-106	8.96
241-C-107	39
241-C-108	12.9
241-C-109	7.6
241-C-110	8
241-C-111	18.5
241-C-112	37.5
241-C-201	0.54
241-C-202	0.56
241-C-203	0.52
241-C-204	0.52
241-C-301	4.90
244-CR Vault	3.33
Pipelines	6.41

The BCF for the hydrogen isotope (tritium) for milk has been changed to 0.01 day/L (from 33.6 day/L in the WMA C PA) while that for beef, poultry, and egg has been changed to 0.01 day/kg (from 33.6 day/kg in the WMA C PA). The values for milk and beef are taken from ANL/EAD-4, *User's Manual for RESRAD Version 6* (Table D-4). The BCF for beef is applied to both poultry and egg due to lack of specific information in the ANL/EAD-4.

The waste layer thickness in the pipeline for the acute inadvertent intruder scenario is changed to 5% of the 3-inch pipeline diameter (instead of the 3-inch pipeline diameter used in the WMA C PA) to be consistent with the conceptualization that the waste layer will occur along the inner surface of the pipeline and not throughout the pipeline. As a result, the new waste layer thickness is calculated to be 3.81E-3 m (instead of 7.6E-2 m).

To run the GoldSim©-based system model certain external files shown in Table 4-3 are needed. These are used to download the parameter values at the time of initiating the calculation.

Table 4-2. Updated Estimate of Inventory of Radionuclides (in Curies) at Closure Used in the Special Analysis (Decay Corrected to January 1, 2020). (sheet 1 of 2)

Tank/ Equipment	Ac-227	Am-241	Am-243	C-14	Cd-113m	Cm-243	Cm-244	Co-60	Cs-137	Eu-152	Eu-154	Eu-155	H-3	I-129	Nb-93m	Ni-59	Ni-63	Np-237	Pa-231	Pb-210	Pu-238	Pu-239
241-C-101	2.01E-06	5.67E+00	5.95E-04	3.50E-03	1.87E-03	7.73E-06	1.38E-04	2.24E-04	1.97E+03	8.10E-05	3.52E-03	5.96E-04	3.11E-02	2.72E-03	3.29E-05	9.18E-04	5.53E+01	2.48E-02	3.14E-08	0.00E+00	3.03E-01	1.92E+01
241-C-102	2.20E-05	1.68E+01	1.22E-03	8.24E-03	5.01E-03	1.56E-05	2.80E-04	5.75E-04	5.72E+02	1.93E-04	8.62E-03	1.52E-03	8.30E-02	1.60E-03	9.31E-05	2.60E-03	5.63E+02	4.03E-03	9.90E-08	0.00E+00	5.38E-01	6.30E+01
241-C-103	9.44E-08	4.85E+00	3.70E-05	7.00E-03	1.49E-02	7.65E-07	1.51E-05	1.83E-02	6.07E+02	2.57E-05	1.40E+00	4.37E-01	3.98E-03	3.00E-03	5.29E-04	1.12E-01	1.86E+01	1.35E-02	1.66E-07	0.00E+00	1.30E+00	4.99E+00
241-C-104	2.49E-05	8.65E+00	5.24E-03	3.08E-03	5.10E-02	3.64E-03	6.66E-02	3.68E-01	6.21E+02	3.53E-02	1.57E+00	2.30E-01	9.31E-03	2.12E-04	4.57E-02	8.64E-02	9.89E+01	1.83E-03	7.47E-05	0.00E+00	5.89E-01	5.14E+00
241-C-105	6.82E-07	2.73E+00	1.87E-04	7.93E-04	6.35E-04	4.05E-04	7.25E-03	7.63E-05	3.32E+03	2.76E-05	1.20E-03	2.02E-04	8.38E-03	2.33E-03	1.12E-05	3.12E-04	2.10E+01	2.21E-02	1.07E-08	0.00E+00	2.63E-01	1.08E+01
241-C-106	2.24E-03	5.67E+01	2.69E-03	7.24E-03	1.88E+00	4.89E-02	6.54E-01	1.96E+00	8.83E+02	1.78E+00	1.99E+01	6.75E+00	3.67E-03	5.56E-04	8.93E+00	9.23E+00	5.75E+01	4.77E-02	2.23E-03	0.00E+00	2.10E+00	1.48E+01
241-C-107	1.93E-05	1.32E+01	1.35E-03	3.15E-02	3.64E-03	1.76E-05	3.14E-04	1.33E-03	2.16E+02	1.98E-04	8.28E-03	1.26E-03	1.40E-02	2.98E-03	1.75E-01	1.72E-03	3.00E+02	2.40E-02	5.58E-05	0.00E+00	9.94E-02	1.60E+01
241-C-108	6.33E-06	9.47E-01	9.78E-05	3.98E-03	1.97E-03	1.50E-06	2.96E-05	7.25E-04	8.54E+01	1.07E-04	4.51E-03	6.84E-04	1.95E-02	3.81E-05	7.56E-02	9.30E-04	2.80E+00	2.17E-05	3.02E-05	0.00E+00	4.38E-03	6.68E-01
241-C-109	7.27E-06	3.79E-01	3.91E-05	7.65E-04	1.37E-03	5.09E-07	9.09E-06	5.02E-04	4.31E+01	7.43E-05	3.14E-03	4.76E-04	3.51E-03	2.66E-05	6.57E-02	6.47E-04	8.76E-01	6.48E-04	2.10E-05	0.00E+00	1.56E-02	4.01E-01
241-C-110	2.06E-06	5.58E-02	5.55E-06	1.51E-03	3.89E-04	7.22E-08	1.29E-06	1.42E-04	2.02E+01	2.11E-05	8.90E-04	1.35E-04	1.80E-03	2.82E-04	1.87E-02	1.83E-04	4.07E-01	1.09E-03	5.96E-06	0.00E+00	1.56E-02	1.17E+00
241-C-111	4.27E-06	7.73E+00	7.90E-04	3.90E-03	8.09E-04	6.11E-03	1.09E-01	2.95E-04	1.45E+02	4.37E-05	1.84E-03	2.79E-04	4.66E-03	1.56E-05	3.87E-02	3.80E-04	3.44E+00	1.31E-03	1.23E-05	0.00E+00	8.42E-02	7.62E-01
241-C-112	1.56E-05	1.99E+01	1.55E-04	1.75E-02	2.94E-03	2.02E-06	3.61E-05	1.08E-03	5.70E+02	1.60E-04	6.72E-03	1.02E-03	5.58E-02	5.70E-05	1.42E-01	1.39E-03	3.51E+01	2.16E-02	4.51E-05	0.00E+00	3.66E-01	6.27E+00
241-C-201	4.70E-09	2.61E+00	9.77E-04	7.64E-04	5.75E-04	3.10E-03	5.55E-02	2.38E-03	7.01E+00	2.10E-03	9.46E-02	1.45E-02	1.57E-04	4.57E-07	1.08E-03	4.07E-03	8.32E-01	3.42E-03	6.79E-09	0.00E+00	4.42E-01	1.58E+01
241-C-202	4.79E-09	1.34E+00	4.72E-04	2.03E-04	5.87E-04	1.50E-03	2.68E-02	2.43E-03	6.17E+00	2.14E-03	9.60E-02	1.48E-02	1.61E-04	7.35E-06	1.10E-03	4.16E-03	2.00E-01	2.90E-03	6.93E-09	0.00E+00	4.00E-01	1.43E+01
241-C-203	3.92E-09	3.61E-02	1.22E-05	1.66E-04	4.80E-04	3.87E-05	6.94E-04	2.15E-03	9.10E+00	1.75E-03	1.50E-02	1.80E-02	1.31E-04	1.47E-05	8.98E-04	3.40E-03	5.54E-02	2.70E-05	5.67E-09	0.00E+00	1.36E-02	4.86E-01
241-C-204	3.66E-09	3.25E-03	1.22E-06	1.87E-04	4.50E-04	3.87E-06	6.93E-05	1.86E-03	4.12E+00	1.64E-03	5.63E-02	1.13E-02	1.13E-04	3.57E-07	8.40E-04	3.18E-03	1.46E-02	2.16E-02	5.30E-09	0.00E+00	2.76E-04	9.83E-03
241-C-301	6.64E-05	5.39E+00	1.19E-03	2.12E-03	6.63E-02	4.50E-03	7.32E-02	8.64E-02	3.20E+02	6.48E-02	9.18E-01	2.81E-01	3.64E-03	3.51E-04	2.55E-01	3.22E-01	1.51E+01	2.04E-02	7.99E-05	0.00E+00	6.42E-01	1.94E+01
244-CR Vault	4.51E-05	3.66E+00	8.07E-04	1.44E-03	4.51E-02	3.06E-03	4.98E-02	5.87E-02	2.18E+02	4.40E-02	6.24E-01	1.91E-01	2.47E-03	2.39E-04	1.74E-01	2.19E-01	1.02E+01	1.39E-02	5.43E-05	0.00E+00	4.36E-01	1.32E+01
Pipelines	8.69E-05	7.05E+00	1.55E-03	2.78E-03	8.68E-02	5.89E-03	9.58E-02	1.13E-01	4.19E+02	8.48E-02	1.20E+00	3.68E-01	4.76E-03	4.60E-04	3.34E-01	4.22E-01	1.97E+01	2.67E-02	1.04E-04	0.00E+00	8.40E-01	2.54E+01

Table 4-3. Updated Estimate of Inventory of Radionuclides (in Curies) at Closure Used in the Special Analysis (Decay Corrected to January 1, 2020). (sheet 2 of 2)

Tank/ Equipment	Pu-240	Pu-241	Pu-242	Ra-226	Ra-228	Rn-222	Se-79	Sm-151	Sn-126	Sr-90	Tc-99	Th-229	Th-230	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Zr-93
241-C-101	2.06E+00	8.53E+00	2.83E-05	7.50E-07	8.32E-13	0.00E+00	4.51E-03	5.08E+00	7.78E-02	9.15E+03	7.88E-01	1.68E-10	0.00E+00	1.43E-12	1.76E-05	1.73E-06	1.70E+00	7.78E-02	1.95E-02	1.73E+00	4.25E-05
241-C-102	5.92E+00	2.15E+01	2.00E-06	1.10E-05	1.57E-03	0.00E+00	2.34E-03	1.44E+01	1.82E-03	4.97E+02	4.26E-01	4.87E-10	0.00E+00	2.70E-03	3.59E-05	3.14E-01	1.95E-01	8.40E-03	5.48E-03	2.01E-01	1.21E-04
241-C-103	1.04E+00	1.80E+00	3.24E-05	1.54E-08	1.16E-04	0.00E+00	2.64E-05	4.31E-01	5.27E-05	6.77E+03	4.48E-02	2.60E-11	0.00E+00	1.99E-04	4.28E-06	5.85E-03	1.36E-02	7.10E-04	3.74E-04	1.64E-02	7.03E-04
241-C-104	1.54E+00	1.14E+01	1.97E-02	3.24E-07	2.15E-03	0.00E+00	2.36E-03	3.18E+03	8.79E-03	4.88E+03	3.03E-01	8.57E-08	0.00E+00	3.69E-03	3.53E-02	2.18E+00	4.16E-01	1.98E-02	4.84E-03	4.39E-01	6.24E-02
241-C-105	1.16E+00	5.55E+00	1.60E-05	2.55E-07	3.81E-05	0.00E+00	1.21E-04	1.73E+00	1.29E-01	3.84E+03	4.85E-02	5.72E-11	0.00E+00	6.55E-05	1.21E-06	3.59E-02	1.14E-01	5.01E-03	2.47E-03	1.20E-01	1.45E-05
241-C-106	3.15E+00	1.62E+01	3.67E-04	4.52E-04	4.94E-04	0.00E+00	8.44E-03	6.90E+03	1.56E+00	3.97E+04	1.45E-01	1.68E-05	0.00E+00	4.94E-04	4.30E-04	1.61E-03	8.29E-04	3.40E-05	1.52E-05	7.96E-04	9.20E+00
241-C-107	1.74E+00	1.35E+00	2.42E-05	8.68E-07	4.58E-05	0.00E+00	3.94E-04	1.52E+04	7.21E-04	8.37E+03	8.83E-02	2.76E-09	0.00E+00	7.87E-05	1.50E-06	1.47E-07	1.42E-01	6.33E-03	1.58E-03	1.44E-01	2.25E-01
241-C-108	7.27E-02	7.92E-02	1.01E-06	4.72E-07	9.13E-06	0.00E+00	1.62E-03	6.66E+00	3.91E-04	1.25E+03	4.87E-02	1.49E-09	0.00E+00	1.57E-05	4.50E-07	4.10E-08	3.25E-02	1.82E-03	2.85E-04	4.03E-02	1.22E-01
241-C-109	4.36E-02	5.10E-01	6.07E-07	3.27E-07	5.08E-12	0.00E+00	1.49E-04	4.66E+00	2.72E-04	2.32E+03	8.77E-03	1.04E-09	0.00E+00	8.73E-12	9.95E-08	9.69E-09	9.35E-03	4.01E-04	9.61E-05	9.53E-03	8.47E-02
241-C-110	1.27E-01	3.58E-01	1.77E-06	9.27E-08	1.44E-12	0.00E+00	4.21E-05	1.32E+00	2.38E-02	2.62E+03	4.46E-02	2.95E-10	0.00E+00	2.48E-12	2.70E-08	2.63E-09	2.64E-03	1.14E-04	2.93E-05	2.59E-03	2.41E-02
241-C-111	8.29E-02	6.46E-02	1.15E-06	1.93E-07	1.66E-06	0.00E+00	8.73E-05	2.73E+00	1.60E-04	4.06E+04	4.97E-02	6.11E-10	0.00E+00	2.85E-06	6.96E-08	6.79E-09	6.55E-03	2.84E-04	2.30E-04	6.68E-03	4.99E-02
241-C-112	6.82E-01	1.03E+01	1.02E-02	7.02E-07	1.09E-11	0.00E+00	3.19E-04	9.95E+00	5.83E-04	6.43E+04	2.83E-01	2.23E-09	0.00E+00	1.88E-11	7.18E-07	3.96E-02	6.77E-02	2.20E-02	5.88E-03	4.89E-01	1.82E-01
241-C-201	3.40E+00	8.37E+00	1.60E-04	1.01E-09	2.34E-06	0.00E+00	5.49E-05	2.39E+01	1.10E-04	1.71E+02	2.63E-03	1.18E-11	0.00E+00	4.03E-06	2.25E-06	1.14E-05	3.65E-02	1.48E-03	5.23E-04	3.69E-02	1.46E-03
241-C-202	3.08E+00	7.55E+00	1.45E-04	1.03E-09	2.39E-06	0.00E+00	5.61E-05	2.43E+01	1.13E-04	3.31E+02	2.50E-03	1.20E-11	0.00E+00	4.11E-06	2.00E-06	1.02E-05	3.52E-02	1.42E-03	3.52E-04	3.28E-02	1.49E-03
241-C-203	1.05E-01	2.58E-01	4.94E-06	8.40E-10	1.11E-06	0.00E+00	4.58E-05	1.99E+01	9.21E-05	1.56E+02	2.32E-03	9.81E-12	0.00E+00	1.90E-06	6.61E-06	3.37E-05	1.13E-01	4.79E-03	8.33E-04	1.09E-01	1.22E-03
241-C-204	2.12E-03	5.21E-03	9.98E-08	7.86E-10	8.26E-06	0.00E+00	4.29E-05	1.86E+01	8.61E-05	1.03E+02	3.18E-03	9.18E-12	0.00E+00	1.42E-05	4.92E-06	2.51E-05	8.27E-02	3.42E-03	5.13E-04	8.13E-02	1.14E-03
241-C-301	4.03E+00	1.08E+01	1.11E-03	1.51E-05	1.24E-04	0.00E+00	6.33E-04	5.33E+02	6.13E-02	4.01E+03	4.88E-02	5.61E-07	0.00E+00	2.12E-04	1.52E-03	9.70E-02	2.09E-01	9.09E-03	2.03E-03	2.10E-01	3.21E-01
244-CR Vault	2.74E+00	7.34E+00	7.54E-04	1.03E-05	8.39E-05	0.00E+00	4.31E-04	3.62E+02	4.16E-02	2.72E+03	3.32E-02	3.81E-07	0.00E+00	1.44E-04	1.04E-03	6.59E-02	1.42E-01	6.18E-03	1.38E-03	1.43E-01	2.18E-01
Pipelines	5.28E+00	1.41E+01	1.45E-03	1.98E-05	1.62E-04	0.00E+00	8.29E-04	6.97E+02	8.02E-02	5.24E+03	6.39E-02	7.34E-07	0.00E+00	2.78E-04	2.00E-03	1.27E-01	2.73E-01	1.19E-02	2.66E-03	2.75E-01	4.20E-01

Table 4-4. External Files Used to Run the GoldSim©-based System Model.

Spreadsheet Name	Purpose
All_Pathway_Parameter.xlsx	This file is read in GoldSim© to get the input parameters for all-pathways dose calculation. This file was updated for bio-concentration factor for tritium.
DCF_Air_Intruder_Parameter.xlsx	This file is read in GoldSim© model to get the dose conversion factors for atmospheric pathway, groundwater pathway and intruder dose calculation. This also contains input parameters needed for atmospheric pathway calculation and inadvertent intruder dose calculation.
Tapwater_Scenario_Parameters.xlsx	This file is read in GoldSim© to get the input parameters for risk calculation for the tap-water scenario. This is not applicable to the dose calculations.
Hyd_Prop_5thPercentile_Base_Recharge.xlsx	Flow field for 5th percentile vadose zone hydraulic properties.
Hyd_Prop_25thPercentile_Base_Recharge.xlsx	Flow field for 25th percentile vadose zone hydraulic properties.
Hyd_Prop_50thPercentile_Base_Recharge.xlsx	Flow field for 50th percentile vadose zone hydraulic properties.
Hyd_Prop_75thPercentile_Base_Recharge.xlsx	Flow field for 75th percentile vadose zone hydraulic properties.
Hyd_Prop_95thPercentile_Base_Recharge.xlsx	Flow field for 95th percentile vadose zone hydraulic properties.

GoldSim© simulation software is copyrighted by GoldSim Technology Group LLC of Issaquah, Washington (see http://www.goldsim.com).

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5.0 SOFTWARE APPLICATIONS

Calculations have been performed using GoldSim© Pro simulator software, version 11.1. GoldSim© Pro simulator is approved for use by CH2M HILL Plateau Remediation Company (CHPRC) at the Hanford Site in accordance with the requirements of PRC-PRO-IRM-309, "Controlled Software Management." The installed GoldSim© Pro simulator software was tested in accordance with the procedure per CHPRC-00175, *GoldSim Pro Software Management Plan*, Revision 1. Washington River Protection Solutions, LLC recognizes CHPRC's role as Hanford Site environmental modeling integrator (TFC-PLN-155, "General Project Plan for Environmental Modeling") and accepts CHPRC's qualification of GoldSim© software.

GoldSim© is a versatile simulation software system for modeling complex systems. GoldSim© provides the ability to rapidly develop and deploy environmental fate and transport models of intermediate complexity, such as those abstracted from multidimensional process models, that include treatment of uncertainty (e.g., by means of a Monte Carlo stochastic method). GoldSim© models are built in an intuitive visual manner and the GoldSim© architecture facilitates diagnostic understanding of the calculational model.

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

- GoldSim© Pro
- Version 11.1
- Hanford Information System Inventory Identification Number: 2461
- Workstation type and property number: Lenovo® Thinkpad®[11] with Windows 10®[12] Pro; INTERA – 00786.

5.1 SOFTWARE INSTALLATION AND CHECKOUT

The software installation and checkout forms for STOMP and GoldSim© are provided in Attachment 1 to this environmental model calculation file.

5.2 STATEMENT OF VALID SOFTWARE APPLICATION

The WMA C PA requires calculations of the potential long-term impact on groundwater of post-retrieval SST waste residuals and waste left in ancillary equipment, including pipelines. GoldSim© provides the ability to rapidly develop and deploy models abstracted from the

[11] Lenovo® and ThinkPad® are registered trademarks of Lenovo in the United States, other countries, or both.
[12] Windows 10® is a registered trademark of Microsoft Corporation in the U.S. and other countries.

three-dimensional process model results, and include evaluation of parameter uncertainty and perform sensitivity analyses.

The WMA C PA implementation of GoldSim© for the system model to perform calculations conforms to the capabilities of the software. The following confirms that GoldSim© is a valid software application and was applied in this environmental model calculation file within its range of intended uses for which it was tested and approved.

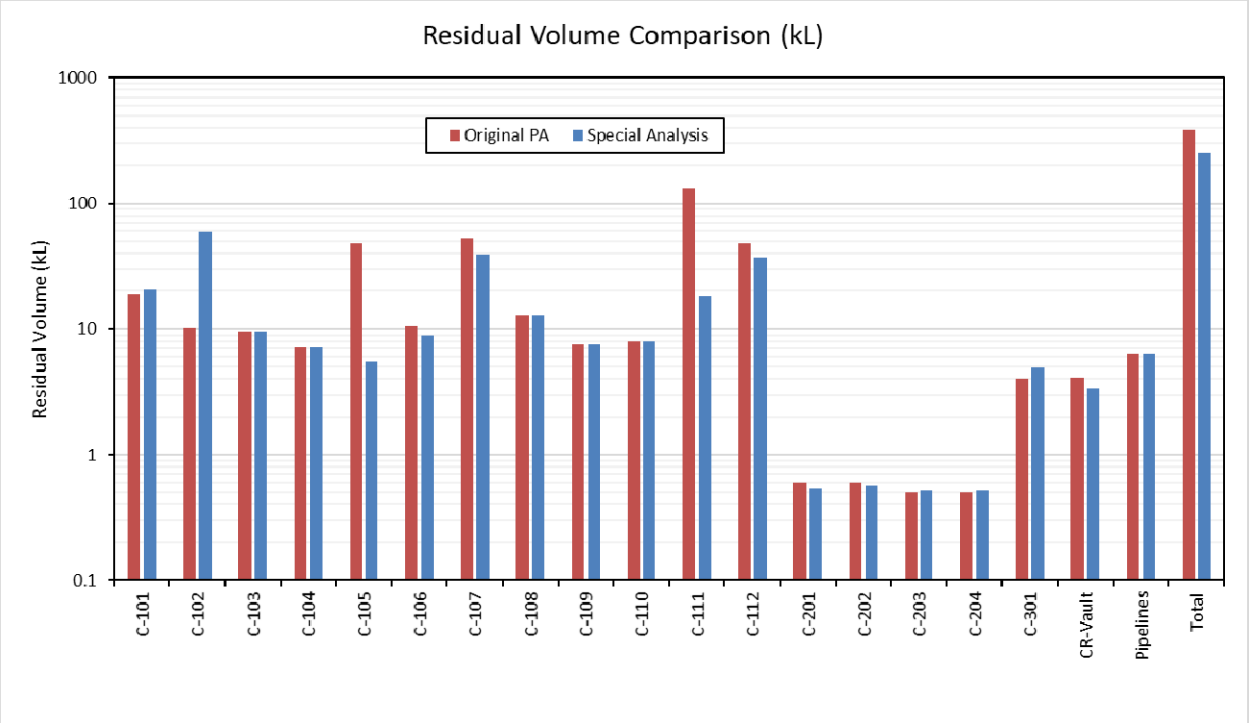
- GoldSim© Pro was utilized for DOE to assist in performing simulation of radioactive mass conservation including decay and ingrowth, contamination mass transport in subsurface environment and to perform human health dose and risk assessment for the Hanford Site.

- GoldSim© Pro as it is used here has been implemented within the range of its limitations.

6.0 CALCULATIONS

Comparison of residual volumes between the WMA C PA and the SA for various tanks and ancillary equipment is presented in Figure 6-1. Except for tanks C-102, C-105, and C-111, the residual volume estimates have not changed appreciably. Because the retrieval was in progress for tanks C-102, C-105, and C-111, the residual volume was estimated at the time of conducting the WMA C PA. The post-retrieval residual volume is higher for tank C-102 and lower for tanks C-105 and C-111 compared to that estimated for WMA C PA.

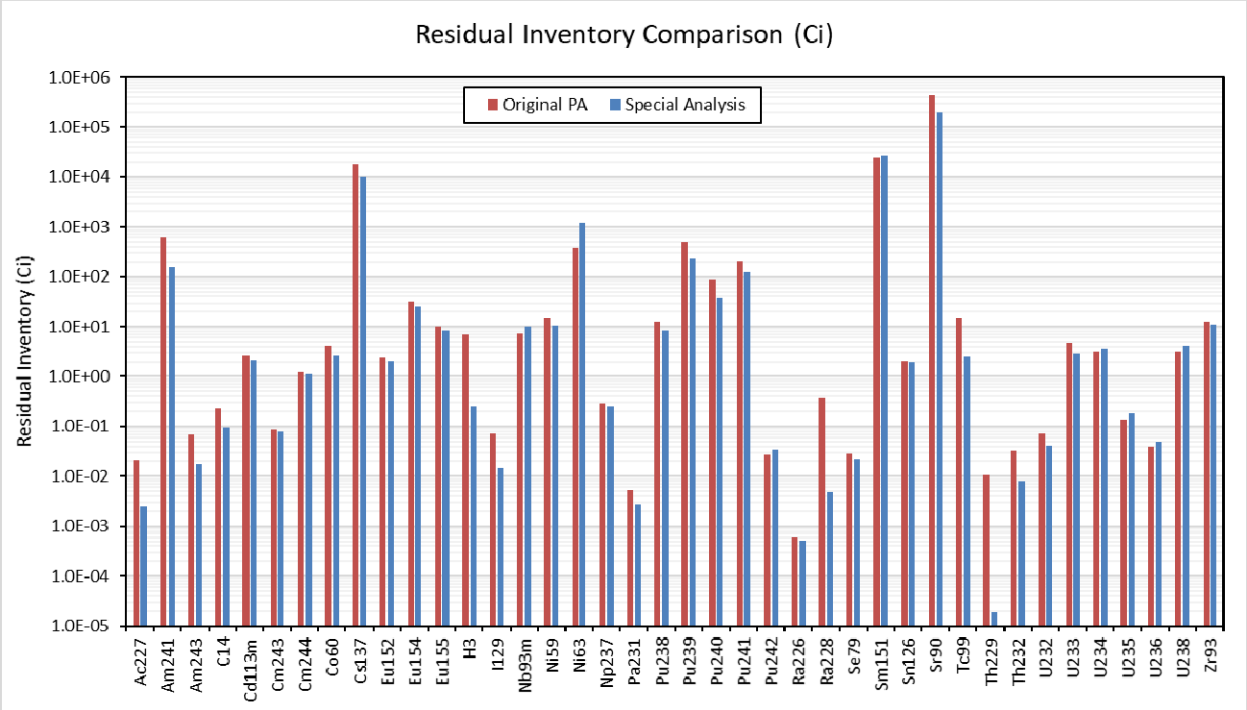
Figure 6-1. Comparison of Residual Volume (kiloliters) between Waste Management Area C Performance Assessment (Base Case) and the Special Analysis.



PA = performance assessment

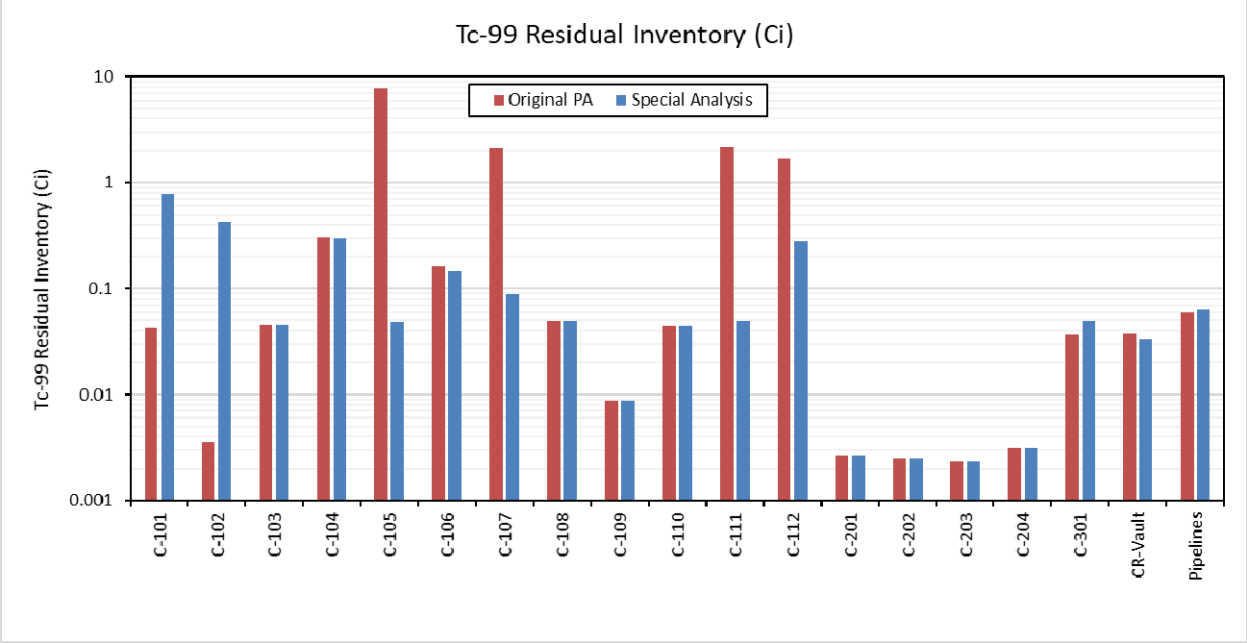
Comparison of residual inventory estimate between the WMA C PA (base case) and the SA is presented in Figure 6-2 for the entire tank farm. The residual inventory estimate for most radionuclides has decreased for the SA compared to the estimate developed at the time of conducting the WMA C PA. For example, the total inventory estimate for technetium-99 (^{99}Tc) in the WMA C PA at closure was about 14.7 Ci while for the SA it is about 2.4 Ci. This reduction is primarily due to retrieval of tank C-105 that resulted in reduction of ^{99}Tc inventory estimate from about 7.8 Ci to 0.05 Ci. On the other hand, the residual ^{99}Tc inventory estimates for tanks C-101 and C-102 are higher for the SA compared to the WMA C PA.

Figure 6-2. Comparison of Residual Inventory for Radionuclides (Curies) between Waste Management Area C Performance Assessment (Base Case) and the Special Analysis.



PA = performance assessment

Figure 6-3. Comparison of Residual Inventory for Technetium-99 between Waste Management Area C Performance Assessment (Base Case) and the Special Analysis.



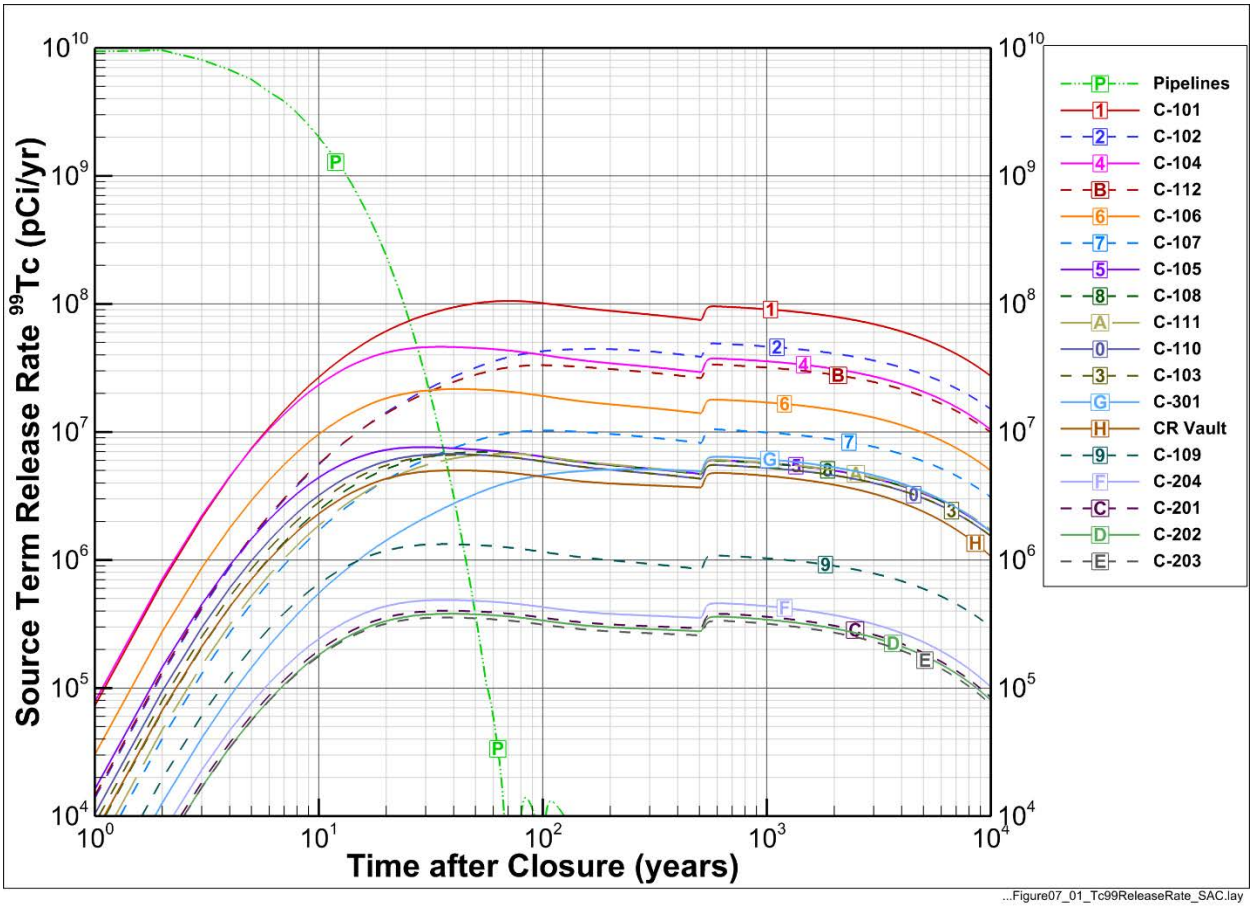
PA = performance assessment

7.0 RESULTS AND INTERPRETATION OF SPECIAL ANALYSIS

7.1 GROUNDWATER PATHWAY

The impact on the groundwater pathway for the SA is first evaluated by reviewing the source term release for ^{99}Tc, which is the primary dose driver in the WMA C PA. Source term release for ^{99}Tc for the SA using the updated residual inventory and residual volume is shown in Figure 7-1, while that from the base case of WMA C PA is shown in Figure 7-2. While the advection dominated pipeline release did not change appreciably between the two cases the tank releases (diffusive) changed significantly, with the peak tank release getting reduced by an order of magnitude for the SA. Due to the reduction in ^{99}Tc inventory, the release rate from tank C-105 (highest among all tanks in the WMA C PA [base case]) decreased by over an order of magnitude in the SA. Tank C-101 has the highest ^{99}Tc source term release rate among tanks for the SA, which is in proportion to the residual inventory.

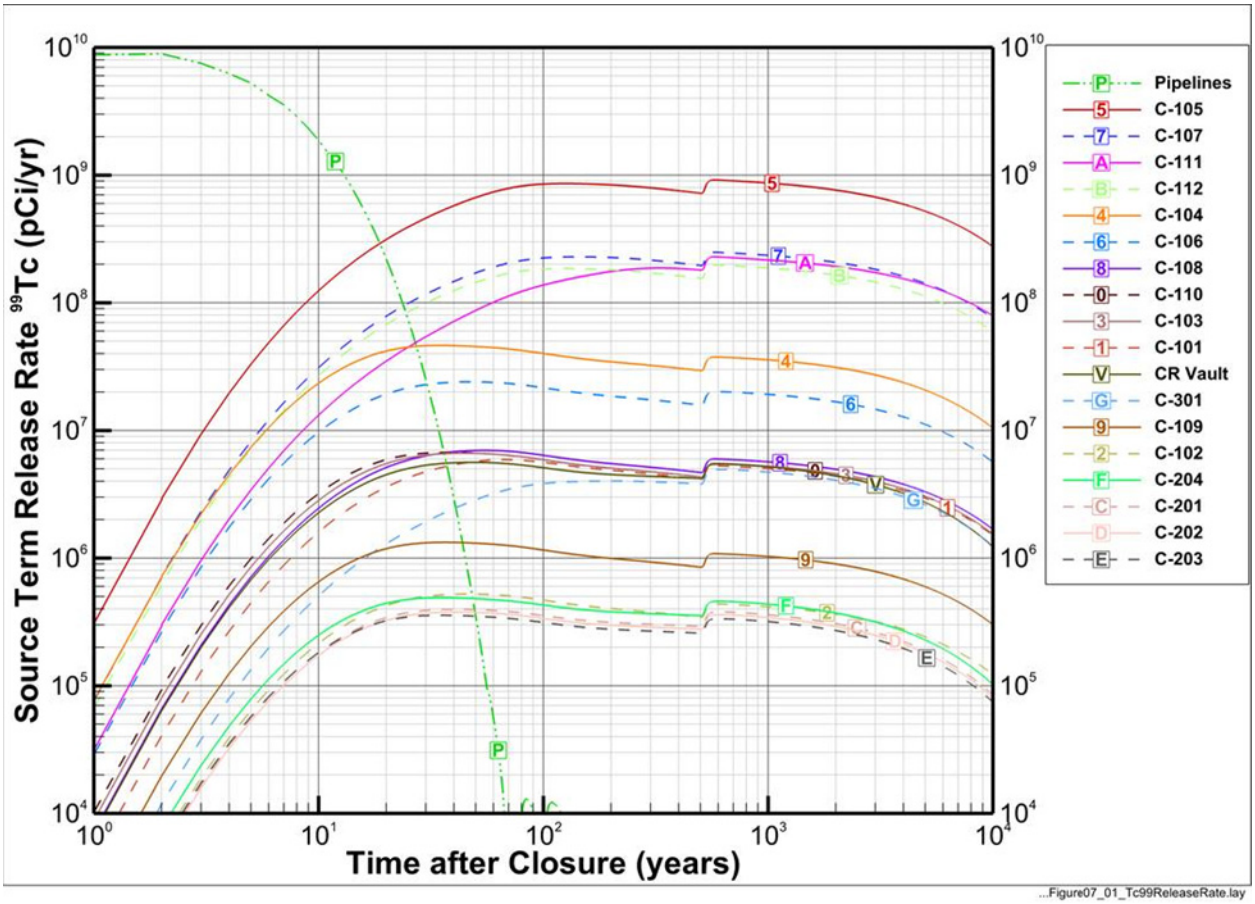
Figure 7-1. Release Rate of Techetium-99 (pCi/yr) from Each Source for the Special Analysis with Updated Inventory.



Groundwater concentrations are presented in Figure 7-3 for selected analytes for the SA. The results presented are based on calculations performed using the system model. Comparable

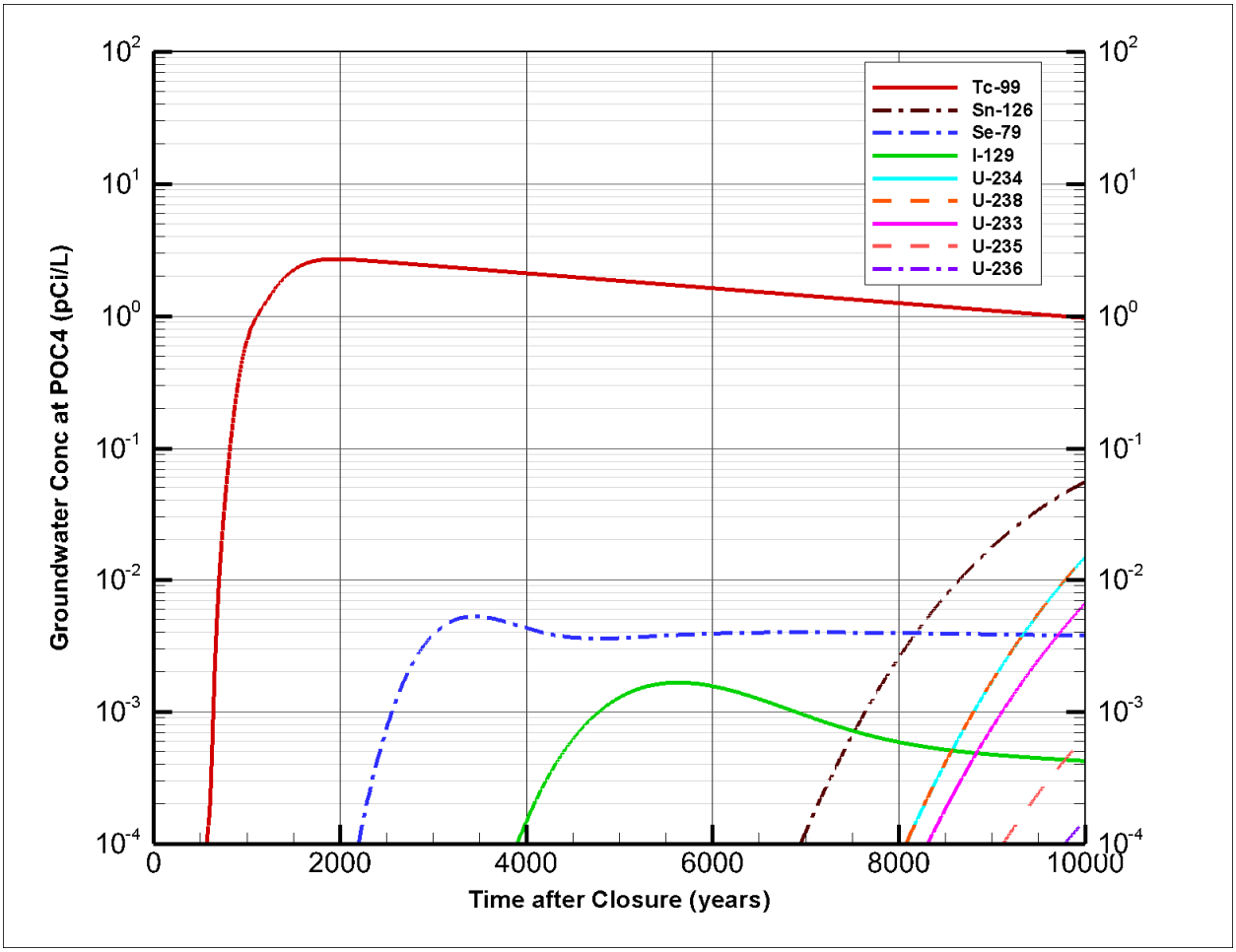
results for the WMA C PA are presented in Figure 7-4 using the system model. The groundwater concentrations are presented for the approximate spatial location that is 100 m downgradient from the WMA C fenceline and results in highest peak groundwater concentration, designated as Point of Calculation 4 in the WMA C PA (see Figure 7-24 in RPP-ENV-58782). The peak concentration for ^{99}Tc for the SA is about 3 pCi/L, which is about an order of magnitude lower than that calculated in the WMA C PA.

Figure 7-2. Release Rate of Technetium-99 (pCi/yr) from Each Source in the Waste Management Area C Performance Assessment Base Case.



The groundwater pathway dose results are presented in Figure 7-5 for the SA. The results presented are based on calculations performed using the system model groundwater concentrations. Comparable results for the WMA C PA are presented in Figure 7-6 using the system model. The peak total dose for the SA is about 0.01 mrem/yr (in the post-compliance time period), which is an order of magnitude lower when compared with the WMA C PA. Technetium-99 remains the primary dose contributor for both the SA and the WMA C PA throughout the simulated duration, with relatively smaller contributions from iodine-^{129}I and ^{79}Se up to about 8,000 years followed by uranium isotopes after 8,000 years.

Figure 7-3. Groundwater Concentration (pCi/L) for the Special Analysis Using the System Model at Point of Calculation 4.



POC = Point of Calculation

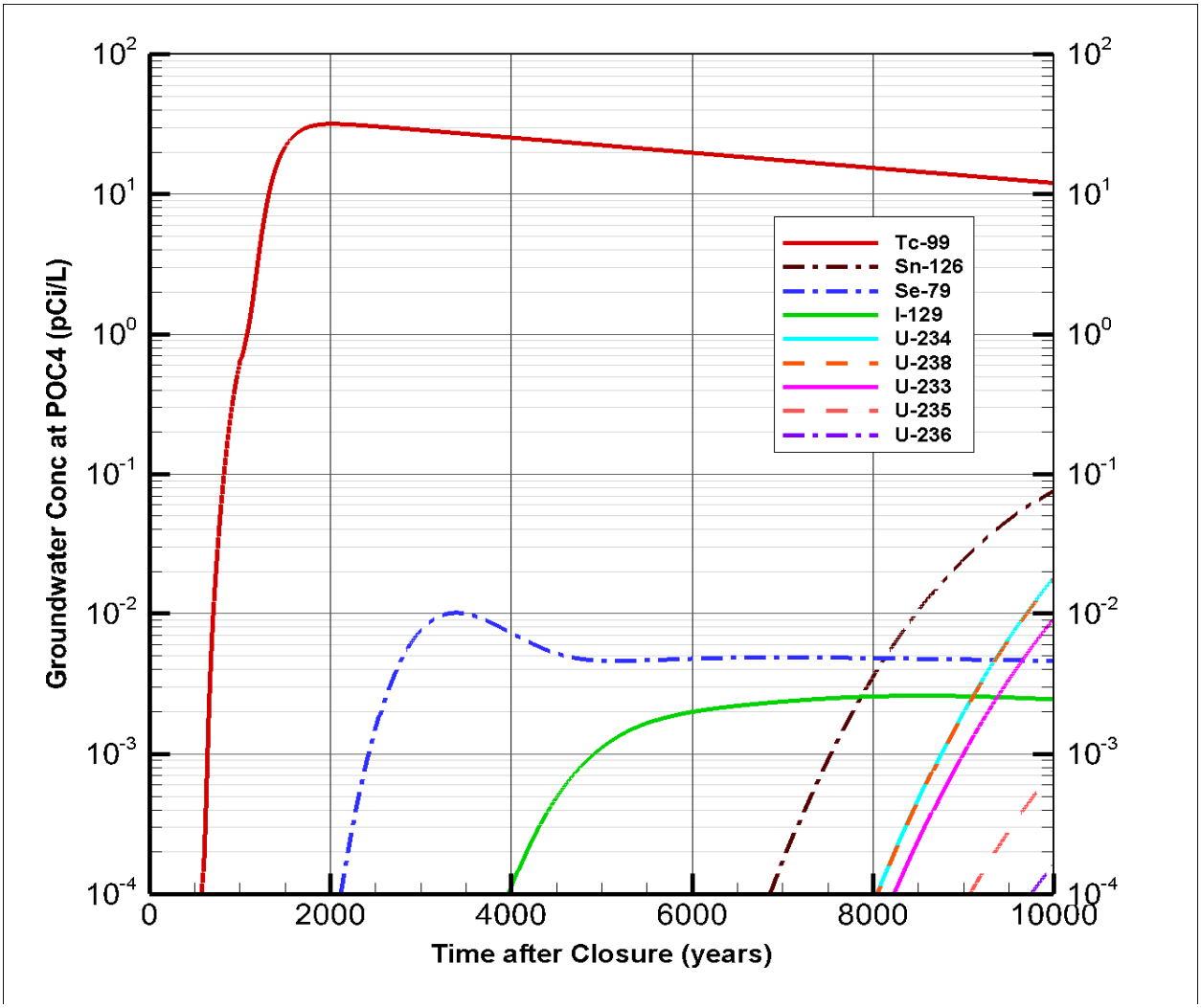
7.1.1 Air Pathway

The air pathway dose is negligible (of about 4E-3 mrem/yr) in the WMA C PA base case, and therefore air pathway calculations have not been conducted in the SA. The expectation is that the already-negligible air pathway dose will reduce further due to reduction in inventory. Similarly, due to negligible radon flux (of about 2E-4 pCi/m^2/s) in the WMA C PA base case the radon flux calculations have not been conducted in the SA.

7.2 INADVERTENT INTRUDER RESULTS

This section summarizes the calculated effective dose for each of the four inadvertent intruder scenarios.

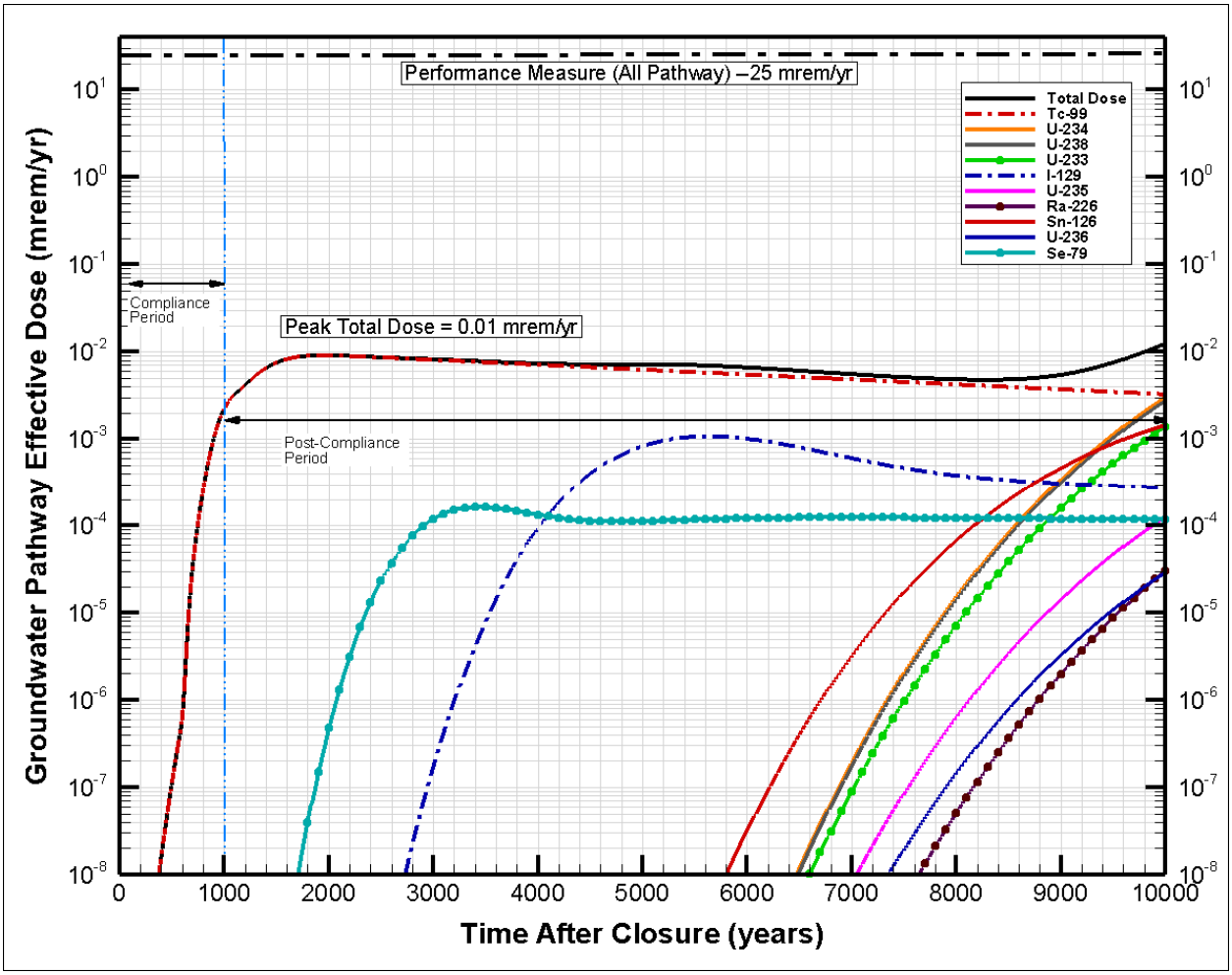
Figure 7-4. Groundwater Concentration (pCi/L) for the Waste Management Area C Performance Assessment Using the System Model at Point of Calculation 4.



POC = Point of Calculation

Tanks represent a significant intrusion barrier, both from the tank structures themselves and from the large thickness of grout that will fill tanks at closure. Projections of the longevity of these structures indicate that they will remain significant barriers over the entire analysis period. However, for consistency with NRC regulatory guidance in NUREG-1854, *NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations – Draft Final Report for Interim Use*, the consequences of intrusion into tanks are calculated beginning 500 years after facility closure. By contrast, pipelines do not represent a significant barrier to intrusion, and as a result consequences are calculated at alternative assumed times, based on the differing views of the appropriate regulatory time for the assumed end of institutional control.

Figure 7-5. Groundwater Pathway Dose for the Special Analysis Using the System Model.



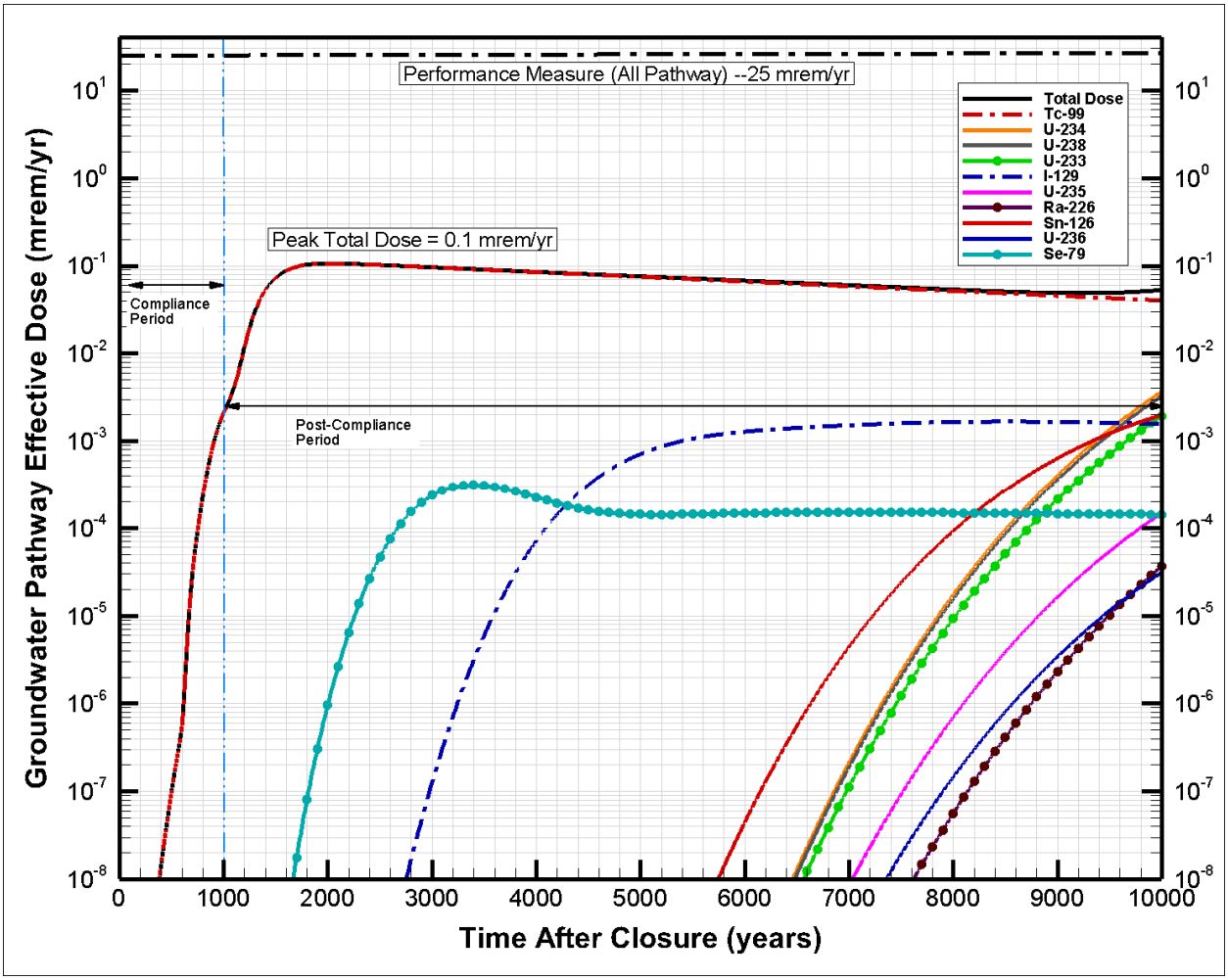
Figures 7-7 through 7-15 show the effective dose at several different times of assumed intrusion, displayed as vertical lines on the graphs. These lines are as follows.

- Line 1: An existing *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) record of decision (ROD) for the 100 Area.
- Line 2: Another existing CERCLA ROD in the 100 Area.
- Line 3: An existing CERCLA ROD in the 200 Area.
- Line 4: The assumed time in Revision 0 of this PA, 100 years after an assumed closure in 2020.

- Line 5: An assumed intrusion time of 100 years after an assumed closure date of the double-shell tank system in 2070.

- Line 6: 500 years after an assumed closure date of 2020.

Figure 7-6. Groundwater Pathway Dose for the Waste Management Area C Performance Assessment Using the System Model.

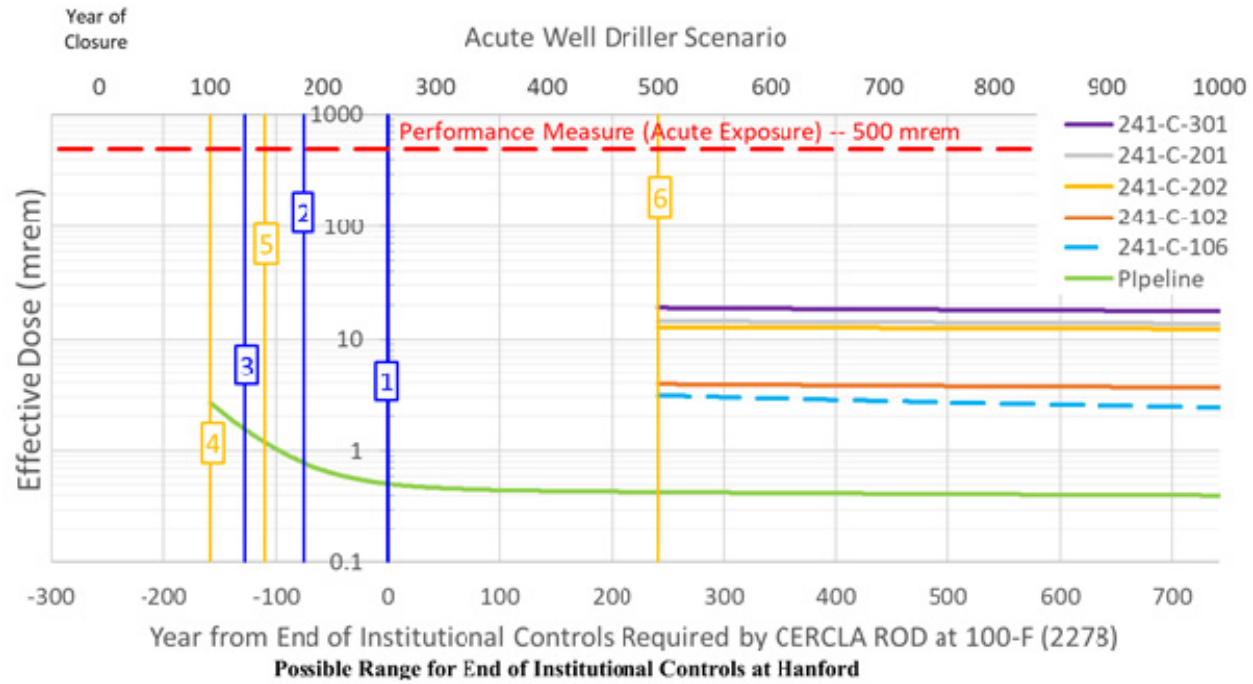


The first 5 alternatives assumed that times for inadvertent intrusion are relevant to a pipeline source and alternative 6 is relevant for the other 18 waste sources. The graphical results illustrate the importance of the assumed date of inadvertent intrusion. Over the compliance time period (1,000 years after closure), the relative contributions of radionuclides vary, but the total dose decreases, with highest dose being at loss of institution control.

Sections 7.2.1 and 7.2.2 summarize the calculated effective dose for each of the four inadvertent intruder scenarios. Graphic displays show the effective dose starting 100 years after closure for intrusion into a pipeline source and 500 years after closure for the other sources that produce significant intruder dose. Over the compliance time period (1,000 years after closure), the

relative contributions of radionuclides vary, but the total dose decreases, with highest dose being at 100 years after closure. Table 7-1 summarizes the calculated effective doses for each intruder scenario, assuming intrusion at 100 years for intrusion into a pipeline source and 500 years after closure for the other 18 waste sources. These times of intrusion are consistent with NRC regulatory guidance in NUREG-1854.

Figure 7-7. Effective Dose for the Well Driller Acute Exposure Scenario.



Possible Range for End of Institutional Controls at Hanford

1 — *ROD 100 Area Superfund Site for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (EPA 2014b) Waste Site: 116-F-8.3*

2 — *ROD 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (EPA 2018) Waste Sites: 116-D-1A, 116-D-1B, 100-D-46*

3 — *ROD 200 Area 200-ZP-1 Superfund Site Benton County, Washington* (EPA 2008) Section 12*

4 — 100 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)**

5 — 100 Years after DST Closure *(System Plan, Revision 8, Lifecycle Cost Analysis*, Baseline Case Table 5 [RPP-RPT-60192])**

6 — 500 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)**

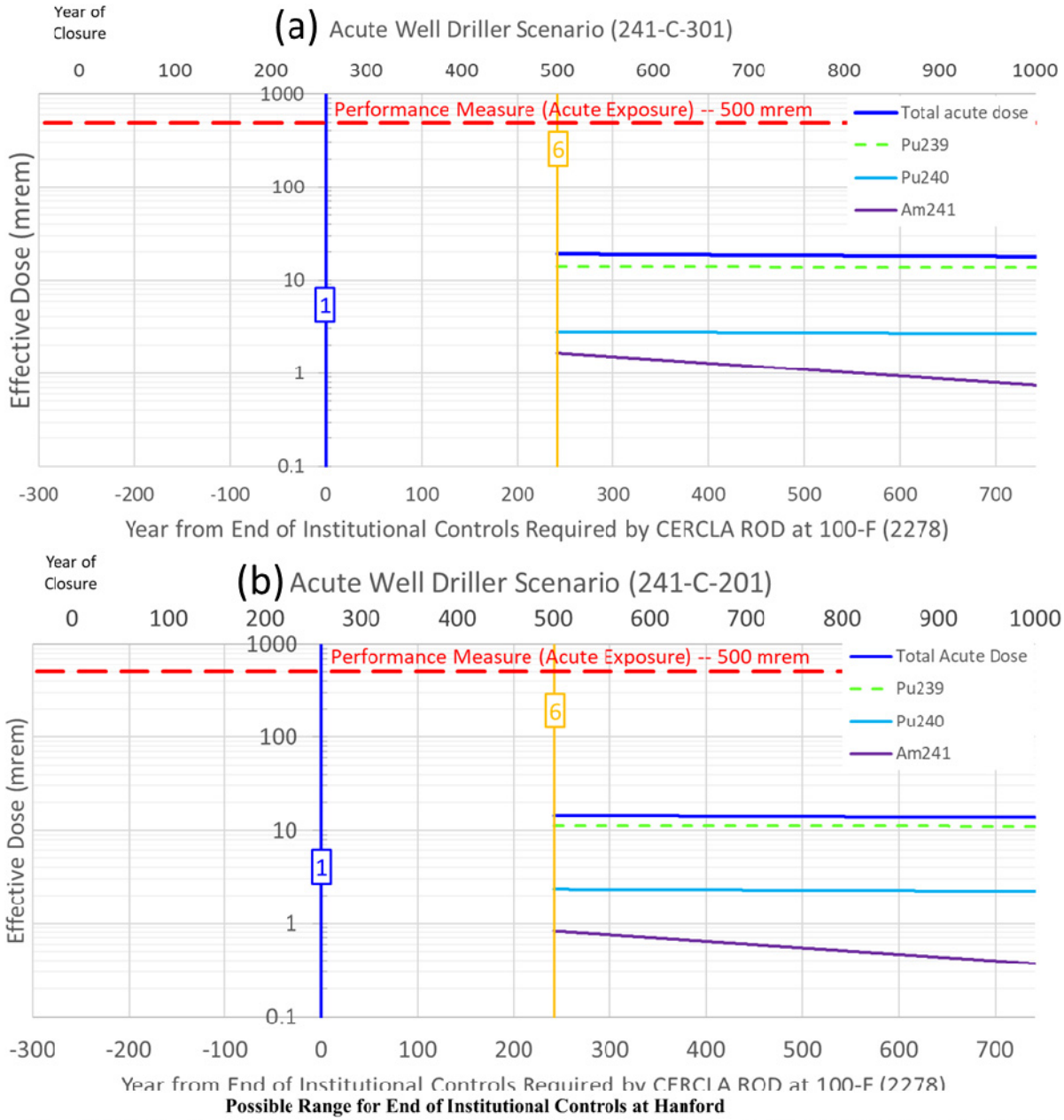
**Record of Decison (ROD) providing the year Institutionel Controls may be removed with concurrence of EPA and/or Washington Department of Ecology*

****Based 100 Years for pipelines and 500 Years for SSTs after scheduled closure of the facility from existing documents**

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

The total intruder dose and doses from major radionuclide contributors from intrusion into the two sources with the highest possible dose are presented separately for each intruder scenario. The source with the highest possible dose for all intruder scenarios except the rural pasture scenario is tank C-301 (500-year intrusion time). For the rural pasture scenario it is a pipeline (100-year intrusion time). The relative importance of various pathways is presented for each intruder scenario in Table 7-2 for intruding through the pipeline. The tables present the results at the upper end of the range of assumed intrusion times.

Figure 7-8. Effective Dose for the Well Driller Acute Exposure Scenario for (a) Tank 241-C-301 and (b) Tank 241-C-201.



Possible Range for End of Institutional Controls at Hanford

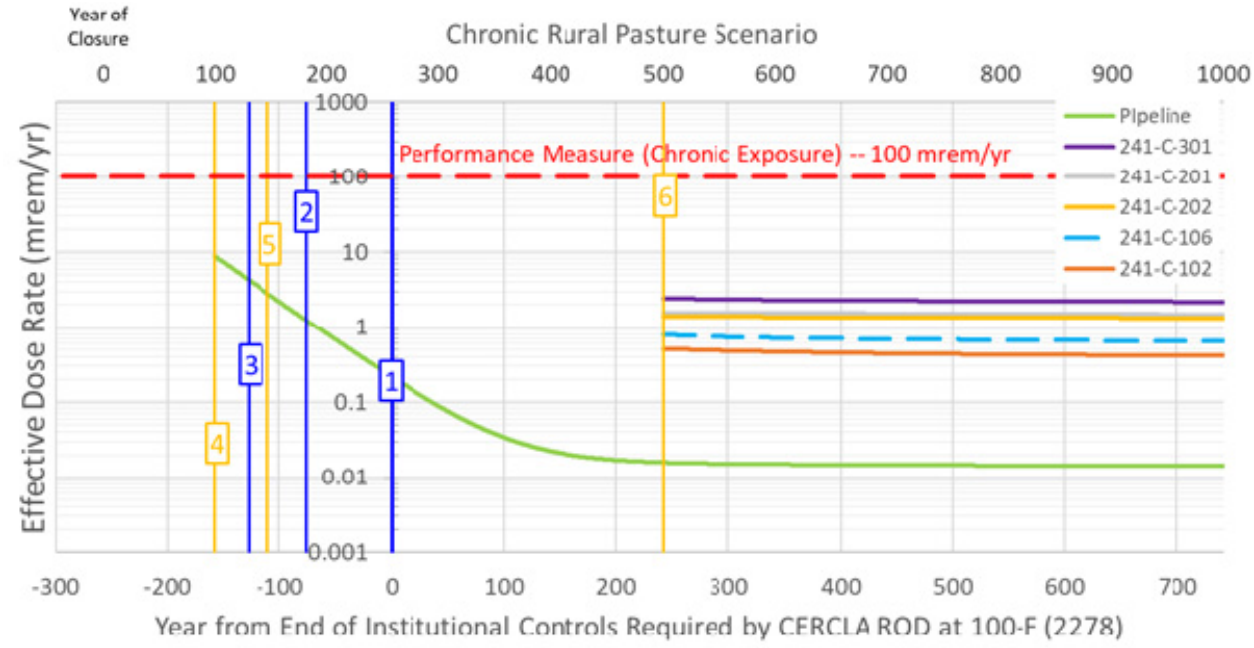
1. ***ROD 100 Area Superfund Site for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*** **(EPA 2014b) Waste Site: 116-F-8.3***
2. ***ROD 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*** **(EPA 2018) Waste Sites: 116-D-1A, 116-D-1B, 100-D-46***
3. ***ROD 200 Area 200-ZP-1 Superfund Site Benton County, Washington*** **(EPA 2008) Section 12***
4. **100 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)****
5. **100 Years after DST Closure *(System Plan, Revision 8, Lifecycle Cost Analysis*, Baseline Case Table 5 [RPP-RPT-60192])****
6. **500 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)****

Record of Decison (ROD) providing the year Institutional Controls may be removed with concurrence of EPA and/or Washington Department of Ecology

****Based 100 Years for pipelines and 500 Years for SSTs after scheduled closure of the facility from existing documents**

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

Figure 7-9. Effective Dose for the Rural Pasture Chronic Exposure Scenario.

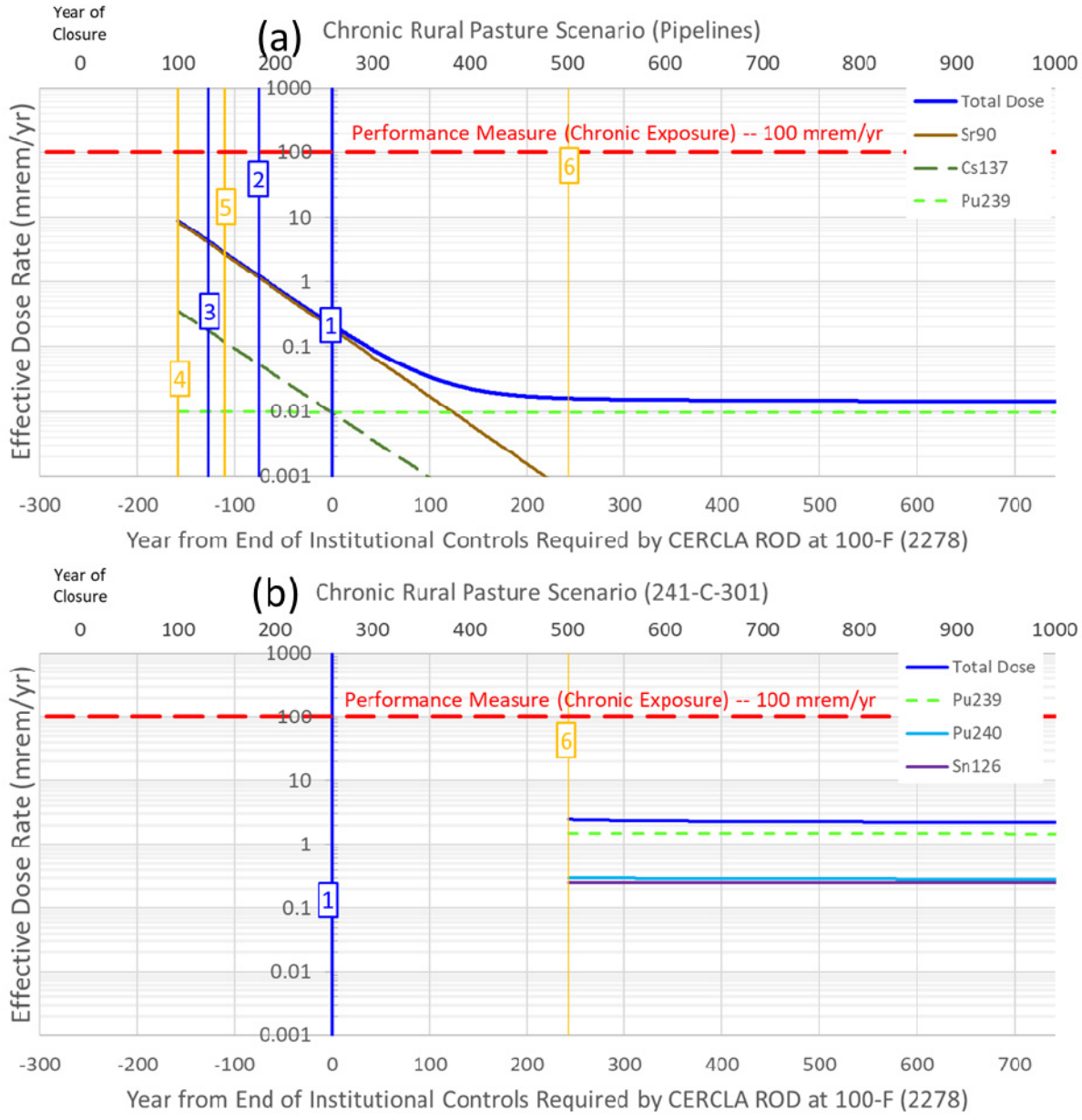


CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

7.2.1 Acute Exposure Results

Figure 7-7 shows the calculated acute dose to the well driller assuming that the intrusion takes place 100 years or beyond for pipelines and 500 years or beyond for sources with substantial intrusion barriers. Among the 19 residual waste sources, the sources with the top six intruder doses are displayed in the figure. For all sources, the dose remains below the 500 mrem performance measure. Figure 7-8(a) shows the total well driller dose produced by tank C-301 residual waste source along with major dose-contributing radionuclides, while Figure 7-8(b) shows the results for the tank C-201 residual waste source. The major contributor to dose to the well driller is ^{239}Pu for both sources, followed by ^{240}Pu. Tank C-301 also has a small contribution from residual ^{241}Am. The major pathway for well driller dose from these sources is soil inhalation. While the C pipeline is not one of the top five dose contributing sources, it should be noted that the top pathway for intrusion into the C pipeline is external exposure driven by the relatively short-lived radionuclides ^{137}Cs and ^{90}Sr because of the earlier time of potential intrusion (100 years post-closure).

Figure 7-10. Effective Dose for the Rural Pasture Chronic Exposure Scenario for (a) Pipeline Residual Waste and (b) Tank 241-C-301.



Possible Range for End of Institutional Controls at Hanford

1 — *ROD 100 Area Superfund Site for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (EPA 2014b) Waste Site: 116-F-8.3*

2 — *ROD 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (EPA 2018) Waste Sites: 116-D-1A, 116-D-1B, 100-D-46*

3 — *ROD 200 Area 200-ZP-1 Superfund Site Benton County, Washington* (EPA 2008) Section 12*

4 — 100 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)**

5 — 100 Years after DST Closure (*System Plan, Revision 8, Lifecycle Cost Analysis*, Baseline Case Table 5 [RPP-RPT-60192])**

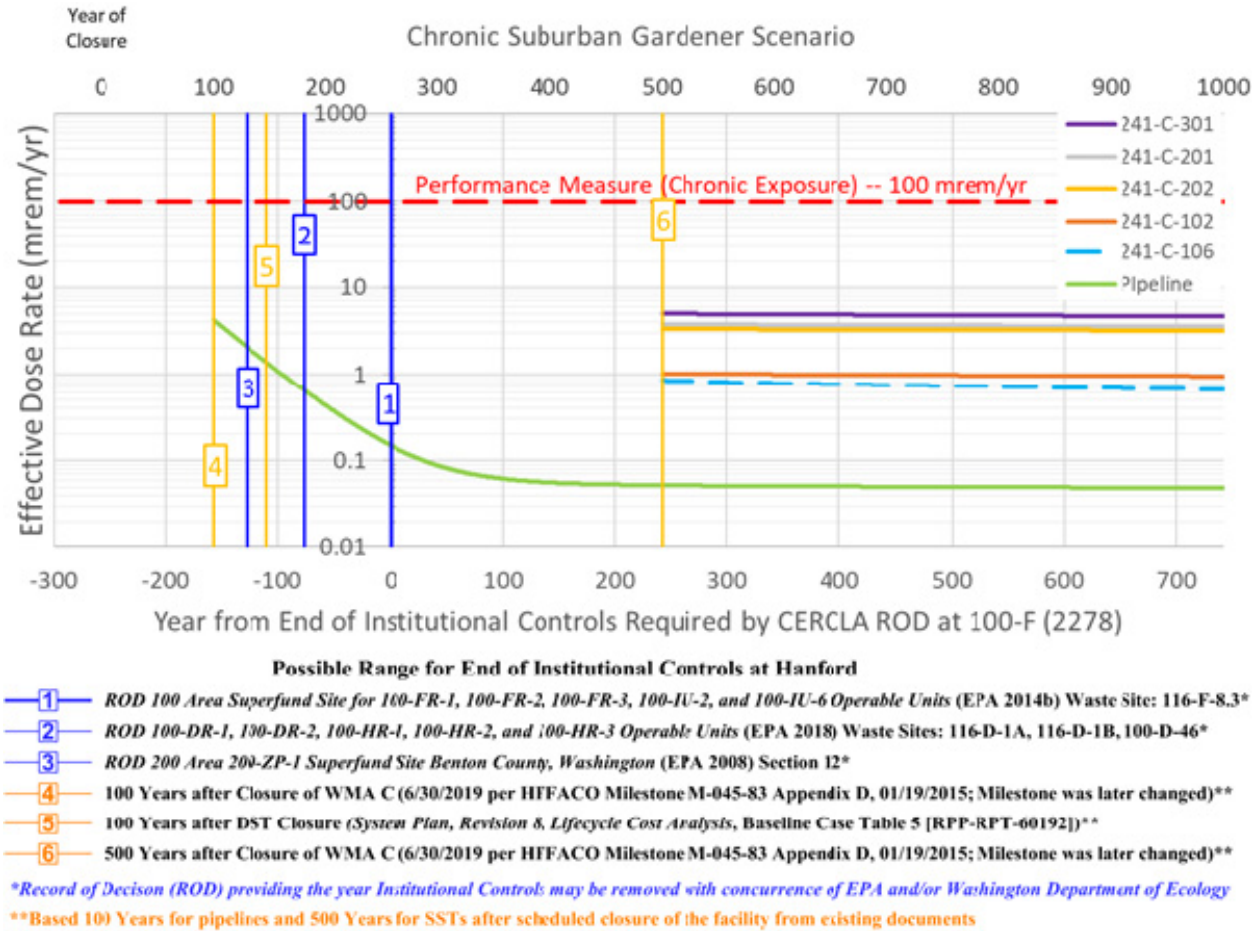
6 — 500 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)**

**Record of Decison (ROD) providing the year Institutional Controls may be removed with concurrence of EPA and/or Washington Department of Ecology*

****Based 100 Years for pipelines and 500 Years for SSTs after scheduled closure of the facility from existing documents**

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

Figure 7-11. Effective Dose for the Suburban Garden Chronic Exposure Scenario.

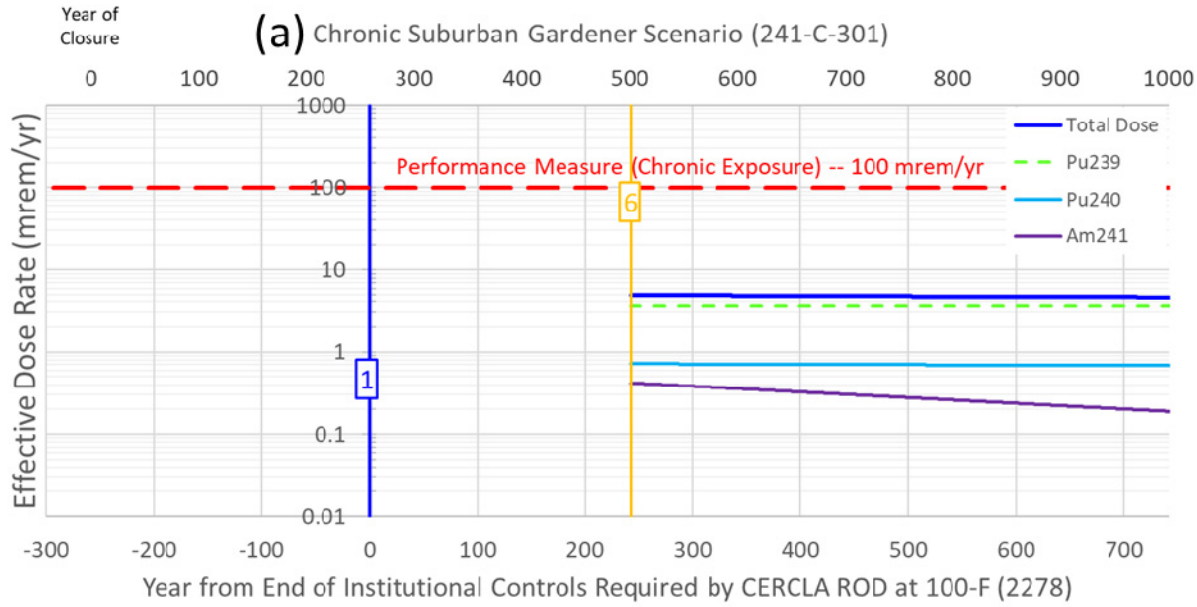


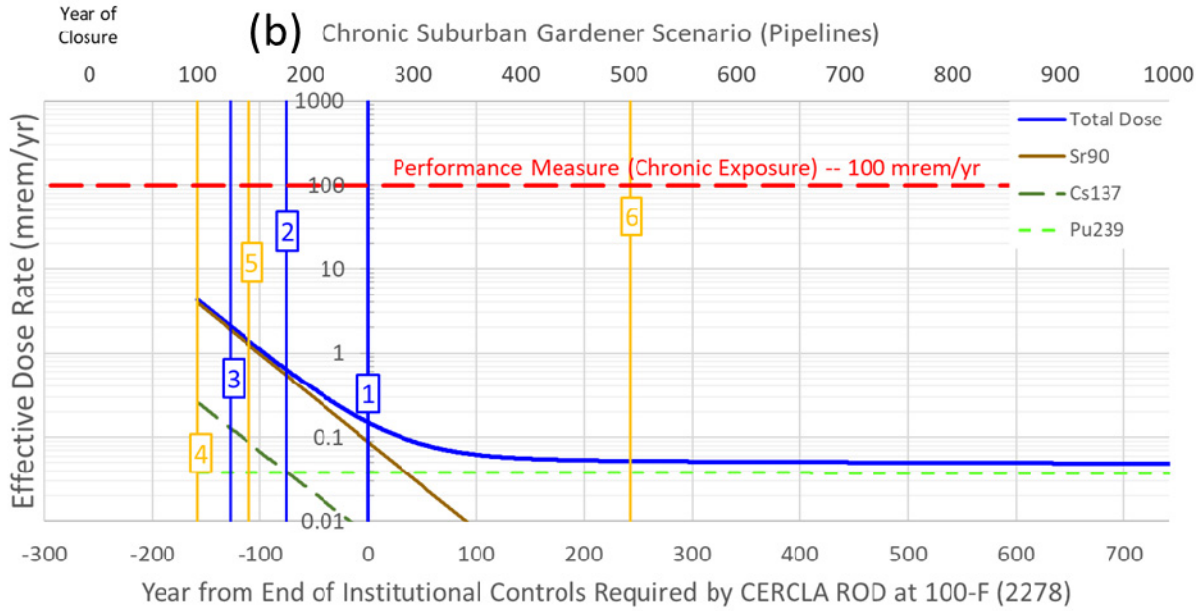
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

7.2.2 Chronic Exposure Doses

Figure 7-9 shows the calculated dose for the rural pasture scenario for the top six residual waste sources. All remain below the 100 mrem/yr performance measure throughout the simulated time period. Figure 7-10(a) shows the total rural pasture dose produced by intrusion into tank C-301 along with major dose-contributing radionuclides (Note: Additional lines are added to the plot to highlight effective doses from a pipeline source for a range of assumed end of institutional control times), while Figure 7-10(b) shows the results for intrusion into a pipeline. Strontium-90 is the major contributor to pipelines up until almost 400 years after closure, with the major pathway being milk ingestion. Cesium-137 through the milk ingestion pathway is also a major contributor to dose at early time period. Plutonium-239 becomes the major contributor for both pipelines after 400 years following closure and tank residuals.

Figure 7-12. Effective Dose for the Suburban Garden Chronic Exposure Scenario for (a) Tank 241-C-301 and (b) Pipeline Residual Waste.





Possible Range for End of Institutional Controls at Hanford

1 — ***ROD 100 Area Superfund Site for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*** **(EPA 2014b) Waste Site: 116-F-8.3***

2 — ***ROD 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*** **(EPA 2018) Waste Sites: 116-D-1A, 116-D-1B, 100-D-46***

3 — ***ROD 200 Area 200-ZP-1 Superfund Site Benton County, Washington*** **(EPA 2008) Section 12***

4 — **100 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)****

5 — **100 Years after DST Closure *(System Plan, Revision 8, Lifecycle Cost Analysis*, Baseline Case Table 5 [RPP-RPT-60192])****

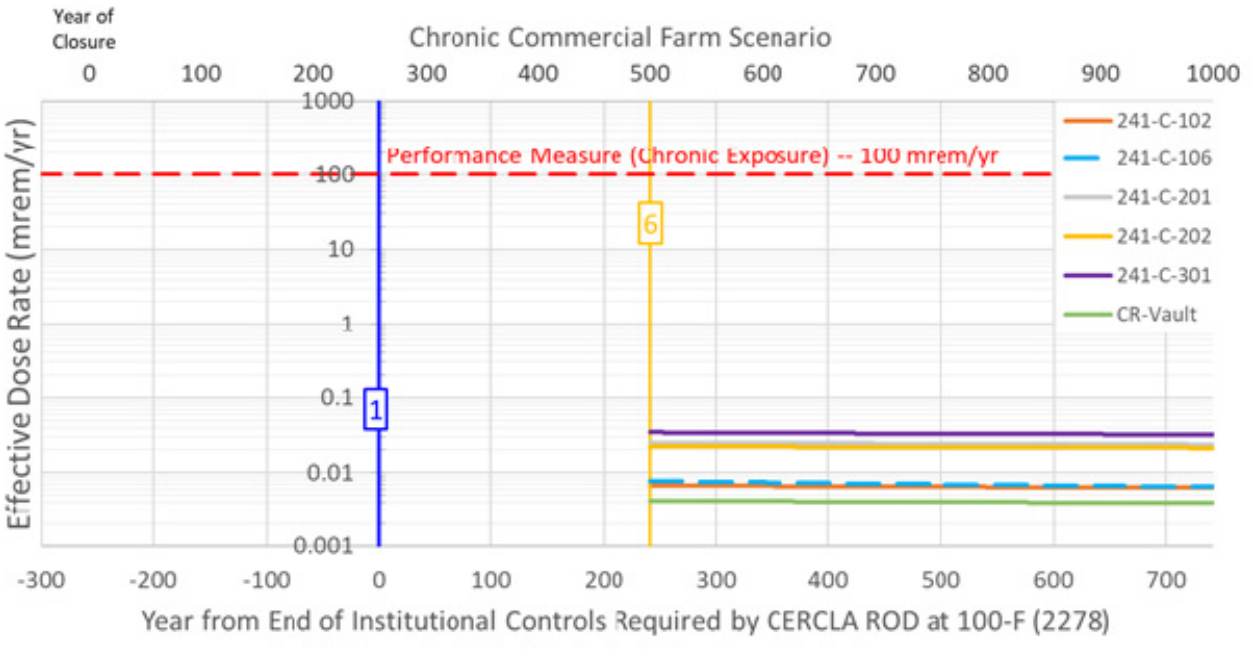
6 — **500 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)****

****Record of Decison (ROD) providing the year Institutional Controls may be removed with concurrence of EPA and/or Washington Department of Ecology***

*****Based 100 Years for pipelines and 500 Years for SSTs after scheduled closure of the facility from existing documents***

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

Figure 7-13. Effective Dose for the Commercial Farm Chronic Exposure Scenario.



Possible Range for End of Institutional Controls at Hanford

1 — *ROD 100 Area Superfund Site for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (EPA 2014b) Waste Site: 116-F-8.3*

2 — *ROD 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (EPA 2018) Waste Sites: 116-D-1A, 116-D-1B, 100-D-46*

3 — *ROD 200 Area 200-ZP-1 Superfund Site Benton County, Washington* (EPA 2008) Section 12*

4 — 100 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)**

5 — 100 Years after DST Closure *(System Plan, Revision 8, Lifecycle Cost Analysis*, Baseline Case Table 5 [RPP-RPT-60192])**

6 — 500 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)**

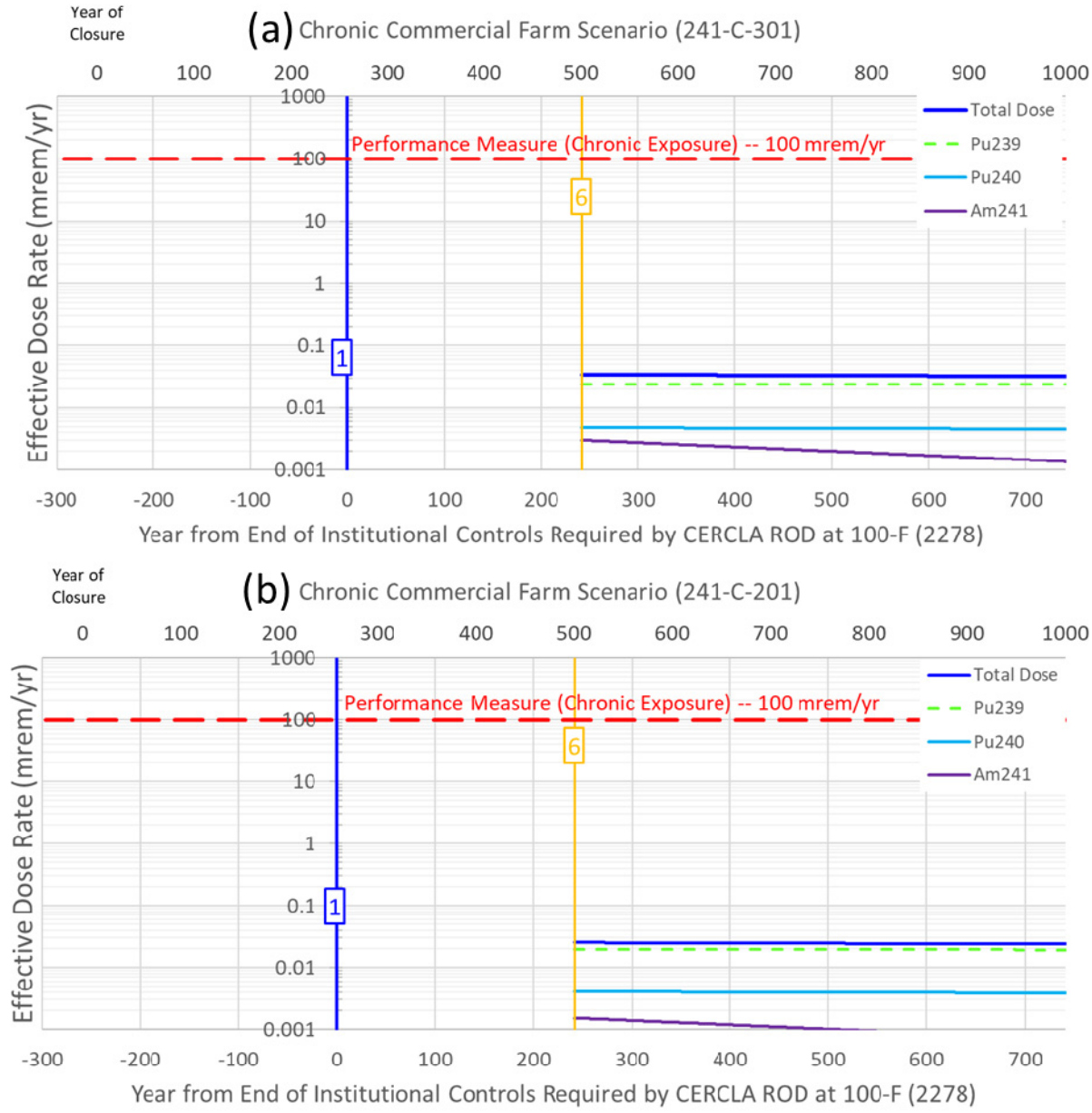
**Record of Decison (ROD) providing the year Institutional Controls may be removed with concurrence of EPA and/or Washington Department of Ecology*

**Based 100 Years for pipelines and 500 Years for SSTs after scheduled closure of the facility from existing documents

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

Figure 7-11 shows the calculated dose for the suburban garden scenario for the top six residual waste sources. All doses remain below the 100 mrem/yr performance measure throughout the compliance time period. Figure 7-12(a) shows the total suburban garden dose produced by intrusion into tank C-301 along with major dose-contributing radionuclides, while Figure 7-12(b) shows the results for intruded pipeline source (Note: Additional lines are added to the plot to highlight effective doses from a pipeline source for a range of assumed end of institutional control times). Strontium-90 is the major contributor up until about 300 years after closure (for intrusion into a pipeline source), with the major pathway being vegetable ingestion. Cesium-137 through the vegetable ingestion pathway is also a major contributor to dose at early times. Plutonium-239 becomes the major contributor for both pipelines after 300 years and tank residuals.

Figure 7-14. Effective Dose for the Commercial Farm Chronic Exposure Scenario for (a) Tank 241-C-301 and (b) Tank 241-C-201.



Possible Range for End of Institutional Controls at Hanford

1 — ***ROD 100 Area Superfund Site for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*** **(EPA 2014b) Waste Site: 116-F-8.3***

2 — ***ROD 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*** **(EPA 2018) Waste Sites: 116-D-1A, 116-D-1B, 100-D-46***

3 — ***ROD 200 Area 200-ZP-1 Superfund Site Benton County, Washington*** **(EPA 2008) Section 12***

4 — **100 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)****

5 — **100 Years after DST Closure *(System Plan, Revision 8, Lifecycle Cost Analysis*, Baseline Case Table 5 [RPP-RPT-60192])****

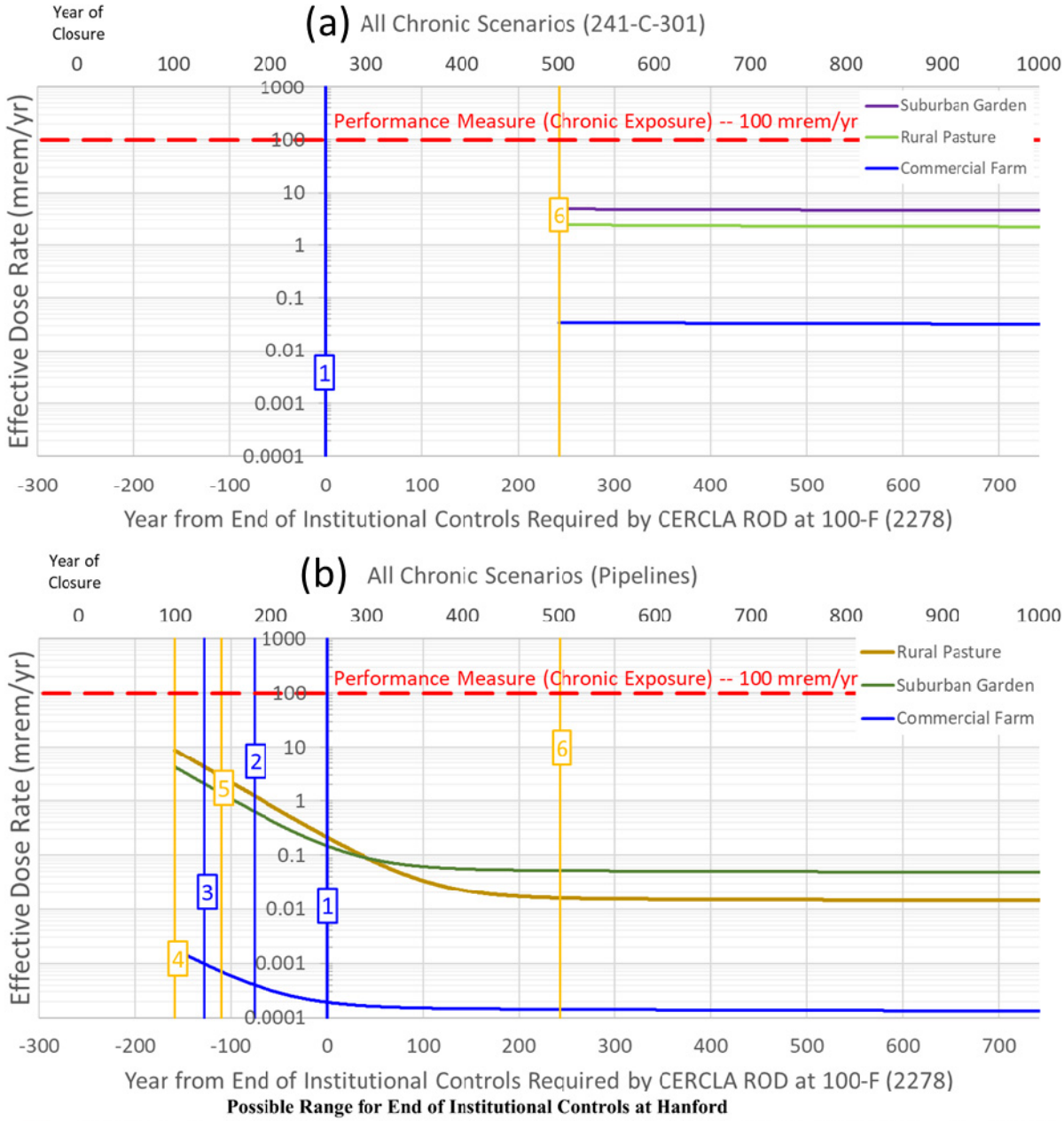
6 — **500 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)****

****Record of Decison (ROD) providing the year Institutional Controls may be removed with concurrence of EPA and/or Washington Department of Ecology***

*****Based 100 Years for pipelines and 500 Years for SSTs after scheduled closure of the facility from existing documents***

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

Figure 7-15. Effective Dose for All Three Chronic Exposure Scenarios for (a) Tank 241-C-301 and (b) Pipeline Residual Waste.



Possible Range for End of Institutional Controls at Hanford

1. ***ROD 100 Area Superfund Site for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*** **(EPA 2014b) Waste Site: 116-F-8.3***
2. ***ROD 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*** **(EPA 2018) Waste Sites: 116-D-1A, 116-D-1B, 100-D-46***
3. ***ROD 200 Area 200-ZP-1 Superfund Site Benton County, Washington*** **(EPA 2008) Section 12***
4. **100 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)****
5. **100 Years after DST Closure *(System Plan, Revision 8, Lifecycle Cost Analysis*, Baseline Case Table 5 [RPP-RPT-60192])****
6. **500 Years after Closure of WMA C (6/30/2019 per HFFACO Milestone M-045-83 Appendix D, 01/19/2015; Milestone was later changed)****

Record of Decison (ROD) providing the year Institutional Controls may be removed with concurrence of EPA and/or Washington Department of Ecology

**Based 100 Years for pipelines and 500 Years for SSTs after scheduled closure of the facility from existing documents

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DST = double-shell tank
EPA = U.S. Environmental Protection Agency
HFFACO = *Hanford Federal Facility Agreement and Consent Order*
SST = single-shell tank
WMA = Waste Management Area

Figure 7-13 shows the calculated dose for the commercial farm scenario for the top six residual waste sources. The dose from all residual waste sources remains below the 100 mrem/yr performance measure throughout the simulated time period. Figure 7-14(a) shows the total commercial farm dose produced by intrusion into tank C-301 along with major dose-contributing radionuclides, while Figure 7-14(b) shows the results for intrusion into tank C-201. For intrusion into both sources, ^{239}Pu, ^{240}Pu and ^{241}Am are the major contributors during the compliance period. The primary exposure pathway for these sources is soil ingestion. While the C pipeline is not in the top six contributing sources, dose from intrusion into a pipeline would be driven by ^{137}Cs and ^{90}Sr in the External Exposure pathway.

Figure 7-15 shows the total dose produced by intrusion into tank C-301 and a pipeline residual waste source for all three chronic scenarios [Note: Additional lines are added to the plot (b) to highlight effective doses from a pipeline source for a range of assumed end of institutional control times]. For about the first 300 years after closure (for intrusion into a pipeline source), the rural pasture scenario produces higher dose than the other chronic scenarios; after that time the suburban garden dose is highest among all of the chronic scenarios. Within the first 300 years for intrusion into a pipeline after closure, the milk ingestion dose (dominant pathway in rural pasture scenario) from ^{90}Sr is higher than the vegetable ingestion dose (dominant pathway in suburban garden scenario). After that, the total vegetable ingestion dose from ^{90}Sr, ^{241}Am and ^{239}Pu exceeds the total milk ingestion dose from ^{90}Sr, ^{241}Am and ^{239}Pu. So, if intrusion occurs at 100 years after closure, the rural pasture scenario will produce the highest chronic dose.

For intrusion into tank wastes, the suburban garden scenario produces the maximum chronic dose, with tank C-301 producing the highest dose. The commercial farm scenario is always lower than the other chronic scenarios.

Table 7-1. Peak Effective Dose for the Inadvertent Intruder Scenarios for All Residual Waste Sources.

Source	Current Special Analysis Results				Waste Management Area C Performance Assessment (RPP-RPT-58782) Results			
	Well Driller Acute Dose (mrem)	Commercial Farm Chronic Dose (mrem/yr)	Rural Pasture Chronic Dose (mrem/yr)	Suburban Garden Chronic Dose (mrem/yr)	Well Driller Acute Dose (mrem)	Commercial Farm Chronic Dose (mrem/yr)	Rural Pasture Chronic Dose (mrem/yr)	Suburban Garden Chronic Dose (mrem/yr)
241-C-101	1.29E+00	2.42E-03	2.25E-01	3.67E-01	1.24E+00	2.17E-03	1.44E-01	3.22E-01
241-C-102	3.87E+00	6.76E-03	5.09E-01	1.02E+00	4.59E+00	8.09E-03	5.37E-01	1.20E+00
241-C-103	4.09E-01	7.26E-04	6.15E-02	1.10E-01	4.09E-01	7.25E-04	6.14E-02	1.10E-01
241-C-104	5.70E-01	1.25E-03	1.46E-01	1.67E-01	5.77E-01	1.10E-03	1.21E-01	1.70E-01
241-C-105	7.59E-01	1.53E-03	1.28E-01	2.03E-01	3.80E+00	6.69E-03	7.18E-01	1.23E+00
241-C-106	3.08E+00	7.76E-03	7.91E-01	8.49E-01	3.47E+00	8.75E-03	8.93E-01	9.57E-01
241-C-107	1.18E+00	2.09E-03	1.86E-01	3.14E-01	1.49E+01	2.66E-02	1.82E+00	3.90E+00
241-C-108	5.81E-02	1.05E-04	1.09E-02	1.71E-02	5.80E-02	1.05E-04	1.09E-02	1.71E-02
241-C-109	3.12E-02	5.60E-05	7.63E-03	9.37E-03	3.10E-02	5.57E-05	7.63E-03	9.33E-03
241-C-110	8.25E-02	1.78E-04	1.99E-02	2.44E-02	8.24E-02	1.78E-04	1.99E-02	2.44E-02
241-C-111	2.02E-01	3.70E-04	8.84E-02	7.09E-02	7.47E+00	1.32E-02	1.40E+00	2.13E+00
241-C-112	7.77E-01	1.41E-03	2.06E-01	2.37E-01	3.48E-01	6.10E-04	9.17E-02	1.41E-01
241-C-201	1.45E+01	2.52E-02	1.58E+00	3.76E+00	1.45E+01	2.52E-02	1.58E+00	3.75E+00
241-C-202	1.28E+01	2.23E-02	1.40E+00	3.33E+00	1.28E+01	2.22E-02	1.39E+00	3.32E+00
241-C-203	4.62E-01	9.20E-04	1.12E-01	1.35E-01	4.61E-01	8.51E-04	7.25E-02	1.26E-01
241-C-204	1.10E-01	4.03E-04	6.97E-02	5.73E-02	5.60E-02	1.77E-04	2.97E-02	2.49E-02
241-C-301	**1.90E+01**	**3.45E-02**	2.45E+00	**4.99E+00**	2.12E+01	**3.86E-02**	2.69E+00	**5.57E+00**
244-CR Vault	2.32E+00	4.22E-03	3.00E-01	6.10E-01	3.91E+00	7.10E-03	4.96E-01	1.03E+00
Pipeline (2120)[a]	2.63E+00	1.82E-03	8.81E+00	4.23E+00	**3.60E+01**	1.13E-03	**8.21E+00**	3.92E+00
Pipeline (2150)[b]	1.55E+00	9.86E-04	4.30E+00	2.09E+00	NR	NR	NR	NR
Pipeline (2168)[c]	1.18E+00	7.03E-04	2.80E+00	1.38E+00	NR	NR	NR	NR
Pipeline (2202)[d]	7.88E-01	4.03E-04	1.25E+00	6.40E-01	NR	NR	NR	NR
Pipeline (2278)[e]	**5.10E-01**	1.93E-04	**2.15E-01**	1.49E-01	NR	NR	NR	NR

Note: Peak dose calculated at 500 years for all sources except for pipeline, which is reported at 100 years after closure.

[a]100 Years after Waste Management Area C Closure (June 30, 2019 per *Hanford Federal Facility Agreement and Consent Order* Milestone M-045-83 Appendix D, January 19, 2015; Milestone was later changed).
[b]*Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County Washington* (EPA 2008).
[c]100 years after Double-Shell Tank Closure (RPP-RPT-60192, *System Plan, Revision 8, Lifecycle Cost Analysis*).
[d]*Record of Decision Hanford 100 Area Superfund Site 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units* (EPA 2018).
[e]*Record of Decision Hanford 100 Area Superfund Site for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (EPA 2014).

The peak dose for each scenario is shown in **bold**.

NR = Not Reported

Reference: RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington*.

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Table 7-2. Relative Fraction of Pathway Contributions to the Inadvertent Intruder Dose for Pipeline at Assumed End of Institutional Control in Year 2278.

Scenario	Pathways				
	Current Special Analysis Results				
	External Exposure	Soil Inhalation	Soil Ingestion	Milk Ingestion	Vegetable Ingestion
Well Driller	0.14	**0.72**	0.14	x	x
Rural Pasture	0.04	0.02	0.04	**0.89**	x
Suburban Garden	0.06	0.03	0.07	x	**0.84**
Commercial Farm	0.27	0.21	**0.52**	x	x
	Waste Management Area C Performance Assessment (RPP-RPT-58782) Results				
Well Driller	**0.59**	0.30	0.11	x	x
Rural Pasture	0.01	<0.01	<0.01	**0.98**	x
Suburban Garden	0.03	<0.01	<0.01	x	**0.96**
Commercial Farm	**0.69**	0.05	0.26	x	x

x = pathway not considered

Pathway contributing the most is **bolded** for each scenario.

Reference: RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington.*

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8.0 CONCLUSIONS

Based on the results of the SA, the performance objective and measures are updated as shown in Table 8-1.

Table 8-1. Comparison of Performance Assessment Results and Selected Results Evaluated in the Special Analysis with Performance Objectives and Measures for the Compliance and Post-Compliance Periods. (2 sheets)

Performance Objective and/or Measure	**Standard**	**Performance Assessment and Selected Special Analysis Results** ***(Selected results evaluated in the Special Analysis are in italics and in bold)***	
		1,000-year Post-Closure Compliance Period[a]	**9,000-year Post-Compliance Period[a]**
All Pathways (DOE O 435.1 Chg 1)	25 mrem/yr EDE	4E-3 mrem/yr	0.1 mrem/yr ***0.01 mrem/yr***[b]
Atmospheric (40 CFR 61, Subpart H)	10 mrem/yr EDE	4E-3 mrem/yr	2E-5 mrem/yr
Atmospheric (40 CFR 61, Subpart Q)	20 $pCi.m^{-2}.s^{-1}$ radon flux (at surface of disposal facility)	2E-4 $pCi.m^{-2}.s^{-1}$	7E-3 $pCi.m^{-2}.s^{-1}$
Acute Inadvertent Intruder (DOE O 435.1 Chg 1)	500 mrem EDE[c]	36 mrem[d] ***0.51 mrem***[e]	—
Chronic Inadvertent Intruder (DOE O 435.1 Chg 1)	100 mrem/yr EDE[c]	8.2 mrem/yr[d] ***0.2 mrem/yr***[e]	—
Groundwater Protection (water resources) (40 CFR 141)	Beta-gamma dose equivalent ≤ 4 mrem/yr	5E-4 mrem/yr	0.13 mrem/yr[f] ***0.013 mrem/yr***[f,b]
	Gross alpha activity concentration (excluding radon and uranium) ≤ 15 pCi/L	0 pCi/L	1E-10 pCi/L[g]
	Combined Ra-226 and Ra-228 concentration ≤ 5 pCi/L	0 pCi/L	7E-7 pCi/L[g]
	Uranium concentration ≤ 30 μg/L	0 μg/L	0.05 μg /L[g]
	Sr-90 concentration ≤ 8 pCi/L[h]	Not applicable	Not applicable
	H-3 concentration ≤ 20,000 pCi/L	0 pCi/L	1E-10 pCi/L[g]

Table 8-1. Comparison of Performance Assessment Results and Selected Results Evaluated in the Special Analysis with Performance Objectives and Measures for the Compliance and Post-Compliance Periods. (2 sheets)

[a] Compliance at 100 m downgradient of Waste Management Area C except for inadvertent intruder scenarios.

[b] Based on calculations performed using the system model.

[c] Not applicable for post-compliance time period.

[d] Acute and chronic peak doses in Rev. 0 of RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington* based on assumed inadvertent intrusion into a waste transfer line at 100 years following loss of institutional control using acute driller and chronic rural pasture exposure scenarios, respectively. Peak doses occur at 100 years after assumed closure at year 2020.

[e] Acute and chronic peak doses in this Special Analysis based on assumed inadvertent intrusion into a waste transfer line at the assumed loss of institutional control in year 2278 using acute driller and chronic rural pasture exposure scenarios, respectively. Peak dose occurs at the assumed loss of institutional control in year 2278.

[f] Beta-gamma dose equivalent ≤ 4 mrem/yr (based on Federal MCL) and calculated as $(C_{Peak}/MCL) \times 4$ mrem/yr. For Tc-99, which contributes almost the entire dose, C_{Peak} = 30 pCi/L and MCL = 900 pCi/L, so the equivalent dose is calculated to be 0.1 mrem/yr.

[g] Concentrations less than 1E-10 pCi/L are essentially zero.

[h] Not applicable; Sr-90 was screened out during evaluation of the groundwater pathway due to its relatively short half-life and its low mobility in the subsurface.

EDE = effective dose equivalent MCL = maximum contaminant level

References:

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart H—National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities, *Code of Federal Regulations*, as amended.

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart Q—National Emission Standards for Radon Emissions From Department of Energy Facilities, *Code of Federal Regulations*, as amended.

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

DOE O 435.1, 2001, *Radioactive Waste Management*, Change 1, U.S. Department of Energy, Washington, D.C.

9.0 REFERENCES

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40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart Q—National Emission Standards for Radon Emissions From Department of Energy Facilities, *Code of Federal Regulations*, as amended.

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RPP-ENV-58782, 2020, *Performance Assessment of Waste Management Area C, Hanford Site, Washington*, Rev. 1, INTERA, Inc./CH2M HILL Plateau Remediation Company/ Ramboll Environ, Inc./Washington River Protection Solutions, LLC/TecGeo, Inc., Richland, Washington.

RPP-RPT-42323, 2015, *Hanford C-Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*, Rev. 3, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-42323, 2019, *Post-Closure Hanford C-Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*, Rev. 4, Washington River Protection Solutions, LLC, Richland, Washington.

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UWMQ-WMA-C-2020-003, 2020, *Unreviewed Waste Management Question Screening (UWMQS)*, Washington River Protection Solutions, LLC, Richland, Washington.

ATTACHMENT 1

SOFTWARE INSTALLATION AND CHECKOUT FORMS

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

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

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

GENERAL INFORMATION:

1. Software Name: GoldSim Pro Software Version No.: 11.1

EXECUTABLE INFORMATION:

2. Executable Name (include path):

Network pathway redacted. GoldSim 11.1

3. Executable Size (bytes): 3,158 KB

COMPILATION INFORMATION:

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

Compiled by vendor

5. Operating System (include version number):

Windows 10 Pro

INSTALLATION AND CHECKOUT INFORMATION:

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

INTERA-00786

7. Operating System (include version number):

Windows Version 10.0.16299

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

TEST CASE INFORMATION:

9. Directory/Path:

Network pathway redacted.

10. Procedure(s):

per CHPRC-00224 Rev 2, 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: S. Mehta

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

18. Disposition (include HISI update):

Accepted; installation added to HISI Entry

Page 1 of 2 A-6005-149 (REV 0)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: GoldSim Pro Software Version No.: 11.1

Prepared By: WILLIAM NICHOLS Digitally signed by WILLIAM NICHOLS (Affiliate) Date: 2019.08.30 09:07:38 -07'00'

19. (Affiliate)	Software Owner (Signature)	WE Nichols	Print / Date
20. Test Personnel:	Sign	S. Mehta	Print / 08/28/2019 Date
	Sign		Print / Date
	Sign		Print / Date
Approved By:			
21.	Software SME (Signature)	N/R per SMP	Print / Date

ATTACHMENT 2

CHECKER LOGS

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RPP-CALC-64406, Rev. 0
UWMQ-WMA-C-2020-002-SA

CHECKER LOG FOR SYSTEM MODELS

Project and Environmental Model Calculation Specific Information:

Project: Waste Management Area C Performance Assessment

Responsible Manager or Designee, and Position: Marcel Bergeron, Project Manager

Originating Group or Department: Closure and Interim Measures | Date: 11/23/2020

Environmental Model Calculation File Report and Revision No.: RPP-CALC-64406, Rev. 0

Environmental Model Calculation File Title: WMA_C_PA_System_Model_Special_Analysis.gsm

Check: Environmental Model Calculation File Document Elements

	List where Information is Described *(EMCF Section Number)*	Is the Description Correct and Sufficient?			Checker Signature
		Yes	No	If No, describe deficiency:	
Purpose	1.0, 2.0	◉	○		DJW
Calculation Approach	3.0	◉	○		DJW
Assumptions	4.0	◉	○		DJW
Inputs *(reference detailed checklist below as well)*	4.0	◉	○		DJW
Equations used	N/A: Model is unchanged from the WMA C PA. The EMCF refers to the WMA C PA in section 3.0	○	○		DJW
Conclusions	8.0	◉	○		DJW
References	9.0	◉	○		DJW

Check: Controlled Software Use

	List where Information is Described *(EMCF Section Number)*	Is the Criteria Met?			Checker Signature
		Yes	No	If No, describe deficiency:	
Software used in the calculation is appropriate for application	5.0	◉	○		DJW
Software use is approved and properly validated in accordance with approved software management plan	Attachment 1	◉	○		DJW
Software use is properly documented	Attachment 1	◉	○		DJW
Verify data was input correctly to approved software or spreadsheets	4.0	◉	○		DJW
If a spreadsheet is used, verify inputs/outputs of calculation(s) to ensure accuracy	N/A; no spreadsheet was used for calculations	○	○		DJW

Check: Perform Calculation to Verify Free of Errors

	Describe how calculation was performed	List any discrepancies encountered *(If none, enter "None")*	Checker Signature
Perform the environmental	Model changes	None	

CHECKER LOG FOR SYSTEM MODELS (Continued)

	Describe how calculation was performed	List any discrepancies encountered *(If none, enter "None")*	Checker Signature
model calculation as described to verify it is free of errors	described in the EMCF were independently replicated in a copy of the WMA C PA system model and the results were compared with the Special Analysis model and the EMCF.		DJW

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

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Simulation duration	Duration not explicitly stated in EMCF, however section 3 states the methodology is the same as the WMA C PA, which calls out a simulation time-frame of 10,000 years	yes	yes
Simulation time step control	No	N/A	N/A
Simulated chemical list	N/A; Radiological analysis only	N/A	N/A
Simulated radionuclides list	Table 4-2	yes	yes
External model components identified and documented or referenced	4.0	yes	yes
External model linkages *(dynamic link libraries, etc.)* checked	N/A; no external model linkages were used	N/A	N/A
If model is probabilistic, stochastic distributions are defined and consistent	N/A; Deterministic model	N/A	N/A
Input units are declared and of correct dimensionality	Input units match those in source data; GoldSim enforces correct dimensionality	yes	yes
Equations used in the model file are presented in EMCF and consistent	N/A; no new equations were added to the this model. The PA model that this is based on has been checked.	N/A	N/A

CHECKER LOG FOR SYSTEM MODELS (Continued)

Check: Further Checks *(Record additional checks performed and results)*

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Inventory: Radiological Decay Correction. Does the inventory *(source term)* include radionuclides, and if so, is it decay-corrected to the appropriate date for inclusion as a source?	Section 4.0 states that the inventories are decay corrected to January 1, 2020.	yes	yes
Inventory: Mass Balance. Is mass balance of inventory maintained in system model calculation(s)?	Mass balance is not an input, and is not documented in the EMCF. Mass Balance was performed for all sources in the model. Mass Balance was performed with decay and ingrowth for the entire 10,000 year model time frame. No errors were found.	N/A	N/A
Checked results spreadsheets to ensure results were exported correctly from model.	Since these are results and not inputs they are not documented in the inputs section of the EMCF. No errors found in check.	N/A	N/A
Checked inventory and volume values in input spreadsheets against the source data and EMCF	Tables 4-1 and 4-2	yes	yes
Checked results charts in document against those in the GoldSim model	Figures 7-1, 7-3 and 7-5	yes	yes

Watson, David J

Digitally signed by Watson, David J
Date: 2020.12.03 11:20:15 -08'00'

RPP-CALC-64406, Rev. 0
UWMQ-WMA-C-2020-002-SA

Calculation Checklist

Calculation Number/Revision/Title: Intruder_Results_WMA_C_Special_Analysis.20200728_r3.xlsx
Scope of Review[1]: Technical review
Engineer/Analyst: Kearn Patrick Lee
Organization Manager: Paul Rutland

Yes	No[2]	NA	
☐	☐	☒	a. The calculation was formatted in accordance with Attachment A of TFC-ENG-DESIGN-C-10.
☒	☐	☐	b. The objective/purpose of the calculation is clearly stated and the problem is completely defined by the purpose statement.
☒	☐	☐	c. Analytical and technical approaches and results are reasonable and appropriate.
☒	☐	☐	d. Input data are adequately described, referenced to their source, and checked for consistency with original source information.
☒	☐	☐	e. Necessary assumptions are reasonable, explicitly stated, and technically justifiable. Assumptions requiring verification prior to use are clearly stated and identified/tracked using TBD/HOLD numbers.
☐	☐	☒	f. For both qualitative and quantitative data, uncertainties are recognized and discussed and the data is presented in a manner to minimize design interpretations.
☒	☐	☐	g. Mathematical derivations were checked, including dimensional consistency of results.
☒	☐	☐	h. Calculations are sufficiently detailed such that a technically qualified person can understand the analysis without requiring recourse to the originator.
☒	☐	☐	i. Calculations were verified, including review that correct input data are used, equations are correctly applied to the problem being analyzed, correct units are used, and results are reasonable and appropriate.
☐	☐	☒	j. Results produced by Mathcad® were replicated/verified by hand or alternate methods. If results could not be replicated/verified by hand, the utilized Mathcad® feature (e.g. advanced math function, equation, macro, etc.) is verified and registered in HISI.
☐	☐	☒	k. Software[3] used is identified by the software name, version, HISI ID#, and if applicable the Software Management Plan (SMP).
☐	☐	☒	l. Software is used in accordance the requirements prescribed by the Software Owner.[4] This includes adherence to limits of use, training requirements, software settings, specific software checklists, usage logs, error report checks, etc.
☐	☐	☒	m. Software input reports and input files are attached.
☒	☐	☐	n. The input was correctly entered/modeled in the Software, and consistent with the calculation document.
☒	☐	☐	o. Software output is consistent with the input and with the results reported in the calculation document.
☐	☐	☒	p. Multiple-Use spreadsheets are used in accordance with TFC-ENG-DESIGN-C-32, and identified by file name, version, HISI ID#, and as applicable; the SMP or Spreadsheet Verification Form.
☒	☐	☐	q. Single-Use spreadsheets used in the calculation have adequate explanation of their method, are identified by file name, and checked/verified as part of the calculation.
☒	☐	☐	r. Data or results presented in tables and graphs have been checked against original source.
☒	☐	☐	s. The number of significant digits is appropriate and consistent.
☐	☐	☒	t. Limits/criteria/guidelines applied to the analysis results are appropriate and referenced. Limits/criteria/guidelines were checked against references.
☒	☐	☐	u. Conclusions are consistent with analytical results and applicable limits.
☒	☐	☐	v. Results and conclusions address all points in the purpose.
☒	☐	☐	w. Referenced documents are retrievable or otherwise available and the version or revision of each reference is cited.
☐	☐	☒	x. Impacts on requirements have been assessed and change documentation initiated to incorporate revisions to affected documents, as appropriate.
☐	☐	☒	y. The design media matches the calculations.

Checker: Kearn Patrick Lee

Checkbox Justifications:
a) Calculation is completed in accordance with TFC-ESHQ-ENV_FS-C-05.
f,t) Post-processing of model output only, no assumptions, uncertainties or limits apply.
j,k,l,m,p) Calculation is performed in single-use Excel spreadsheet.
w) Submission to model archive is pending.
x, y) No engineering design requirements or design media.

K Pat Lee Digitally signed by K Pat Lee Date: 2020.12.09 09:54:31 -08'00'

[1] If less than the entire calculation was checked, the scope of the check should be discussed.
[2] If any blocks are checked "No", a justification must be provided here or attached.
[3] Does not apply to non-computational software (e.g. Word®, Visio®).
[4] The Software Owner is responsible for managing software, including requirements, in accordance with TFC-BSM-IRM_HS-C-01.

SPF-021 (REV. 0-B)

Review of Intruder_Results_WMA_C_Special_Analysis.xlsx dated 7/14/2020 @ 10:51 AM

Worksheet: 'About'

Read, but did not review for accuracy

Worksheet: 'Named_Data_Ranges'

Read, but did not review for accuracy. Check of usage is reviewed by replicating data post-processing without using named data ranges and confirming equivalent responses.

Worksheet: 'WellDriller'

Electronically compared values exported from model in cells A6:AEL1906. Minor discrepancies in last exported digit for about 43 of 1.553+ million values reviewed. No difference exceeded tolerance from a difference at the 4th significant digit. Checker only exported data values with 4 sig figs.

Electronically verified (by independent replication and electronic comparison) that headers in cells B2:AEL3 match exported data order. To perform this verification, a listing of the order included in the model result element was developed manually from information in the model (result element properties and radionuclide array order).

Electronically verified (by independent replication and electronic comparison) that max values in cells B1908:AEL1908 are calculated correctly for each column.

Electronically verified (by independent replication and electronic comparison) that time and total dose values for each source in cells AEN6:AFG1906 are calculated correctly for each source. Checker used alternative method to compute sum (SUMIF function). Comparison was performed in other workbooks. Calculated values reported by the model that occur before the earliest intrusion time were manually deleted prior to comparison with the values being reviewed. The values being reviewed also zero out doses prior to the intrusion time, but do so using computational logic (IF THEN ELSE). Verified values were within same level of tolerance for exported values with four sig figs.

Verified (by formula review) that max values in cells AEO1908:AFG1908 are calculated correctly for each column.

Verified by inspection of values that the performance measure in cells AFH6:AFH1906 is correct.

Verified using ranks of peak total doses and visual inspection that sources listed in cells AFK1, AFN1 and AFQ1 have the three highest peak total doses.

Verified using ranks and visual inspection that radionuclides listed in cells AFK2:AFK4, AFN2:AFN4, and AFQ2:AFQ4 are the three highest peak radionuclide doses from each source.

Electronically verified using a comparison made with a direct link to the proper data that the values in cells AFJ6:AFR1906 are the correct values to plot.

Worksheet: 'SuburbanGardener' (verification methodology identical to description provided for the worksheet 'WellDriller'

Verified values in cells A6:AEL1906. No difference (51 records) exceeded tolerance from a difference at the 4th significant digit. Checker only exported data values with 4 sig figs.

Verified that headers in cells B2:AEL3 match exported data order.

Verified that max values in cells B1908:AEL1908 are calculated correctly for each column.

Verified that time and total dose values for each source in cells AEN6:AFG1906 are calculated correctly for each source. Verified values were within same level of tolerance for exported values with four sig figs.

Verified that max values in cells AEO1908:AFG1908 are calculated correctly for each column.

Verified performance measure in cells AFH6:AFH1906 is correct.

Verified that sources listed in cells AFK1, AFN1 and AFQ1 have the three highest peak total doses.

Verified that radionuclides listed in cells AFK2:AFK4, AFN2:AFN4, and AFQ2:AFQ4 are the three highest peak radionuclide doses from each source.

Verified that the values in cells AFJ6:AFR1906 are the correct values to plot.

Worksheet: 'RuralPasture' (verification methodology identical to description provided for the worksheet 'WellDriller'

Verified values in cells A6:AEL1906. No difference (37 records) exceeded tolerance from a difference at the 4th significant digit. Checker only exported data values with 4 sig figs.

Verified that headers in cells B2:AEL3 match exported data order.

Verified that max values in cells B1908:AEL1908 are calculated correctly for each column.

Verified that time and total dose values for each source in cells AEN6:AFG1906 are calculated correctly for each source. Verified values were within same level of tolerance for exported values with four sig figs.

Verified that max values in cells AEO1908:AFG1908 are calculated correctly for each column.

Verified performance measure in cells AFH6:AFH1906 is correct.

Verified that sources listed in cells AFK1, AFN1 and AFQ1 have the three highest peak total doses.

Verified that radionuclides listed in cells AFK2:AFK4, AFN2:AFN4, and AFQ2:AFQ4 are the three highest peak radionuclide doses from each source. Technical comment: The third highest radionuclide for tank 241-C-301 is incorrect. This worksheet is implemented correctly, the error occurs on another worksheet that this worksheet is linked to get the data. That error is described for worksheet 'Top_10_RNs'. Fixing the error on that worksheet should correct the error on this worksheet once the evaluated expression is updated. Correction verified by observing the correction being made and saving the file and then protecting the changed file.

Verified that the values in cells AFJ6:AFR1906 are the correct values to plot (once the error on worksheet 'Top_10_RNs' is corrected).

Worksheet: 'CommercialFarm' (verification methodology identical to description provided for the worksheet 'WellDriller'

Verified values in cells A6:AEL1906. No difference (11 records) exceeded tolerance from a difference at the 4th significant digit. Checker only exported data values with 4 sig figs.

Verified that headers in cells B2:AEL3 match exported data order.

Verified that max values in cells B1908:AEL1908 are calculated correctly for each column.

Verified that time and total dose values for each source in cells AEN6:AFG1906 are calculated correctly for each source. Verified values were within same level of tolerance for exported values with four sig figs.

Verified that max values in cells AEO1908:AFG1908 are calculated correctly for each column.

Verified performance measure in cells AFH6:AFH1906 is correct.

Verified that sources listed in cells AFK1, AFN1 and AFQ1 have the three highest peak total doses.

Verified that radionuclides listed in cells AFK2:AFK4, AFN2:AFN4, and AFQ2:AFQ4 are the three highest peak radionuclide doses from each source.

Verified that the values in cells AFJ6:AFR1906 are the correct values to plot.

Worksheet: 'Table'

Electronically compared and verified table values match peak total doses calculated for each scenario and reported in cells AEO1908:AFG1908 of each of the worksheets listed above.

Verified by inspection that bolded values in the table are highest values for each scenario.

Editorial comment: Starred footnote (*) does not have a matching star (*) within the table.

Worksheet: 'Top_10_RNs'

The functionality in this worksheet is complex, each formula was inspected for consistency and the results of the formula were verified by comparing to ranks developed on the worksheets previously reviewed.

Formulas in cells B3:G3 were visually inspected and compared to ranks calculated from cells AEO1908:AFG1908 on worksheet 'WellDriller'.

Formulas in cells B4:B13 were visually inspected and compared to ranks calculated from cells ZN1908:ABD1908 on worksheet 'WellDriller'. After confirming functionality generated expected results, the remainder of the cells with similar expressions in this workbook were reviewed for consistency (rather than actually comparing against ranks).

Formulas and cell references in cells C4:G13 were reviewed for consistency with equivalent formulas in cells B4:B13. No discrepancies were noted. NOTE: Ranks for the 3 highest sources and 3 highest peak doses from each of these sources has already been confirmed on the worksheet 'WellDriller'.

Formulas in cells J3:O3 were reviewed for consistency with equivalent formulas in cells B3:G3, but ensuring that the referenced were linked to the worksheet for the Suburban Gardener scenario (which is referenced by named ranges).

Formulas in cells J4:O13 were reviewed for consistency with equivalent formulas in cells B3:G13, but ensuring that the referenced were linked to the worksheet for the Suburban Gardener scenario (which is referenced by named ranges). Non-impacting comment: With the exception of cell J4, formulas in cells J4:O13 are linked to the rank positions for the well driller scenario (Column A) instead of the adjacent cells for the Suburban Gardener scenario (Column I). Since the ranks are equivalent, the discrepancy has no impact on displayed results.

Formulas in cells B17:G17 were reviewed for consistency with equivalent formulas in cells B3:G3, but ensuring that the referenced were linked to the worksheet for the Rural Pasture scenario (which is referenced by named ranges). No discrepancies were noted.

Formulas in cells B18:G27 were reviewed for consistency with equivalent formulas in cells B3:G13, but ensuring that the referenced were linked to the worksheet for the Rural Pasture scenario (which is referenced by named ranges). Technical comment: The formulas in cells C18:G27 all point to the ranked sources for the well driller scenario (row 3) instead of the ranked sources for the Rural Pasture Scenario (row 17). This needs to be corrected. When the reference links are corrected, the impacted display of results on worksheet 'RuralPasture' should be confirmed to be changed and the rural pasture plots should be reviewed to ensure data display is correct. Correction verified by observing the correction being made and saving the file and then protecting the changed file.

Formulas in cells J17:O17 were reviewed for consistency with equivalent formulas in cells B3:G3, but ensuring that the referenced were linked to the worksheet for the Commercial Farm worker scenario (which is referenced by named ranges). No discrepancies were noted.

Formulas in cells J18:O27 were reviewed for consistency with equivalent formulas in cells B3:G13, but ensuring that the referenced were linked to the worksheet for the Commercial Farm worker scenario (which is referenced by named ranges). No discrepancies were noted.

Plot checking:

General editorial comments:

- Within a scenario, plotted ranges on the x- and y-axes should be consistent.
- For each scenario, the time should be plotted from time zero and the range constrained to only show applicable results since doses are calculated for all simulation times, even those that occur before a credible intrusion could occur.
- The number of sources or radionuclides on each plot should be consistent across all scenarios. If the top 3 radionuclides do not register on the scale of the y-axis, a note should be added.
- The colors used for each radionuclide should be consistent across all radionuclide dose plots (i.e. green for Pu239, purple for Pu240, and light orange for Am241 and other colors for the handful of other radionuclides that appear on one or more plots.
- It is noted that the radionuclide plots for specific sources all link to column A for time instead of the column AEN which is the time associated with the data in the charts. The values are the same so there is no discrepancy and a change does not have to be made.

- Consider using consistent tank names in plot titles (e.g., '241-C-201' instead of 'C201'). Tank names in other plots use the longer version of the name.

General comments pertaining to worksheets WD_Chart, WD_C301_by_RN_Chart, WD_C201_by_RN_Chart, and WD_C202_by_RN_Chart. Other than general editorial comments, no discrepancies were observed. Labels and legend text were reviewed.

General comments pertaining to worksheets SG_Chart, SG_C301_by_RN_Chart, SG_Pipeline_by_RN_Chart, and SG_C201_by_RN_Chart. Other than general editorial comments, the legend on SG_Chart is inconsistent with the plotted data. Pipeline data that starts at 100 years is labeled CR-Vault. Also, C203 is not a top source, it should be replaced with C101 if the number of sources shown is retained. Labels and legend text were reviewed. Correction verified by observing the correction being made and saving the file and then protecting the changed file.

General comments pertaining to worksheets RP_Chart, RP_Pipeline_by_RN_Chart, RP_C301_by_RN_Chart, and RP_C201_by_RN_Chart. Other than general editorial comments, confirm updates to plots are correct when error on worksheet 'Top_10_RNs' is corrected. Labels and legend text were reviewed. Correction verified by observing the correction being made and saving the file and then protecting the changed file.

General comments pertaining to worksheets CF_Chart, CF_C301_by_RN_Chart, CF_C201_by_RN_Chart, and CF_C202_by_RN_Chart. Other than general editorial comments, no discrepancies were observed. Labels and legend text were reviewed.

Review of Intruder_Results_WMA_C_Special_Analysis.20200728.xlsx dated 7/29/2020 @ 07:53 AM

Confirmed sheets protected after past checker were still protected (WellDriller, SuburbanGardener, CommercialFarm, RuralPasture, and Top_10_RNs.

Reviewed values in "Table" and confirmed all listed values were computed correctly and peaks for specific date ranges were based on the correct range. Inventory is based on 2020 = simulation time 0 yrs, so 2150 = 130 years simulation time.

Confirmed values in "Timeline" match descriptions.

Made comment that the new X-Axis label is incorrect. The plotted time was not shifted from Time 0 = 2020 to Time 0 = 2278 as suggested by the label. This comment impacts all the plots. Action was to correct the label rather than adjust the plots. Correction verified in Intruder_Results_WMA_C_Special_Analysis.20200728_r2.xlsx dated 8/11/2020 at 3:25 PM.

Verified WD_Chart, WD_C301_by_RN_Chart, WD_C201_by_RN_Chart, WD_C202_by_RN_Chart linked to correct data vales. Also verified SG charts, RP charts, and CF charts. Verified new C301 and Pipeline by scenario charts as well.

Verified tabulated values in Pathway_Contributions_Tables.xlsx dated 7/28/2020 @ 4:24 PM. Compared via replication using values extracted directly from the model and calculating the fraction of the total for each pathway.

Intruder_Results_WMA_C_Special_Analysis.20200728_r2.xlsx dated 8/11/2020 at 3:25 PM

Verified values in unprotected sheet 'Tables' were unchanged from last time they were checked.

Added worksheet 'CERCLA_ROD_Time_Series' performs the correct calculation (spot check simple formula in cells from Columns A and AEN.

Reviewed plots to ensure any changes were consistent with expected changes. Visually compared plots to previously checked plots to make sure plot ranges, trends, lines, and labels matched. Verified that the x-values for each line were changed to the shifted time in 'CERCLA_ROD_Time_Series'.

Noted on WD_Chart plot for C-107 was not linked to shifted time, this is not plotted so there is no impact on the displayed values. Correction verified in Intruder_Results_WMA_C_Special_Analysis.20200728_r2.xlsx dated 8/13/2020 at 6:55 AM.

Noted on SG_Pipeline_by_RN_Chart plot was missing "#6" label for line at @ 500 years post-closure and that the 'Series name' for the Performance Objective line was linked to an arbitrary cell. Correction verified in Intruder_Results_WMA_C_Special_Analysis.20200728_r2.xlsx dated 8/13/2020 at 6:55 AM

Noted on CF_C301_By_RN_Chart plot for Performance Objective was not linked to shifted time, but line displays correctly (plotted against 2nd x-axis??) Same for performance objective plots in CF_C201_By_RN_Chart, CF_C202_By_RN_Chart, and C301_By_Scenario_Chart. Correction verified in Intruder_Results_WMA_C_Special_Analysis.20200728_r2.xlsx dated 8/13/2020 at 6:55 AM

Pipeline_By_Scenario_Chart was not updated and has no labels for time line plots. Correction verified in Intruder_Results_WMA_C_Special_Analysis.20200728_r2.xlsx dated 8/13/2020 at 6:55 AM

Intruder_Results_WMA_C_Special_Analysis.20200728_r3.xlsx dated 11/11/2020 at 1:53 PM

An update to the inventory of C-106 residuals was added to the source model on 11/5/2020. The analysis was re-run with the new inventory and the new results for C-106 were copied out of the model file into the previously checked spreadsheet. Running the model and copying the data into the spreadsheet was observed by the checker in real-time. Careful attention was made to ensure that the C-106 data was pasted into the correct locations in the spreadsheet.

Following the updates to the spreadsheets, the graphics in the report were updated using the graphs in the updated spreadsheet. Again this was done in real-time.

No discrepancies were observed.

K Pat Lee

Digitally signed by K Pat Lee
Date: 2020.12.09 09:55:46 -08'00'