U.S. Department of Energy
Hanford Site

November 28, 2023

23-TWO-0007

Mr. David Bowen, Program Manager
Nuclear Waste Program
Washington State Department of Ecology
3100 Port of Benton Boulevard
Richland, Washington 99354

Dear Mr. Bowen:

U.S. DEPARTMENT OF ENERGY SUBMISSION OF THE RETRIEVAL DATA REPORT FOR TANK 241-AX-103

This letter transmits the U.S. Department of Energy (DOE) RPP-RPT-64284, "Retrieval Data Report for Single-Shell Tank 241-AX-103," Rev. 00, to the Washington State Department of Ecology (Ecology), in accordance with the requirements of the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) and completes Milestone M-045-86M. Per the milestone requirements, RPP-RPT-64284 is due on January 17, 2024. This retrieval data report presents information that the single-shell tank 241-AX-103 has undergone waste retrieval using two retrieval technologies, each to its limits of the respective technology.

DOE transmitted the Retrieval Completion Certification Report for Tank 241-AX-103 to Ecology via DOE letter 23-TF-000067, dated January 17, 2023, which certified retrieval completion and established the 12-month due date for this milestone as January 17, 2024.

If you have any questions, please contact Paul A. Schroder, Deputy Assistant Manager, Tank Waste Operations, at (509) 373-8939.

Sincerely,

Delmar L. Noyes

Digitally signed by Delmar L. Noyes
Date: 2023.11.28 11:25:17 -08'00'

Delmar L. Noyes, Assistant Manager
Tank Waste Operations

TWO:JTG

Attachment: RPP-RPT-64284 Rev.00

cc w/ attach: See page 2

cc w/ attach: J. Alzheimer, Ecology
J. Bell, NPT
H.M. Bowers, WRPS
W.H. Bryan, WRPS
C. Buck, Wanapum
L. Contreras, YN
D. R. Einan, EPA
H.M. Hamilton, WRPS
J.T. Hamilton, WRPS
T. Q. Howell, Ecology
J. J. Lyon, Ecology
M. Murphy, CTUIR
A.R. Olander, WRPS
J. K. Perry, HMIS
E. A. Rochette, Ecology
M. J. Turner, HMIS
M. Woods, ODOE
Administrative Record (S-2-4)
Environmental Portal
HAB Facilitation
WRPS Correspondence

Attachment
23-TWO-0007

Retrieval Data Report for Single Shell Tank 241-AX-103

RPP-RPT-64284 Rev.00

(102 Pages Including Cover Sheet)

DOCUMENT RELEASE AND CHANGE FORM

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

Release Stamp

DATE:
Oct 30,2023
HANFORD RELEASE

1. **Doc No:** RPP-RPT-64284 **Rev.** 00

2. **Title:**
Retrieval Data Report for Single Shell Tank 241-AX-103

3. **Project Number:** ☒N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Aardal, Janis D	*Aardal, Janis D*	10/30/2023
Document Control Approval	Meinecke, Kathryn R	*Meinecke, Kathryn R*	10/30/2023
Originator	Prindiville, Kerry A	*Prindiville, Kerry A*	09/07/2023
Other Approver	Smith, David A	*Smith, David A*	09/28/2023
Responsible Manager	Bergeron, Marcel P	*Bergeron, Marcel P*	09/28/2023

8. **Description of Change and Justification**

Initial release.

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☐N/A	b. **Related Systems** ☒N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A
241-AX-103		

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☒N/A

Document Number	Rev.	Title

14. **Distribution**

Name	Organization
Bergeron, Marcel P	CLOSURE & INTERIM MEASURES
Field, Jim G	PROCESS ENGINEERING
Hamilton, Peggy	SST RETRIEVALS
Olander, Alan R	PROCESS & INTEGRITY ENG
Parkman, David B	S FARM RETRIEVAL ENGINEERING
Prindiville, Kerry A	CLOSURE & INTERIM MEASURES
Smith, David A	SST RETRIEVALS PROJECT MGMT
Stevens, Michael	SST RETRIEVALS PROJECT MGMT
Watson, David (Dj) J	CLOSURE & INTERIM MEASURES

INFORMATION CLEARANCE REVIEW AND RELEASE APPROVAL

Part I: Background Information

Title: Retrieval Data Report for Single Shell Tank 241-AX-103	Information Category: ☐ Abstract ☐ Journal Article ☐ Summary ☐ Internet ☐ Visual Aid ☐ Software ☐ Full Paper ☑ Report ☐ Other
Publish to OSTI? ☐ Yes ☑ No	
Trademark/Copyright "Right to Use" Information or Permission Documentation	Yes ☐ NA ☑
Document Number: RPP-RPT-64284 Revision 0	Date: October 2023
Author: Prindiville, Kerry A	

Part II: External/Public Presentation Information

Conference Name:		
Sponsoring Organization(s): DOE ORP		
Date of Conference:	Conference Location:	
Will Material be Handed Out? ☐ Yes ☑ No	Will Information be Published? ☐ Yes ☑ No	*(If Yes, attach copy of Conference format instructions/guidance.)*

Part III: WRPS Document Originator Checklist

Description	*Yes*	*N/A*	*Print/Sign/Date*
Information Product meets requirements in TFC-BSM-AD-C-01?	☑	☐	Prindiville, Kerry A Approved via att. IDMS data file.
Document Release Criteria in TFC-ENG-DESIGN-C-25 completed? (Attach checklist)	☐	☑	
If product contains pictures, safety review completed?	☑	☐	Prindiville, Kerry A Approved via att. IDMS data file.

Part IV: WRPS Internal Review

Function	*Organization*	*Date*	*Print Name/Signature/Date*
Subject Matter Expert	WRPS		Prindiville, Kerry A Approved via att. IDMS data file.
Responsible Manager	WRPS		Bergeron, Marcel P Approved via att. IDMS data file.
Other:			

Part V: IRM Clearance Services Review

Description	*Yes*	*No*	*Print Name/Signature*
Document Contains Classified Information?	☐	☑	If Answer is "Yes," ADC Approval Required Print Name/Signature/Date
Document Contains Information Restricted by DOE Operational Security Guidelines?	☐	☑	Reviewer Signature: Print Name/Signature/Date
Document is Subject to Release Restrictions? *If the answer is "Yes," please mark category at right and describe limitation or responsible organization below:*	☐	☑	Document contains: ☐ Applied Technology ☐ Protected CRADA ☐ Personal/Private ☐ Export Controlled ☐ Proprietary ☐ Procurement – Sensitive ☐ Patentable Info. ☐ OUO ☐ Predecisional Info. ☐ UCNI ☐ Restricted by Operational Security Guidelines ☐ Other (Specify)
Additional Comments from Information Clearance Specialist Review?	☐	☑	Information Clearance Specialist Approval APPROVED By Julia Raymer at 2:31 pm, Oct 24, 2023 Print Name/Signature/Date

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INFORMATION CLEARANCE REVIEW AND RELEASE APPROVAL

Part VI: Final Review and Approvals

Description	Approved for Release: Yes	Approved for Release: N/A	Print Name/Signature
WRPS External Affairs	☑	☐	Approved via att. IDMS data file.
WRPS Office of Chief Counsel	☑	☐	Approved via att. IDMS data file.
DOE – ORP Public Affairs/Communications	☑	☐	Approved via att. IDMS data file.
Other: DOE SME	☑	☐	Approved via att. IDMS data file.
Other:	☐	☐	

Comments Required for WRPS-Indicate Purpose of Document:

Photos from other release documents and photos of laboratory samples.

APPROVED
By Julia Raymer at 2:33 pm, Oct 24, 2023

Approved for Public Release; Further Dissemination Unlimited

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Was/Is Information Product Approved for Release? ☑ Yes ☐ No

If Yes, what is the Level of Releaser? ☑ Public/Unrestricted ☐ Other (Specify) ______

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RPP-RPT-64284
Revision 0

Retrieval Data Report for Single-Shell Tank 241-AX-103

Prepared by:

K. A. Prindiville
Washington River Protection Solutions, LLC

Date Published
September 2023

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

Contract No. DE-AC27-08RV14800

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EXECUTIVE SUMMARY

This retrieval data report presents information in accordance with the requirements of *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989) Milestone M-045-86M, due 12 months after the U.S. Department of Energy (DOE) certifies to the State of Washington Department of Ecology (Ecology) that DOE has completed retrieval of a single-shell tank covered by the Consent Decree in *State of Washington v. Dept. of Energy*, Case No. 2:08-cv-05085-FVS (E.D. WA October 25, 2010)[1] (hereinafter "Consent Decree"). The DOE submitted its certification of retrieval, RPP-RPT-63983, *Retrieval Completion Certification Report for Tank 241-AX-103*, to Ecology on January 17, 2023 (Letter 23-TF-000067, "The U.S. Department of Energy Submits RPP-RPT-63983, "Retrieval Completion Certification Report for Tank 241-AX-103," Rev. 0, to the Washington State Department of Ecology").

This document presents information that single-shell tank 241-AX-103 has undergone waste retrieval using two retrieval technologies identified in RPP-RPT-58934, *241-AX-103 Tank Waste Retrieval Work Plan*. Extended reach sluicing and high-pressure water were used to complete retrieval activities each to its limit of technology. The waste retrieval operations for tank 241-AX-103 began on August 5, 2021, with the extended reach sluicing system. The sluicing and high-pressure water technologies were used concurrently to achieve maximum capabilities of waste removal. Retrieval was suspended on February 14, 2022, when the last batch of waste was transferred to double-shell tank 241-AZ-102. On February 17, 2022, DOE concluded that the limits of removal technology had been met and a final flush of the transfer equipment was performed. All waste removed from tank 241-AX-103 was transferred to double-shell tank 241-AZ-102 (RPP-RPT-63691, *Retrieval Completion Report for Extended Reach Sluicing and High Pressure Water of Single-Shell Tank 241-AX-103*).

Prior to retrieval, the estimated waste volume was ~15,012 ft^3 (112,300 gal), per RPP-CALC-65050, *Tank 241-AX-103 Retrieval Tracking Volume Calculation*. Following retrieval, tank 241-AX-103 was estimated to contain ~785 ft^3 (5,875 gal) of residual waste. The residual waste volume was estimated using a Residual Volume Measurement System (RVMS or laser scanning) and video (RPP-RPT-63817, *Laser Scanning Waste Volume Estimates for Tank 241-AX-103*). This volume did not meet the Consent Decree residual waste volume target of 360 ft^3 (2,693 gal), so RPP-RPT-63929, *Practicability Evaluation Request to Forego a Third Retrieval Technology for Tank 241-AX-103* was developed to assess whether a third waste retrieval technology should be implemented at tank 241-AX-103. RPP-RPT-63929 was issued in October 2022. The Practicability Evaluation Request concluded that the two waste retrieval technologies were deployed at tank 241-AX-103 to their respective limits of technology, and that implementation of a third technology was not practicable as that term is used in Appendix C, Part 1, of the Consent Decree in *Washington v. DOE*, Case No. 2:08-cv-05085-FVS. Ecology

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

agreed with the Practicability Evaluation Request (22-NWP-180, "Re: Approval of the United States Department of Energy's Request to Forego a Third Technology for Tank 241-AX-103").

Along with providing details on the retrieval technologies deployed, and their respective performance during the waste retrieval operations, the information in this document also describes measures taken to prevent and detect leaks during waste retrieval operations and summarizes the potential risk to human health from waste remaining in the tank.

Tank 241-AX-103 leak detection, monitoring, and mitigation implemented during retrieval activities consisted of high-resolution resistivity monitoring, drywell moisture readings, waste volume assessments (mass balances), and visual inspections to detect and control potential leaks. Leak detection and monitoring data showed no evidence of any leak or contaminant movement in the drywells during or after tank 241-AX-103 retrieval operations (HGLP-MBL-026, *Hanford Geophysical Logging Project 241-AX-103 Post-Retrieval Drywell Monitoring Report*).

Laboratory analysis of waste samples provided the inventory of constituents for the residual waste in tank 241-AX-103. A model analysis of the release and the environmental transport of these inventories were modeled to estimate possible future concentration levels of constituents of potential concern (COPCs) in the saturated zone at the Waste Management Area fenceline. The results were used to evaluate both cancer risks and non-cancer hazards from chemicals using the U.S. Environmental Protection Agency's residential tap water scenario. These modeled concentrations are also used to demonstrate compliance with the *Model Toxics Control Act* (*Revised Code of Washington* 70A.305, "Hazardous Waste Cleanup—Model Toxics Control Act") by comparing them to groundwater cleanup levels specified in the January 2023 edition of Cleanup Levels and Risk Calculation (CLARC) (Cleanup Levels and Risk Calculation [CLARC], Queried 5/08/2023, [CLARC data tables and other technical information], https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables).

Modeled groundwater concentrations for selected key radionuclides are used to evaluate compliance with the regulatory standard for a beta/photon-emitter dose of 4 mrem/yr. using the dose coefficients reported in DOE-STD-1196-2021, *Derived Concentration Technical Standard*. Additionally, modeled concentrations of radionuclides in groundwater are also used to evaluate potential future impacts to a receptor from tank 241-AX-103 residual waste using different exposure scenarios.

The following conclusions are based on the risk assessment results.

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

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

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

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

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

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

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

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

Specific details associated with the retrieval of tank 241-AX-103 tank waste, residual waste calculation, analysis of remaining waste and risks associated with the residuals, leak detection and monitoring, and opportunities for improvement can all be found within this document.

RPP-RPT-64284, Rev. 0

TABLE OF CONTENTS

APPENDICES

FIGURES

TABLES

TERMS

3D	three-dimensional
ALC	air lift circulator
AX-102	Tank 241-AX-102
AX-103	Tank 241-AX-103
AX-104	Tank 241-AX-104
AZ-102	Tank 241-AZ-102
BBI	Best-Basis Inventory
BBIM	Best-Basis Inventory Maintenance
C-102	Tank 241-C-102
CFR	*Code of Federal Regulations*
CI	confidence interval
COPC	constituent of potential concern
DOE	U.S. Department of Energy
DST	double-shell tank
DQO	data quality objective
EB	equipment blank
Ecology	State of Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
ERS	extended reach sluicer
ERSS	extended reach sluicing system
GPC	Gas Flow Proportional Counting
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HHNM	handheld neutron moisture
HI	Hazard Index
HPW	high-pressure water

HQ	Hazard Quotient
HRR	high-resolution resistivity
ICP	inductively coupled plasma
K_d	distribution coefficient
LDMM	leak detection, monitoring, and mitigation
MCL	maximum concentration level
MS	mass spectrometry
MTCA	*Model Toxics Control Act*
ORP	DOE Office of River Protection
ORSS	off-riser sampling system
P2	PUREX high-level waste
PA	performance assessment
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzofuran
PUREX	Plutonium Uranium Extraction
QA	quality assurance
RCRA	*Resource Conservation and Recovery Act of 1976*
RSD	relative standard deviation
RVMS	Residual Volume Measurement System
SB	sampling blank
SEM-EDX	scanning electron microscopy/ energy dispersive X-ray spectrometry
SST	single-shell tank
SVOC	semi volatile organic compounds
TB	trip blank
TIC	tentatively identified compound

TOC	total organic carbon
TWRWP	Tank Waste Retrieval Work Plan
UCL	upper confidence level
U_{TOTAL}	total uranium
VOC	volatile organic compounds
WMA	Waste Management Area
WTP	Waste Treatment Plant
WTT	well to tank
WTW	well to well

UNITS

degree	
Ci	curie
ft	feet
ft^3	cubic feet
gal	gallon(s)
in.	inch
kg	kilogram
L	liter
mg	milligram
mrem	millirem
psi	pounds per square inch
µCi	microcurie
µg	microgram

RETRIEVAL DATA REPORT FOR TANK 241-AX-103

Pursuant to

Consent Decree in Case No. 2:08-cv-08-050850-FVS
(*State of Washington v. Department of Energy* [E.D. Wa. October 25, 2010])

Including the following subsequent amendments

No: 2:08-cv-05085-RMP (March 11, 2016)

No: 2:08-cv-05085-RMP (April 12, 2016)

No. 2:08-cv-05085-RMP (October 12, 2018)

No: 2:08-cv-05085-RMP (December 10, 2020)

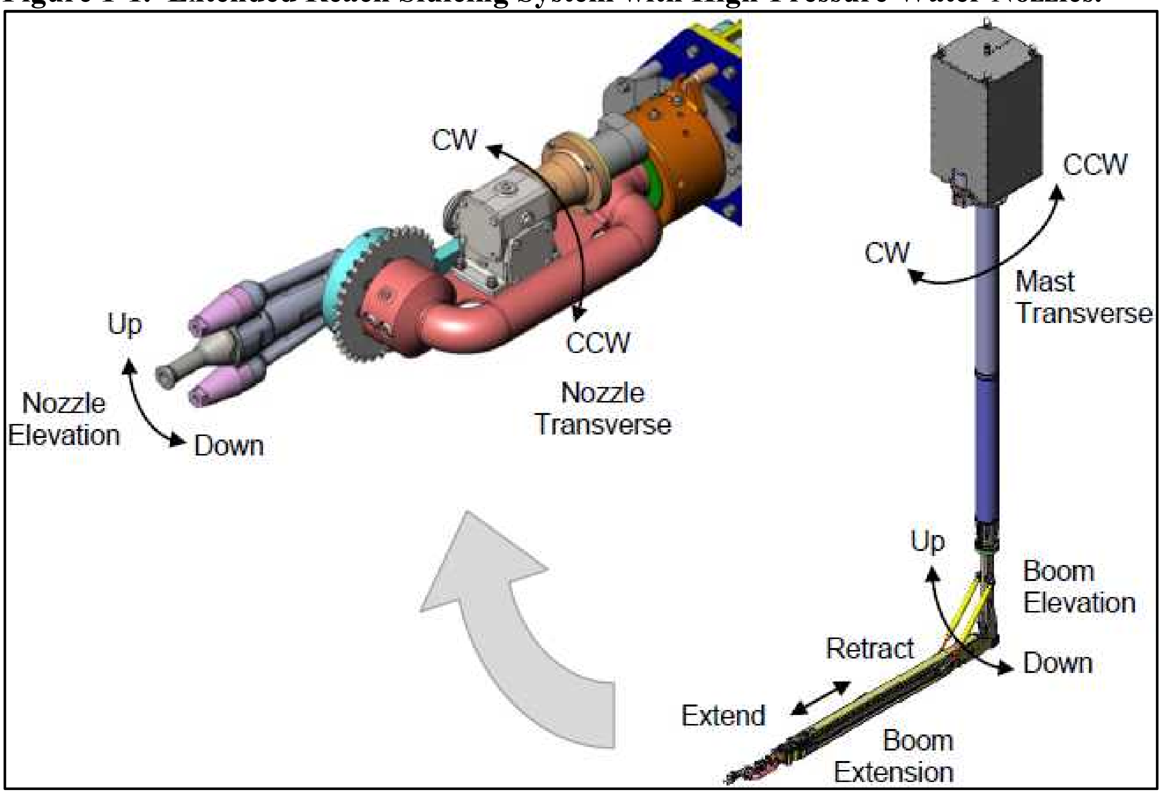
No: 2:08-cv-05085-RMP (July 18, 2022)

1. INTRODUCTION AND BACKGROUND

Tank 241-AX-103 (AX-103) is a nominal 1,000,000-gal capacity single-shell tank (SST) that has been used to store radioactive waste since 1966. Tank AX-103 first received waste from the Plutonium Uranium Extraction (PUREX) Plant and then received waste from B-Plant before it was sluiced from 1976 to 1977. The tank was then used as a receiving tank for the 242-A Evaporator waste until it was declared inactive in 1980. Finally, it was interim stabilized in August 1987 (RPP-RPT-63691, *Retrieval Completion Report for Extended Reach Sluicing and High Pressure Water of Single-Shell Tank 241-AX-103*; RPP-RPT-58934, *241-AX-103 Tank Waste Retrieval Work Plan*; and RPP-RPT-59854, *Derivation of Best-Basis Inventory for Tank 241-AX-103 as of April 1, 2023*).

At the start of retrieval operations, the tank waste volume was 112,300 gallons consisting of supernate, saltcake, and sludge waste forms. Tank AX-103 waste retrieval operations were conducted between August 5, 2021, and February 14, 2022. They were performed in a series of campaigns using a modified sluicing system with an extended reach sluicing system (ERSS), an adjustable height slurry pump, and high-pressure water (HPW) nozzles with water and recirculated supernate waste (Figure 1-1), as planned in RPP-RPT-58934. Modified sluicing and HPW nozzle technologies removed approximately 91.7% of the waste from tank AX-103 (RPP-CALC-65050, *Tank 241-AX-103 Retrieval Tracking Volume Calculation*).

Figure 1-1. Extended Reach Sluicing System with High-Pressure Water Nozzles.



CCW = counter-clockwise CW = clockwise

Tank AX-103 was declared retrieved and RPP-RPT-63691 was published. Tank AX-103 was declared retrieved to the limits of these technologies with a preliminary remaining waste volume estimate of 1,330 ft^3 (9,952 gal) of waste remaining based on liquid displacement measurement and visual evaluation (RPP-CALC-65050).

Using more precise video and laser scanning technology, the final residual waste estimate was determined to be 785 ft^3 (5,875 gal) (RPP-RPT-63817, *Laser Scanning Waste Volume Estimate for Tank 241-AX-103*). The residual waste remaining in the tank includes solids on the bottom, waste remaining on the walls, stiffener rings, and on equipment such as air lift circulators (ALCs) and thermocouples.

In accordance with Appendix C, Part 1, of the Consent Decree in *State of Washington v. Dept. of Energy*, Case No. 2:08-cv-05085-FVS (E.D. WA. October 25, 2010)[2] (hereinafter "Consent Decree"), RPP-RPT-63929, *Practicability Evaluation Request to Forego a Third Retrieval Technology for Tank 241-AX-103* was developed to assess whether a third waste retrieval technology should be implemented at tank AX-103. RPP-RPT-63929, issued in October 2022, determined that implementing a third technology was impractical under the terms of the Consent Decree, Appendix C, Part 1.

The U.S. Department of Energy (DOE) Office of River Protection (ORP) formally requested the State of Washington Department of Ecology (Ecology) to agree with DOE's request to forego implementation of a third technology in a November 2, 2022, letter from D. L. Noyes to D. B. Bowen (Letter 22-TF-003412, "Request for Washington State Department of Ecology Agreement that the U.S. Department of Energy may Forego Implementing a Third Retrieval Technology in Tank 241-AX-103").

Ecology agreed with this request on December 6, 2022, via a letter from J. J. Lyon to P. A. Schroder (Letter 22-NWP-180, "Re: Approval of the United States Department of Energy's Request to Forego a Third Technology for Tank 241-AX-103").

Where information regarding treatment, management, and disposal of the radioactive source, byproduct material, special nuclear material (as defined by the *Atomic Energy Act of 1954*, as amended) and/or the radionuclide component of mixed waste has been incorporated into this document, it is not incorporated for the purpose of regulating the radiation hazards of such components under the authority of RCW 70A.300, "Hazardous Waste Management" (known as the *Hazardous Waste Management Act*) and its implementing regulations, but is provided for information purposes only.

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

1.1 PURPOSE

Transmittal of this document fulfills the requirement of *Hanford Federal Facility Agreement and Consent Order* (HFFACO) Milestone M-045-86M (Ecology et al., 1989) for tank AX-103 retrieval.

1.2 REGULATORY REQUIREMENTS

Waste retrieval from tank AX-103 and submittal of this document (in accordance with conditions stated in the HFFACO) are required for closing the Hanford SST system. The HFFACO Milestone M-045-86M provides in part:

> "Submit a retrieval data report to Ecology for the 19 tanks retrieved under the Consent Decree in *Washington v. DOE*, Case No. 08-5085-FVS, which report shall include the following elements only of Section 2.1.7 of Appendix I to the HFFACO:
> 1) Residual tank waste volume measurement, including associated calculations;
> 2) The results of residual tank waste characterization;
> 3) Retrieval technology performance documentation;
> 4) DOE's updated post-retrieval risk assessment;
> 5) Opportunities and actions being taken to refine or develop tank waste retrieval technologies, based on lessons learned and,
> 6) LDMM *[leak detection, monitoring, and mitigation]* monitoring and performance results."

The Consent Decree, Appendix C, Part 1, states that:

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

A Practicability Evaluation, RPP-RPT-63929, addressed the limits of technology and concluded that a further waste retrieval action for tank AX-103 was not practicable. The DOE submitted the Practicability Evaluation to the State of Washington with a request to forego implementing a third retrieval technology, and on December 6, 2022, via letter 22-NWP-180 the State of Washington (Ecology) concurred with that request.

1.3 DOCUMENT STRUCTURE

This tank AX-103 Retrieval Data Report is organized to present information required by Milestone M-045-86M of the HFFACO Action Plan.

- Section 1, Introduction and Background discusses the purpose and scope of tank AX-103 waste retrieval, presents requirements applicable to this report, and outlines the report structure.

- Section 2, Single-Shell Tank 241-AX-103 Residual Waste Volume Measurement describes the method and associated calculations for determining the residual waste volume in tank AX-103 and presents volume measurement results.

- Section 3, Residual Tank Waste Characterization lists requirements for characterizing tank waste, describes methods and procedures used to sample and analyze the waste, and describes the laboratory analysis results.

- Section 4, Retrieval System Performance evaluates how well the waste retrieval system performed and compares actual performance against predicted performance.

- Section 5, Post-Retrieval Single-Shell Tank 241-AX-103 Risk Assessment describes the potential risk to human health from tank AX-103 residual waste. This section identifies and discusses constituents of potential concern (COPCs) in the waste, describes the effects of waste retrieval and closure on long-term human health risk, predicts cumulative health effects of source terms, relates calculated risk to residual waste volume, and summarizes overall conclusions of the risk assessment.

- Section 6, Leak Detection, Monitoring, and Mitigation describes leak detection, monitoring, and mitigation (LDMM) methods, procedures, and associated calculations; presents an LDMM chronology for tank AX-103 waste retrieval; and summarizes LDMM results.

- Section 7, Opportunities and Actions Being Taken to Refine or Develop Tank Waste Retrieval Technologies, Based on Lessons Learned discusses recommendations for future actions associated with tank AX-103 and actions being taken based on lessons learned.

- Section 8, References contains references for material cited in the report.

2. SINGLE-SHELL TANK 241-AX-103 RESIDUAL WASTE VOLUME MEASUREMENT

This section presents the residual waste volume measurement process and the results for tank AX-103. The post-retrieval residual waste volume estimate was performed using a method described in RPP-RPT-63817.

The total measured volume of residual waste in tank AX-103 is the sum of waste volumes remaining in the tank bottom, on the tank walls and stiffener rings, on ALCs and on risers and instruments. The residual waste volume used for upper-bound calculations in this Retrieval Data Report is the waste volume reported as the 95% upper confidence level (UCL) as shown in Table 2-1.

Table 2-1. Estimated Residual Waste in Tank 241-AX-103.

Component	Actual Waste Volume		95% UCL (ft^3)[a]	95% UCL (gal)
	ft^3	gal		
Tank bottom solids	687	5,139	947	7,081
Waste on walls, stiffener rings, air lift circulators, risers and instruments[b]	98	736	98	736
Total[c]	785	5,875	1,045	7,817

UCL = upper confidence level

[a] Per RPP-23403, *Single-Shell Tank Component Closure Data Quality Objective*, the actual waste volume is the measured Residual Volume Measurement System volume. One standard deviation for the Leica BLK360 (a product of Leica Geosystems AG – Part of Hexagon, Heerbrugg, Switzerland) is ±6 mm. The 95% UCL is the actual plus two times the standard deviation.
[b] The 95% UCL volume is assumed to be equal to the calculated volume for the walls, stiffener rings and waste in air lift circulators, risers, and instruments.
[c] Totals rounded to nearest gallon and cubic foot. Total sums may differ due to rounding.

2.1 RESIDUAL WASTE VOLUME MEASUREMENT PROCESS

Sections 2.2 and 2.3 summarize the waste volume measurement approach, which is described in RPP-RPT-63817. The residual waste volume was estimated using Residual Volume Measurement System (RVMS or laser scanning) estimates for the waste volume in tank AX-103 following the completion of retrievals using modified sluicing and HPW. A liquid displacement measurement was used for a preliminary estimate of the waste volume after sluicing with ERSS and HPW. The liquid displacement estimate uses construction drawings and waste height for the starting volume estimate with liquids covering the waste and subtracts the volume of liquids and waste removed to determine the volume of waste remaining. The laser scans were obtained in May and June 2022, after the displacement measurement, allowing time for the evaporation of most of the liquid pools by forced air ventilation. The laser scans and videos provide estimates for waste areas and waste depth in the tank and an estimate for waste on the tank walls, stiffener rings and equipment. The laser scan showed the actual configuration of the tank compared to tank construction drawings and provided three-dimensional (3D) point cloud measurements of the waste surface.

In-tank video was used to supplement laser scan volume estimates for waste on the walls, stiffener rings, ALCs, risers, and instruments.

2.2 LASER EVALUATION

The post-retrieval laser waste volume was determined per TFC-ENG-FACSUP-C-40, "Supplemental Tank Waste Volume Estimates." The laser scans were completed on May 26, 2022, and June 2, 6, and 8, 2022 from Risers 9B, 9D, 9E and 9G (Figure 2-1). Two scans were taken at three different elevations: 1) in the tank dome just after the scanner emerged from the riser, 2) about midway between the floor and the top of the ALCs, and 3) just above the tank floor under the ALCs (30 in. from tank bottom). Each scan was taken using a Leica BLK360 scanner[3] and provides a 360-degree view of the tank walls and tank bottom and measures from the scanner location to points on the tank or waste surface. Scans were registered (merged) using Leica Register 360 software to create a single unified 3D point cloud. The merged scan effectively combined the scan results for each of the individual scans and scan heights, removed shadows present in individual scans and provided a complete scan and image of the tank bottom showing the best available scan data from each scan location.

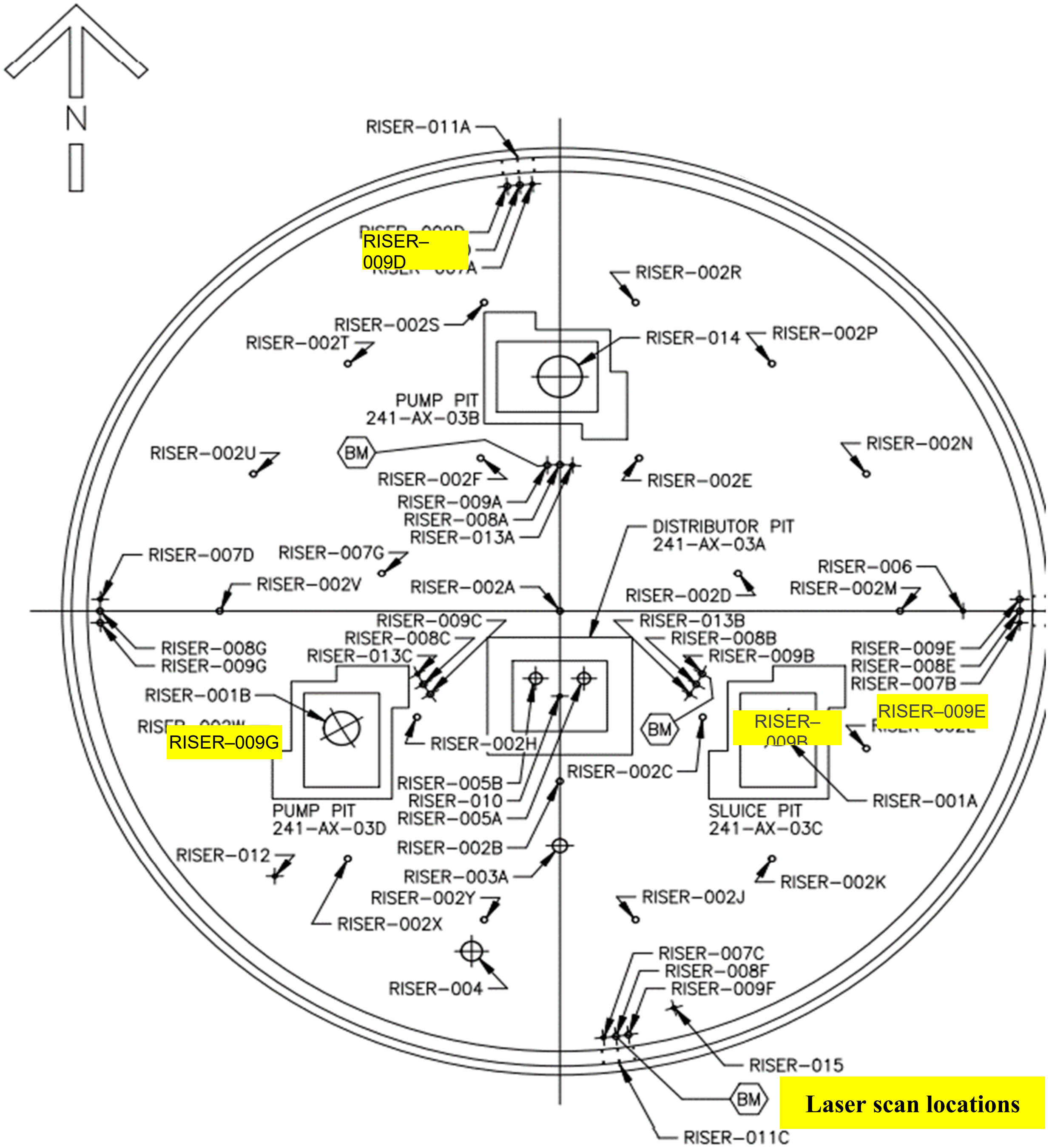
The 3D point cloud laser data was evaluated using Cyclone 3DR software to map the waste surface above the tank bottom, to determine the volume of waste on the tank bottom. The laser scanning process and modeling approach are described in detail in Appendix A of RPP-RPT-63817. The following is a summary of the modeling approach and results.

The laser scan was first evaluated to show elevation differences from the tank floor (Figure 2-2). The distance between a selected fixed starting point and the waste surface was measured. The height of the tank/waste surface varied from -0.584 to 14.7 inches. The height of waste surface is in relation to the location of an origin point determined to be tank bottom. In this figure small portions of the analyzed area were below the origin point resulting in the negative number -0.584; this does not impact the waste volume calculations. The thickest waste was observed near the south and west edges of the tank.

Bare floor was observed along ripples and at the lowest points in the tank. When waste was visible on the tank ripples or on tank floor debris such as pipes and tape coils, the waste thickness was assumed to be the same as the waste thickness adjacent to the ripples or tank floor debris. Debris protruding above the surrounding waste was omitted from the tank floor waste volume. Figure 2-3 shows a high-resolution photo of the tank interior.

[3] Leica BLK360 scanner, and Leica Register 360 and Cyclone 3DR software, are products of Leica Geosystems AG - Part of Hexagon, Heerbrugg, Switzerland.

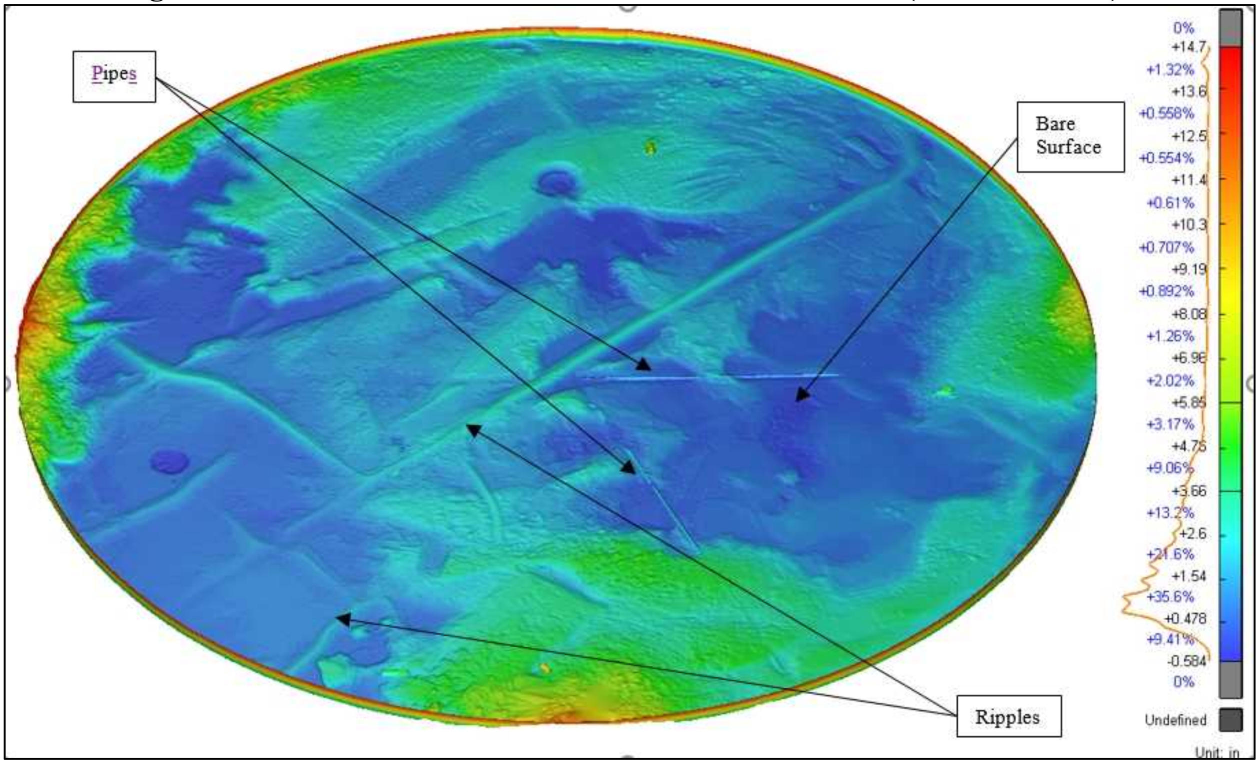
Figure 2-1. Tank 241-AX-103 Tank Profile, Air Lift Circulators and Risers.



Air Lift Circulators: Risers 002A through 002Y

Reference: H-14-010609, "Waste Storage Tank (WST) Riser Data."

Figure 2-2. Tank 241-AX-103 Waste Surface Laser Scan (lower surfaces).



Note: Black scale values are distances from a selected point in inches. Blue values and the orange line next to the scale indicate percent of colorized surfaces measured at each level. The scale ranges from -0.584-in. to 14.7 inches.

Figure 2-3. Tank 241-AX-103 High-Resolution Photo of the Tank Interior, June 6, 2022.

The estimated volume of waste on the tank bottom, calculated using a laser scan estimate, was 687 ft^3 (5,139 gal).

The volume of waste on the walls and stiffener rings was also estimated based on the laser scan. However, the walls were mostly clean, with many locations showing bare metal with no apparent waste (Figure 2-4). Where waste appeared to be present there was no discernable waste depth from the laser scans due to laser scan accuracy. As described in RPP-RPT-63817, given laser scan uncertainty for thin layers of waste, an average waste thickness of 1/32-inch was assumed over the entire surface area of the walls, and on stiffener rings, ALCs and risers (inside and out), and instruments where a waste depth was not discernible by the laser scanner or the waste surface was hidden from view of the laser scans.

Combining laser scan measurements and estimates where the waste thickness was assumed to be 1/32-inch, the volume of waste on the walls, stiffener rings, ALCs, risers and instruments was 98 ft^3 (736 gal), consisting of 39 ft^3 (295 gal) on walls and rings, 51 ft^3 (383 gal) on the ALCs, and 8 ft^3 (58 gal) on risers and instruments. Detailed descriptions and calculations are provided in RPP-RPT-63817.

Figure 2-4. Waste on the Walls, Stiffener Rings, Risers, and Instruments.

2.3 TOTAL RESIDUAL WASTE VOLUME RESULTS

The total post-retrieval residual waste volume in tank AX-103 and the waste volumes associated with the various waste components are given in Table 2-1. The tank bottom laser scan model provided the waste volume estimate for the tank bottom in tank AX-103. Laser scan measurements, supplemented by visual observations, were used to estimate the volume of waste on walls, stiffener rings, ALCs, risers, and instruments. Figure 2-2 shows a waste surface laser scan of the residual waste in tank AX-103. Figure 2-3 shows a high-resolution photo of the tank AX-103 interior.

The estimate for the total post-retrieval waste volume in tank AX-103 is 785 ft^3 (5,875 gal).

The 95% UCL tank bottom waste volume was calculated in Cyclone 3DR by adding 12 mm (two standard deviations [see RPP-RPT-63817]) to the waste thickness which equates to an additional 260 ft^3 of waste and a total of 947 ft^3 (7,081 gal) on the tank bottom. Per RPP-23403, *Single Shell Tank Component Closure Data Quality Objective*, "[t]he assumptions concerning residual waste on the stiffener rings, in the void space of equipment, and on the tank walls are best estimate values and do not allow the determination of a confidence interval." Therefore, the total 95% UCL is the 95% UCL tank bottom value plus the "actual waste volume" estimates for walls, stiffener rings, ALCs, risers, and instruments as summarized in Table 2-1. The total 95% UCL for the tank AX-103 waste volume is 1,045 ft^3 (7,817 gal).

3. RESIDUAL TANK WASTE CHARACTERIZATION

This section presents the average and upper-bound estimates of residual waste inventory based on laboratory analysis of waste samples taken after waste retrieval operations were completed. The calculated inventories were used for estimating the potential human health risk arising from the residual waste (Section 5).

3.1 SAMPLING AND ANALYSIS OF RESIDUAL WASTE

A tank sampling and analysis plan (RPP-PLAN-64988, *Tank Sampling and Analysis Plan for Residual Solid Waste in Tank 241-AX-103*) identified sample collection, laboratory analysis, quality assurance/quality control, and reporting requirements for characterizing waste solids remaining in tank AX-103 after retrieval completion to support tank closure. The samples were analyzed according to the requirements in RPP-23403 and RPP-PLAN-23827, *Sampling and Analysis Plan for Single-Shell Tanks Component Closure*. RPP-PLAN-23827 identifies regulatory requirements for field sampling, laboratory analysis, and data reporting for residual waste samples to ensure appropriate data are collected to support SST closure activities.

The most recent sampling event for tank AX-103 occurred June 22, 2022, through July 5, 2022. Three primary samples and one duplicate sample were taken with the clamshell sampling system (RPP-PLAN-64988). Sample analytical results are reported in RPP-RPT-64090, *Final Analytical Report for Residual Solid Waste Samples from Tank 241-AX-103*. The samples were described as having varying texture. Two of the samples (3AX-22-02 and 3AX-33-03) initially appeared somewhat dry upon collection, but they quickly became wet and tacky during sample homogenization with a spatula. The other two samples (3AX-22-01 and 3AX-33-01DUP) contained a dry, hard material (dry lake bed chips) and were difficult to homogenize. After homogenization, their sample texture was similar to coffee grounds. The wetter samples were homogenized using a spatula only, and the drier samples were homogenized using a spatula and a mortar and pestle. A mechanical homogenizer was not used due to the high activity level and concerns about material loss due to the texture of the samples. The average bulk density and percent water for the samples were 1.03 g/mL and 25.3 wt%, respectively.

3.2 SAMPLING AT SINGLE-SHELL TANK 241-AX-103

RPP-PLAN-23827 states "if away-from-riser methods such as the ORSS and ERSS are judged to be inoperable and if a waste mobilization device such as the FoldTrack® rack is not available … solids located directly under two risers will be sampled with a clamshell or finger trap."[4] Using away-from-riser methods such as the off-riser sampling system (ORSS) and ERSS in tank AX-103 were judged to be infeasible. It was not viable to use the ORSS because its umbilical cord could become tangled with the 22 ALCs or other on-floor obstructions. The low ground clearance of the ORSS would cause it to have difficulties traversing the undulating floor, with ridges and ripples estimated to be as high as approximately 6.6 cm (2.6 in.). Because of

[4] The FoldTrack® Mobile Retrieval Tool is manufactured by Non Entry Systems Ltd., UK Patent Application No: 0718573.9.

in-tank obstructions (namely ALCs), ERSS has limited mobility and could only reach a limited volume of solids. With respect to available risers under which the waste accumulated during retrieval, ERSS provides very little additional access to the remaining tank solids.

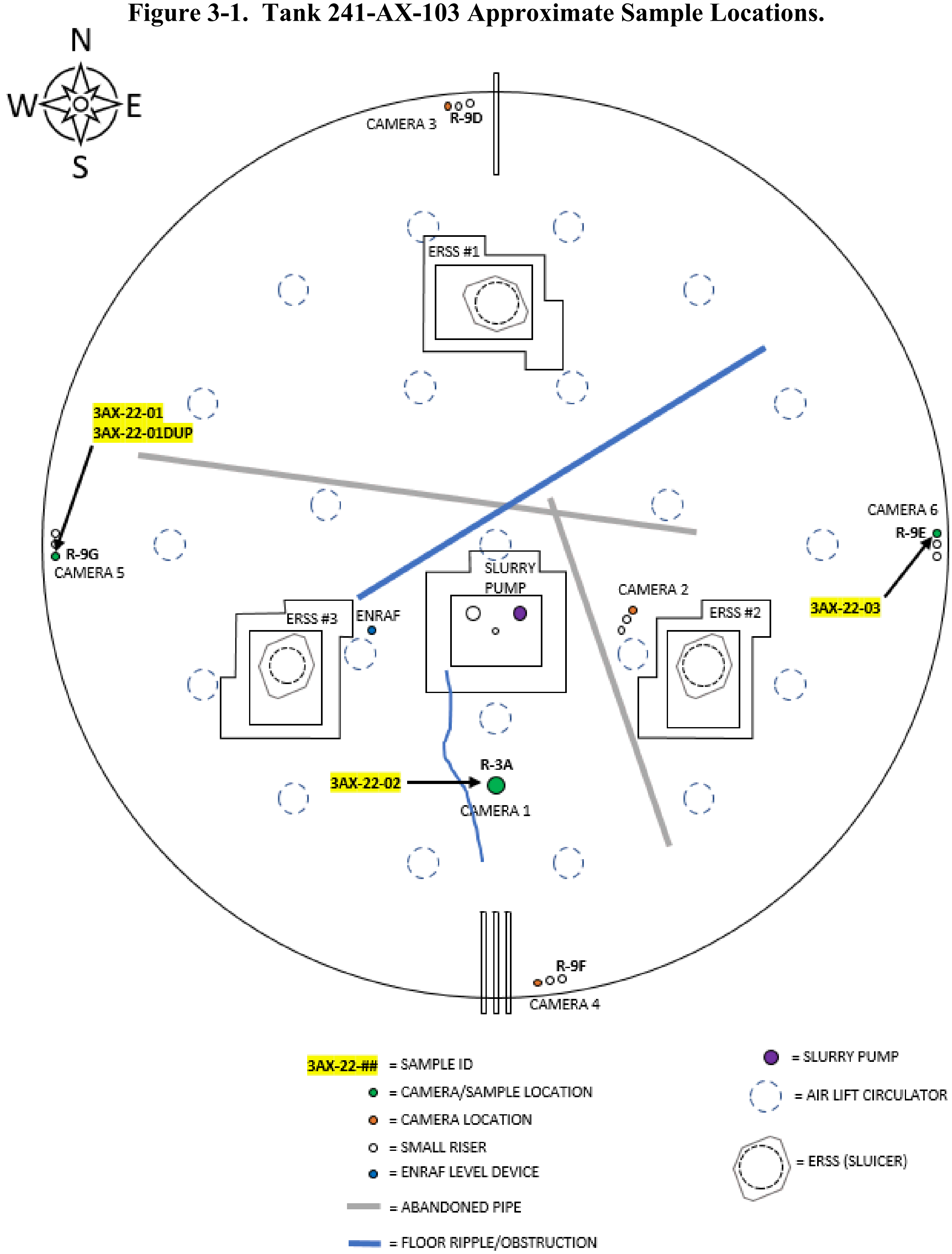
Given these considerations, under-riser sampling using a clamshell, solids crusher, and/or finger trap sampler was determined to provide the best methods for sampling with the greatest chance of success (RPP-PLAN-64988). Accessible risers for sampling were evaluated by Sampling Operations with respect to their proximity to tank waste. Most of the solids under accessible risers were located below risers 9E and 9G, the east and west sides of the tank, respectively. Riser 3A was also chosen for sampling because it was closer to the tank interior where solids appeared to have more fine, less grainy material.

A total of four samples were collected using a clamshell (a solids crusher and fingertrap were unnecessary). One primary sample was collected under each riser, plus a field duplicate sample at riser 9G (RPP-PLAN-64988). Samples 3AX-22-01 and 3AX-22-01DUP were collected under riser 9G. Sample 3AX-22-02 was collected under riser 3A, and sample 3AX-22-03 was collected under riser 9E (Figure **3-1**).

In-tank videos and screen shots of the waste taken on May 26, 2022 showed that the majority of the residual solids were present along the perimeter of the tank. The solids on the tank perimeter appeared to be wet, brown, coarse material, with the exception of the northeast and southwest portions of the tank perimeter. The northeast and southwest portions of the tank perimeter and the tank interior appeared to be fines (small particles) and homogenous in consistency. Figure 3-2 shows a high-resolution photo of the tank interior, looking west from riser 9E, and illustrates the varying texture of the waste.

Residual solids were estimated using the Residual Volume Measurement System or laser scanning (RPP-RPT-63817). Small portions of the tank floor had no solids, and the maximum solids depth was estimated to be approximately 37 cm (14.7 in.) deep, observed near the south and west edges of the tank. Figure 3-3 is a laser scan of the tank floor and shows the location of the samples in relation to the height of the waste and some of the debris in the tank picked up in the laser scan. The laser scans were completed between May 26 and June 8, and by the time sampling occurred (June 28), much of the liquid in the tank (from retrieval) had evaporated.

Figure 3-1. Tank 241-AX-103 Approximate Sample Locations.



Reference: RPP-PLAN-64988, *Tank Sampling and Analysis Plan for Residual Solid Waste in Tank 241-AX-103.*

ERSS = extended reach sluicing system

Honeywell Enraf® is a registered trademark of Honeywell International Inc., Morristown, New Jersey.

Figure 3-2. Tank 241-AX-103 High-Resolution Photo of the Tank Interior, May 26, 2022.

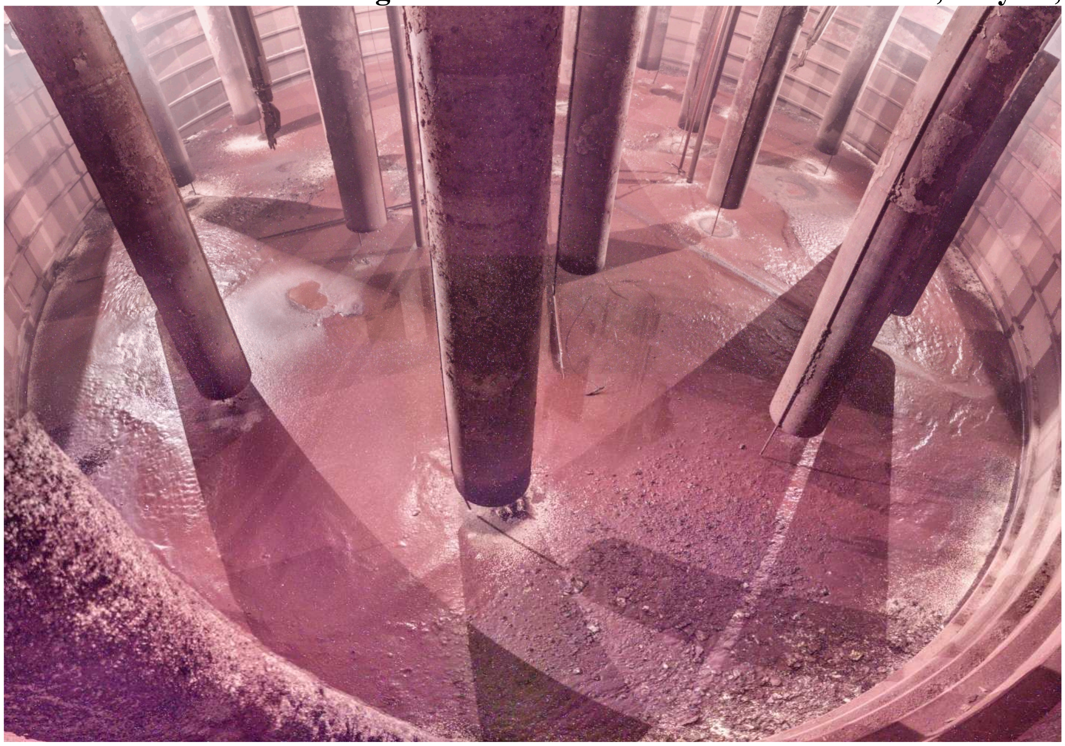
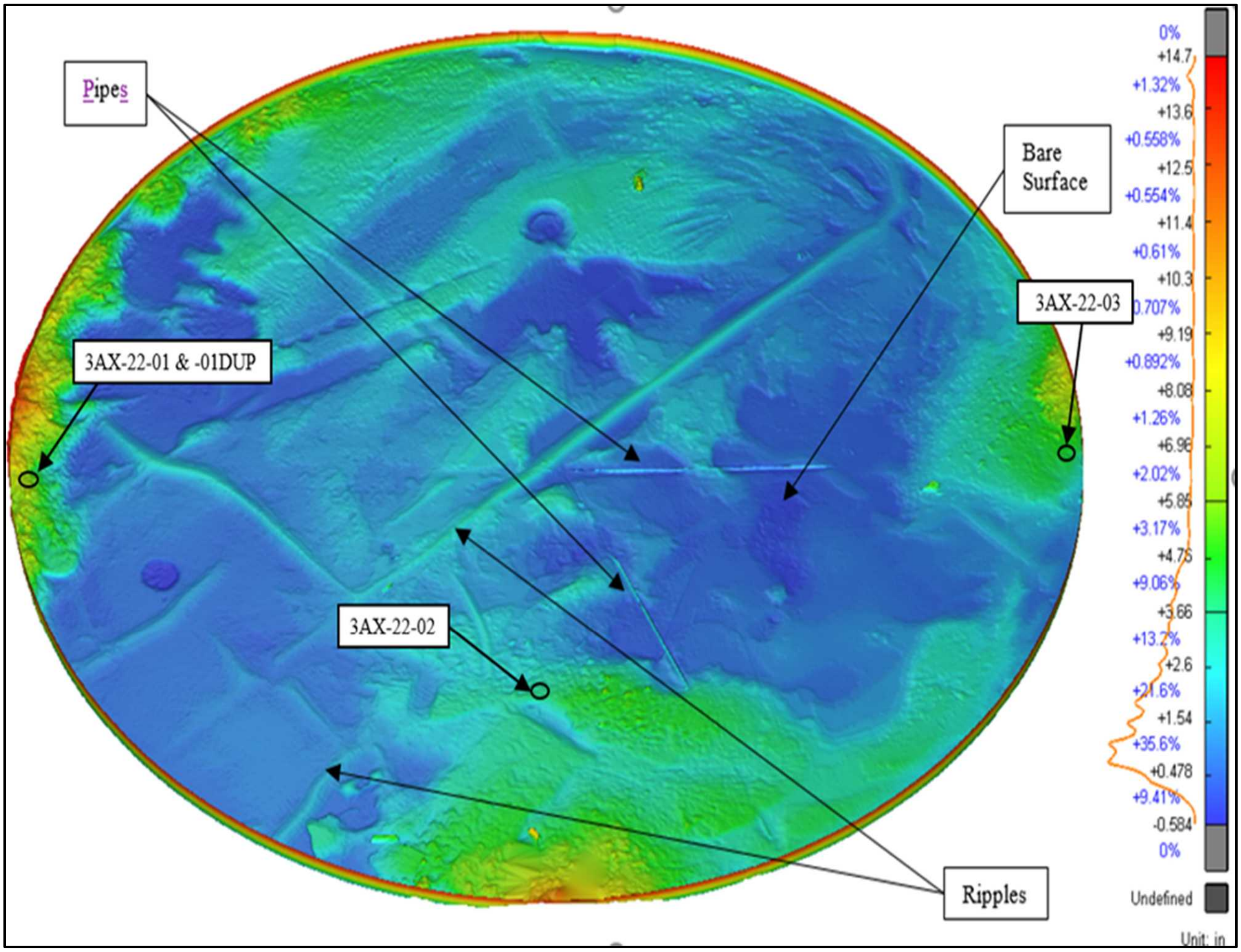


Figure 3-3. Laser Scan Tank Floor Profile Showing Sample Locations (looking north).



3.3 SAMPLE ANALYSES

The samples were analyzed for the constituents identified in RPP-23403 and RPP-PLAN-23827 as defined by RPP-PLAN-64988. Table 3-1 lists the analytical methods performed on the samples and corresponding analysis methods found in standard water methods, or SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, where applicable, in parenthesis (refer to table footnotes). Sample analysis results are reported in RPP-RPT-64090. Electronic data were also loaded into the Tank Waste Information Network System.

Table 3-1. Analytical Methods Used in Analysis of Post Retrieval Samples. (4 sheets)

Analytes	Analytical Technique	Solids Preparation Method	Samples to be Analyzed
Primary: Ag, Al, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sb, Se, Sr, Tl, U, V, Zn	Inductively coupled plasma/ atomic emission spectrometry (SW-846 6010D)	Acid and Fusion [b]	All waste samples, SB, and EB

Table 3-1. Analytical Methods Used in Analysis of Post Retrieval Samples. (4 sheets)

Analytes	Analytical Technique	Solids Preparation Method	Samples to be Analyzed
Secondary: B, Bi, Ca, Ce, Eu, K [a], La, Li, Mg, Mo, Na, Nb, Nd, P, Pd, Pr, Rb, Rh, Ru, S, Si, Sm, Sn, Ta, Te, Th, Ti, W, Y, Zr [a]			
Primary: F^-, NO_2^-, NO_3^-, $S_2O_3^{2-}$, $C_2H_3O_2^-$, CHO_2^-, $C_2H_3O_3^-$, $C_2O_4^{2-}$ Secondary: Br^-, Cl^-, PO_4^{3-}, SO_4^{2-}	Ion chromatography (EPA 300.0, SW-846 9056A)	Water	All waste samples, SB, and EB
As, Sb, Se	Inductively coupled plasma/ mass spectrometry (SW-846 6020B)	Acid	All waste samples, SB, and EB
pH	pH probe (SW-846 9040C & 9045D)	Water leach	All waste samples, SB, and EB
OH^- [c]	Titration	Water leach	All waste samples
Bulk density	Gravimetric	Direct	All waste samples
Percent Water	Thermo-gravimetric analysis	Direct	All waste samples
Total Inorganic Carbon	Persulfate oxidation (AWWA SM5310C)	Direct	All waste samples, SB, and EB
Total Organic Carbon	Persulfate oxidation (AWWA SM5310C)	Water digest or Direct	All waste samples, SB, and EB
Ammonium	Ion chromatography (EPA 300.7)	Distillation	All waste samples, SB, and EB
Mercury	Cold Vapor Atomic Absorption (SW-846 7470A & 7471B)	Acid	All waste samples, SB, and EB
Cyanide	Spectrophotometric	Distillation	All waste samples, SB, and EB
Volatile organic compounds (as specified in RPP-PLAN-64988)	Gas chromatography/ mass spectrometry (SW-846 8260D)	Direct	All waste samples, SB, EB and TB
Semi-volatile organic compounds (as specified in RPP-PLAN-64988)	Gas chromatography/ mass spectrometry (SW-846 8270E)	Extraction	All waste samples, SB, and EB
PCBs (Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260)	Gas chromatography/ electron capture detector (SW-846 8282A)	Extraction	All waste samples, SB, and EB
^3H [d]	Separation/liquid scintillation	Water	All waste samples, SB, and EB

Table 3-1. Analytical Methods Used in Analysis of Post Retrieval Samples. (4 sheets)

Analytes	Analytical Technique	Solids Preparation Method	Samples to be Analyzed
^{14}C	Separation/liquid scintillation	Water	All waste samples, SB, and EB
^{63}Ni	Liquid scintillation	Fusion	All waste samples, SB, and EB
^{79}Se	Anion-cation exchange/ distillation liquid scintillation	Acid	All waste samples, SB, and EB
^{99}Tc	Inductively coupled plasma/ mass spectrometry (SW-846 6020B)	Acid	All waste samples, SB, and EB
^{99}Tc	Extraction/ liquid scintillation counting	Acid	All waste samples, SB, and EB
^{237}Np, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{242}Pu, ^{238}U, ^{229}Th, ^{230}Th, ^{232}Th, ^{231}Pa, ^{126}Sn, ^{151}Sm, ^{243}Am	Inductively coupled plasma/ mass spectrometry (SW-846 6020B)	Acid	All waste samples, SB, and EB
^{129}I	Separation/gamma energy analysis	Fusion/ Water [b]	All waste samples, SB, and EB
^{60}Co, ^{94}Nb, ^{106}Ru, ^{125}Sb, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{134}Cs, ^{137}Cs, ^{126}Sn, ^{226}Ra, ^{241}Am	Gamma energy analysis	Acid or Fusion	All waste samples, SB, and EB
$^{90}Sr/^{90}Y$	Separation/ GPC (alpha/beta) counting	Fusion	All waste samples, SB, and EB
^{228}Th, ^{238}Pu, $^{239/240}Pu$, ^{241}Am, ^{242}Cm, $^{243/244}Cm$	Separation/ alpha energy analysis	Fusion	All waste samples, SB, and EB
^{241}Pu	Separation/ liquid scintillation counting	Fusion	All waste samples, SB, and EB
Solid Phase Characterization	SEM-EDX/XRD	Not applicable	All waste samples
Particle Size Analysis	ATS-LT-519-105	Not applicable	All waste samples
^{59}Ni, ^{93}Zr, ^{93m}Nb, ^{113m}Cd, ^{137m}Ba, ^{227}Ac, ^{228}Ra, ^{232}U	No method of detection [e]	Not applicable	Not applicable

EB = equipment blank
GPC = Gas Flow Proportional Counting
PCBs = polychlorinated biphenyls
SB = sampling blank
SEM-EDX = scanning electron microscopy/ energy dispersive X-ray spectrometry
TB = trip blank
XRD = X-ray diffraction

[a] Potassium (K) and zirconium (Zr) will not be reported from the fusion digest because potassium hydroxide will be used in the fusion digest in a Zr crucible.

[b] The laboratory may either use acid, fusion, or water for digestion method, as appropriate.

[c] Hydroxide analysis was not required, all pH measurements were less than 12.5.

[d] Tritium results may be low biased, water leaching will not release tritium bond in the molecular structure of the tank constituents.

Table 3-1. Analytical Methods Used in Analysis of Post Retrieval Samples. (4 sheets)

Analytes	Analytical Technique	Solids Preparation Method	Samples to be Analyzed

[e] Currently, the 222-S Laboratory does not have a method to detect these radionuclides, but they are included in this table so that if a method becomes available, they can be analyzed.

References:
AWWA, 2012, *Standard Methods for the Examination of Water and Wastewater*, 22nd edition, Method 5310C, "Persulfate-Ultraviolet or Heated-Persulfate Oxidation Method," American Water Works Association, Denver, Colorado.
EPA 300.7, 1986, *Dissolved Sodium, Ammonium, Potassium, Magnesium, and Calcium in Wet Deposition by Chemically Suppressed Ion Chromatography*, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio, as amended.
RPP-PLAN-64988, 2022, *Tank Sampling and Analysis Plan for Residual Solid Waste in Tank 241-AX-103*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.
SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, U.S. Environmental Protection Agency, Washington D.C., as amended.

Figure 3-4 through Figure 3-7 displays each of the samples taken along with the sample date and sample names. The sample names correspond with the sample locations as shown.

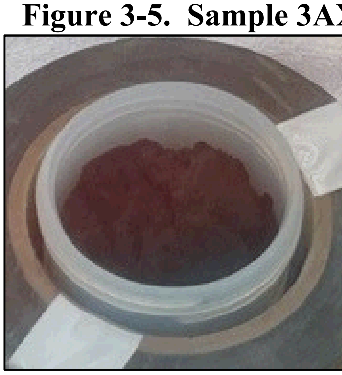
Figure 3-4. Sample 3AX-22-03, Collected from Riser 9E on June 22, 2022.

3AX-22-03 Upon Collection

3AX-22-03 Upon Arrival at the Hot Cells

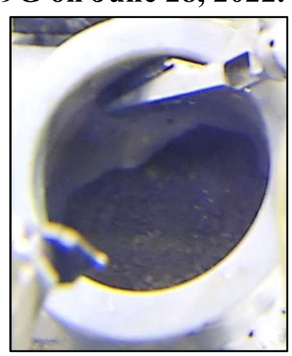
3AX-22-03 During Homogenization

Figure 3-5. Sample 3AX-22-01, Collected from Riser 9G on June 28, 2022.



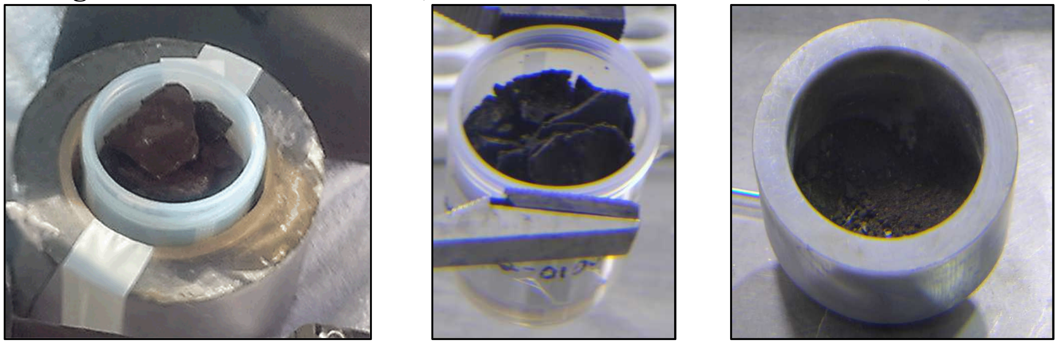
3AX-22-01 Upon Collection

3AX-22-01 Upon Arrival at the Hot Cells



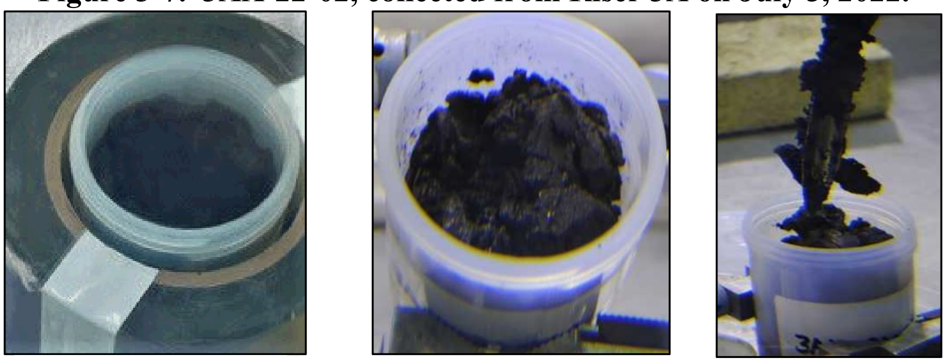
3AX-22-01 After Homogenization

Figure 3-6. 3AX-22-01DUP, Collected from Riser 9G on June 29, 2022.



3AX-22-01DUP Upon Collection | 3AX-22-01DUP Upon Arrival at the Hot Cells | 3AX-22-01DUP After Homogenization

Figure 3-7. 3AX-22-02, collected from Riser 3A on July 5, 2022.



3AX-22-02 Upon Collection | 3AX-22-02 Upon Arrival at the Hot Cells | 3AX-22-02 During Homogenization

Tentatively identified compounds (TICs) from organic analyses that met the TIC evaluation criteria in RPP-23403 and were reported as a TIC in RPP-RPT-64090 are listed in Table 3-2. These compounds are only semi-quantitative; therefore, inventories were not computed for TICs.

Table 3-2. Tentatively Identified Compounds in Tank 241-AX-103 Residual Solids. (4 sheets)

Laboratory Sample Number	Field Sampling Sample Number	Tentatively Identified Compound	Result (µg/kg)	Retention Time (minutes)	CAS Number
S22T007370	3AX-22-01	2,3,3-Trimethyl-1-hexene	1.0E+04	5.98	1000113-52-1
S22T007370	3AX-22-01	Cyclopentane, 1,2,3,4,5-pentamethyl-	1.5E+04	16.83	1000152-79-7
S22T007370	3AX-22-01	Cyclopentane, 1,2,3,4,5-pentamethyl-	4.0E+04	18.63	1000152-79-7
S22T007370	3AX-22-01	5-Hexen-1-ol, 2-(2-methyl-1-pr	7.8E+03	5.97	18675-19-9

Table 3-2. Tentatively Identified Compounds in Tank 241-AX-103 Residual Solids. (4 sheets)

Laboratory Sample Number	Field Sampling Sample Number	Tentatively Identified Compound	Result (µg/kg)	Retention Time (minutes)	CAS Number
S22T007370	3AX-22-01	Cyclohexane, 1-methyl-3-propyl	1.8E+04	16.83	4291-80-9
S22T007370	3AX-22-01	2-Butanone, 3-methyl-	1.4E+04	18.63	563-80-4
S22T007370	3AX-22-01	2-Butanone, 3-methyl-	3.5E+04	2.65	563-80-4
S22T007370	3AX-22-01	Butane, 2-chloro-2-methyl-	1.3E+04	3.26	594-36-5
S22T007370	3AX-22-01	Butane, 2-chloro-2-methyl-	3.1E+04	3.34	594-36-5
S22T007370	3AX-22-01	1,1`-Biphenyl, 3,4-diethyl-	7.6E+03	6.21	61141-66-0
S22T007370	3AX-22-01	Octane, 3-methyl-6-methylene-	7.8E+03	6.59	74630-07-2
S22T007370	3AX-22-01	2-sec-Butyl-3-methyl-1-pentene	1.5E+04	14.97	75144-24-0
S22T007370	3AX-22-01	Ethene, 1,1-dichloro-	1.7E+04	2.41	75-35-4
S22T007370	3AX-22-01	Amylene hydrate	1.1E+04	3.11	75-85-4
S22T007370	3AX-22-01	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	2.2E+04	3.26	84-69-5
S22T007370	3AX-22-01	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	1.6E+04	3.34	84-69-5
S22T007370	3AX-22-01	Methane-d, trichloro-	2.8E+06	5.79	865-49-6
S22T007370	3AX-22-01	Methane-d, trichloro-	2.6E+06	5.97	865-49-6
S22T007356	3AX-22-01	Unknown	76	6.21	
S22T007356	3AX-22-01	Unknown	230	6.40	
S22T007356	3AX-22-01	Unknown-1	89	6.55	
S22T007356	3AX-22-01	Unknown-2	270	6.59	
S22T007357	3AX-22-01	Unknown	81	13.73	
S22T007357	3AX-22-01	Unknown	530	14.97	
S22T007357	3AX-22-01	Unknown-1	89	16.83	
S22T007357	3AX-22-01	Unknown-2	270	18.63	
S22T007390	3AX-22-01DUP	2,3,3-Trimethyl-1-hexene	1.0E+04	16.83	1000113-52-1
S22T007390	3AX-22-01DUP	Cyclopentane, 1,2,3,4,5-pentamethyl-	1.7E+04	18.63	1000152-79-7
S22T007390	3AX-22-01DUP	Cyclopentane, 1,2,3,4,5-pentamethyl-	4.0E+04	2.41	1000152-79-7
S22T007390	3AX-22-01DUP	Ethylene, 1,2-dichloro-, (E)-	1.8E+04	2.64	156-60-5
S22T007390	3AX-22-01DUP	5-Hexen-1-ol, 2-(2-methyl-1-pr	7.8E+03	3.11	18675-19-9

Table 3-2. Tentatively Identified Compounds in Tank 241-AX-103 Residual Solids. (4 sheets)

Laboratory Sample Number	Field Sampling Sample Number	Tentatively Identified Compound	Result (µg/kg)	Retention Time (minutes)	CAS Number
S22T007390	3AX-22-01DUP	Cyclohexane, 1-methyl-3-propyl	1.8E+04	3.26	4291-80-9
S22T007390	3AX-22-01DUP	2-Butanone, 3-methyl-	1.5E+04	3.34	563-80-4
S22T007390	3AX-22-01DUP	2-Butanone, 3-methyl-	3.5E+04	5.79	563-80-4
S22T007390	3AX-22-01DUP	Butane, 2-chloro-2-methyl-	1.4E+04	6.21	594-36-5
S22T007390	3AX-22-01DUP	Butane, 2-chloro-2-methyl-	3.1E+04	6.40	594-36-5
S22T007390	3AX-22-01DUP	1,1`-Biphenyl, 3,4-diethyl-	7.6E+03	6.59	61141-66-0
S22T007390	3AX-22-01DUP	Octane, 3-methyl-6-methylene-	7.8E+03	13.73	74630-07-2
S22T007390	3AX-22-01DUP	2-sec-Butyl-3-methyl-1-pentene	1.5E+04	14.97	75144-24-0
S22T007390	3AX-22-01DUP	Amylene hydrate	1.1E+04	2.41	75-85-4
S22T007390	3AX-22-01DUP	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	5.9E+03	2.65	84-69-5
S22T007390	3AX-22-01DUP	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	1.6E+04	3.11	84-69-5
S22T007390	3AX-22-01DUP	Methane-d, trichloro-	2.6E+06	3.26	865-49-6
S22T007400	3AX-22-01DUP	Unknown	72	3.34	
S22T007400	3AX-22-01DUP	Unknown	350	5.79	
S22T007400	3AX-22-01DUP	Unknown-1	89	6.21	
S22T007400	3AX-22-01DUP	Unknown-2	270	6.39	
S22T007414	3AX-22-02	2,3,3-Trimethyl-1-hexene	1.0E+04	3.20	1000113-52-1
S22T007414	3AX-22-02	Cyclopentane, 1,2,3,4,5-pentamethyl-	2.1E+04	3.44	1000152-79-7

Table 3-2. Tentatively Identified Compounds in Tank 241-AX-103 Residual Solids. (4 sheets)

Laboratory Sample Number	Field Sampling Sample Number	Tentatively Identified Compound	Result (µg/kg)	Retention Time (minutes)	CAS Number
S22T007414	3AX-22-02	Cyclopentane, 1,2,3,4,5-pentamethyl-	4.0E+04	3.57	1000152-79-7
S22T007414	3AX-22-02	5-Hexen-1-ol, 2-(2-methyl-1-pr	7.8E+03	6.73	18675-19-9
S22T007414	3AX-22-02	Cyclohexane, 1-methyl-3-propyl-	9.0E+03	7.19	4291-80-9
S22T007414	3AX-22-02	Cyclohexane, 1-methyl-3-propyl	1.8E+04	7.39	4291-80-9
S22T007414	3AX-22-02	2-Butanone, 3-methyl-	1.8E+04	7.60	563-80-4
S22T007414	3AX-22-02	2-Butanone, 3-methyl-	3.5E+04	5.94	563-80-4
S22T007414	3AX-22-02	Butane, 2-chloro-2-methyl-	1.6E+04	16.65	594-36-5
S22T007414	3AX-22-02	Butane, 2-chloro-2-methyl-	3.1E+04	18.41	594-36-5
S22T007414	3AX-22-02	1,1`-Biphenyl, 3,4-diethyl-	7.6E+03	5.95	61141-66-0
S22T007414	3AX-22-02	Octane, 3-methyl-6-methylene-	7.8E+03	16.65	74630-07-2
S22T007414	3AX-22-02	2-sec-Butyl-3-methyl-1-pentene	1.5E+04	18.31	75144-24-0
S22T007414	3AX-22-02	Ethene, 1,1-dichloro-	1.7E+04	18.40	75-35-4
S22T007414	3AX-22-02	Amylene hydrate	1.1E+04	21.19	75-85-4
S22T007414	3AX-22-02	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	2.1E+04	5.95	84-69-5
S22T007414	3AX-22-02	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	1.6E+04	16.65	84-69-5
S22T007414	3AX-22-02	Methane-d, trichloro-	2.6E+06	18.41	865-49-6
S22T007402	3AX-22-02	Unknown	740	5.95	
S22T007402	3AX-22-02	Unknown	70	16.65	
S22T007402	3AX-22-02	Unknown	89	18.31	
S22T007402	3AX-22-02	Unknown-1	47	18.40	

3.4 CALCULATION OF RESIDUAL INVENTORY

The residual waste inventories were computed by following the Best-Basis Inventory (BBI) process described in RPP-7625, *Guidelines for Updating Best-Basis Inventory*. Two inventories were computed: an averaged best-estimate inventory based on mean concentrations, density, and volume; and an upper-bound inventory that is an estimate of an inventory at the 95% UCL. The inventories are discussed in the following sections.

3.4.1 Averaged Best Estimate Inventory

The averaged best estimate inventory (average inventory) for each waste constituent was calculated using the automated Best-Basis Inventory Maintenance (BBIM) tool (RPP-5945, *Best-Basis Inventory Maintenance Tool (BBIM): Database Description and User Guide*). This tool calculates the average inventory by finding the product of the mean concentration, the mean density, and the waste volume (i.e., inventory = concentration × density × volume). Pre-retrieval and post-retrieval BBIs are provided in Appendix A, Table A-1. The calculations by the BBIM tool are summarized below. Table 3-3 identifies the residual solid compounds in tank AX-103.

Table 3-3. Description of the Tank 241-AX-103 Post-Retrieval Samples.

Sample Identification Number	Date Sampled	Date Received	Sample Weight (g)	Sample Description
3AX-22-01	6/28/2022 08:55	6/28/2022 09:45	199.1	240 mL Teflon™ jar with approximately 200 g of dark brown opaque solid material with chunks, no organic layer visible.
3AX-22-01DUP	6/29/2022 08:30	6/29/2022 09:50	200.6	240 mL Teflon™ jar with approximately 225 g of a dark brown opaque solid material with chunks, no organic layer visible.
3AX-22-02	07/05/2022 09:20	07/05/2022 10:45	267.2	240 mL Teflon™ jar with approximately 240 g of a dark brown opaque solid material with chunks, no organic layer visible.
3AX-22-03	06/22/2022 09:35	06/22/2022 10:45	202.8	240 mL Teflon™ jar with approximately 175 g of a dark brown opaque solid material with chunks, no organic layer visible.

Teflon™ is a trademark of The Chemours Company, Wilmington, Delaware.

To calculate the average analyte inventories, the BBIM tool automatically used the mean concentrations from the samples taken after retrieval when available. The concentration means used by the BBIM tool to calculate the average inventories are provided in Appendix B. The BBIM also used the SW-846 equations to calculate the mean density and standard deviation for each set of samples. The density for the samples taken after retrieval was used for the inventory calculations.

3.4.2 Bounding Inventories

The 95% UCL inventory of each constituent was estimated based on a statistical method described in RPP-6924, *Statistical Methods for Estimating the Uncertainty in the Best Basis Inventories*. This method is based on calculation of the average inventory (as shown in Section 2.0) and a statistical uncertainty (quantified using a standard deviation) for the inventory. The standard deviation of the average inventory was calculated based on statistical uncertainties associated with the concentration, waste volume, and density measurements. Standard deviations for the mean concentrations and density were calculated using the BBIM tool. The standard deviation for waste volume was estimated as described below.

As shown in Table 2-1, a residual waste volume of 785 ft^3 (5,875 gal) was estimated based on RVMS for waste on the tank bottom and video estimates for the thickness of waste on walls, stiffener rings and equipment (RPP-RPT-63817). The upper bounding estimate for the waste volume components, based on a ±6 mm standard deviation in laser scan measurements applied to tank floor estimates, added up to 1,045 ft^3 (7,817 gal). The estimated error for the total waste volume may be represented as ± 0.331 ([1,045 – 785] / 785). Using a factor of 2 for a two-sided 95% confidence level based on a normal distribution with a known variance, the relative standard deviation (RSD) for the total waste volume was estimated to be 0.166 (0.331 / 2) (RPP-RPT-64056, *Tank 241-AX-103 Residual Waste Inventory Estimates for Component Closure Risk Assessment*). This RSD was used to approximate the RSD associated with the solids volume.

The BBIM tool calculated the inventory RSD using the equation:

$$\mathrm{RSD}^2(\hat{\mathrm{I}}) \cong \mathrm{RSD}^2(\overline{\mathrm{C}}) + \mathrm{RSD}^2(\mathrm{D}) + \mathrm{RSD}^2(\hat{\mathrm{V}})$$

where $\mathrm{RSD}^2(\hat{\mathrm{I}})$ is the squared inventory RSD, $\mathrm{RSD}^2(\overline{\mathrm{C}})$ is the squared average concentration RSD, $\mathrm{RSD}^2(\mathrm{D})$ is the squared average density RSD, and $\mathrm{RSD}^2(\hat{\mathrm{V}})$ is the squared total volume RSD.

According to RPP-6924, the t-distribution (or any other probability distribution) is not applicable for determining a confidence interval (CI) for the mean inventory because there are no degrees of freedom associated with the waste volume measurement. The 95% UCL inventory was approximated by the equation:

$$\mathrm{UCL} = \hat{\mathrm{I}} + 2 \times \hat{\mathrm{I}} \times \mathrm{RSD}(\hat{\mathrm{I}})$$

where $\hat{\mathrm{I}}$ is the inventory estimate and $\mathrm{RSD}(\hat{\mathrm{I}})$ is the RSD of the inventory estimate. The factor "2 times the standard deviation of the estimate" in this equation is analogous to the factor "1.96 times the standard deviation of the mean" for a two-sided 95% CI on the mean based on a normal distribution with a known variance (in accordance with the BBI process, which uses a two-sided 95% CI for inventory). The 95% UCL inventories were calculated using the above equation; the average inventory estimates, and associated RSDs and 95% UCLs were calculated by the BBIM tool.

3.4.3 Evaluation of Sample Data Usability

Tank AX-103 residual waste solids were sampled using the clamshell sampler for all sampling locations. A sampling design specific to the residual waste in tank AX-103 was developed and documented in the sampling and analysis plan (RPP-PLAN-64988). Sample data collected by implementing this design can be used to estimate the mean concentration and data uncertainty for constituents of interest. The mean concentrations are shown in Appendix B. The solids RSDs in

Appendix B represent the uncertainty in the estimates due to sampling and analysis errors and due to the waste variability in the tank.

The 222-S Laboratory maintains a quality assurance (QA) program to ensure data quality. The waste samples were analyzed according to QA plans established by the program. In addition, the data quality objectives (DQOs) specify quality control criteria (e.g., standard recovery, matrix spike recovery, relative difference between duplicate analyses) that are specific to the closure project. The DQOs also provide direction for addressing data that do not meet the criteria. Results for most constituents satisfied the DQO criteria; those that did not meet the criteria were addressed according to the direction provided in the DQOs. Communications that were used to address data issues are included in the laboratory data report (RPP-RPT-64090).

Based on this assessment, it was concluded that the sampling and analysis met the DQO document objectives and, therefore, the sample results are acceptable for uses discussed in the DQO document, including risk assessment calculations.

3.4.4 Inventory Calculation Assumptions and Clarifications

The inventories were calculated in accordance with the BBI creation rules documented in RPP-7625. The calculation includes the following assumptions and clarifications (RPP-RPT-64056).

- Inventories were generated only for constituents specified in the DQO document (RPP-23403). Inventories for BBI analytes that are not included in RPP-23403 are included in Appendix A.
- Only data from the post-retrieval samples were used to calculate the inventories. Inventories of constituents not detected in the samples were calculated using the analytical method detection limits. Therefore, these specific inventories are considered conservative estimates. Detection limits reported for some radionuclides are high compared to template-based concentrations used in the BBI (RPP-RPT-59854).
- Concentration data are available only for solids on the bottom of the tank. Solids on the tank stiffener ring and the tank wall were not sampled and were assumed to have the same composition as the solids on the tank bottom.
- Thorium concentration was measured by inductively coupled plasma (ICP)/atomic emission spectrometry and ^{232}Th was measured by ICP/mass spectrometry (MS). Analyses by ICP/MS are generally more reliable at low concentration; therefore, the thorium inventory was calculated based on the ICP/MS results.
- The $^{239/240}$Pu value from the analytical results and PUREX high-level waste (P2) sludge template isotopic distribution ratios were used to estimate concentrations of the plutonium isotopes as sample results for plutonium isotopes were not consistent with process knowledge of plutonium isotope ratios.

- Curium isotopes (^{243}Cm and ^{244}Cm) were calculated from the $^{243/244}$Cm analytical results, using the P2 sludge template isotopic distribution ratios (RPP-8847, *Best-Basis Inventory Template Compositions of Common Tank Waste Layers*).

- In accordance with RPP-7625, the ^{137m}Ba inventory is equal to 0.944 times the ^{137}Cs inventory and the ^{90}Y inventory is equal to the ^{90}Sr inventory.

- The total uranium (U_{TOTAL}) is based on the sum of the detected uranium isotopes.

- The total organic carbon (TOC) calculation from oxalate was slightly higher than the TOC measurement; therefore, oxalate was calculated from the TOC (oxalate = TOC × 0.98 [factor for P2 waste] / 0.273).

- The laboratory was not able to measure xylene (m) and xylene (p) separately; therefore, these compounds were reported as xylene (m & p).

- The laboratory was not able to measure cresol (m) and cresol (p) separately; therefore, these compounds were reported as cresol (m & p).

- As the name implies, TICs from organic analyses were not identified with certainty. In addition, measured concentrations for these compounds are only semi-quantitative. Therefore, inventories were not computed for TICs. Only TICs that met the TIC evaluation criteria in RPP-23403 and were reported as a TIC in RPP-RPT-64090 (Attachment 9) are included in Table 3-2.

- Bulk density sample results had a range from 0.89 g/mL to 1.16 g/mL (RPP-RPT-64090) and a sample mean density of 1.03 g/mL. Some bulk density results were lower than expected, but none of the bulk density analyses were flagged as suspect by the laboratory.

3.5 INVENTORY ESTIMATES

Table 3-4 shows the average (best-estimate) and upper-bounding inventories for the residual solid. Note that the symbol "<" indicates that the inventory was calculated based on the analytical method detection limit because the analyte was not detected in the samples. Radionuclide inventories are decay-corrected to January 1, 2022. Appendix A shows pre-retrieval and post-retrieval inventory estimates for standard BBI constituents (RPP-7625).

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Best Estimate	Upper-Bounding Inventory	Inventory Units*
1,1,1-Trichloroethane	71-55-6	<	2.79E-04	8.48E-04	kg
1,1,2,2-Tetrachloroethane	79-34-5	<	1.22E-04	3.71E-04	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Best Estimate	Upper-Bounding Inventory	Inventory Units*
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	<	1.22E-04	3.71E-04	kg
1,1,2-Trichloroethane	79-00-5	<	3.50E-04	1.06E-03	kg
1,1-Dichloroethene	75-35-4	<	1.64E-04	4.99E-04	kg
1,2,4-Trichlorobenzene	120-82-1	<	1.98E-04	6.02E-04	kg
1,2-Dichlorobenzene	95-50-1	<	1.18E-04	3.59E-04	kg
1,2-Dichloroethane	107-06-2	<	2.44E-04	7.42E-04	kg
1,4-Dichlorobenzene	106-46-7	<	1.29E-04	3.92E-04	kg
^{125}Sb	14234-35-6	<	1.39E+01	4.23E+01	Ci
^{126}Sn	15832-50-5	—	1.34E+00	2.27E+00	Ci
^{129}I	15046-84-1	—	6.66E-03	1.17E-02	Ci
^{134}Cs	13967-70-9	<	2.95E+01	8.97E+01	Ci
^{137}Cs	10045-97-3	—	3.08E+03	5.35E+03	Ci
^{137m}Ba	N/A	—	2.91E+03	5.06E+03	Ci
^{14}C	14762-75-5	—	7.58E-03	1.38E-02	Ci
^{151}Sm	15715-94-3	—	2.66E+03	4.41E+03	Ci
^{152}Eu	14683-23-9	<	1.12E+01	3.40E+01	Ci
^{154}Eu	15585-10-1	—	1.48E+01	2.25E+01	Ci
^{155}Eu	14391-16-3	<	1.36E+01	4.13E+01	Ci
1-Butanol	71-36-3	<	5.76E-03	1.75E-02	kg
2,4,5-Trichlorophenol	95-95-4	<	6.46E-02	1.96E-01	kg
2,4,6-Trichlorophenol	88-06-2	<	6.50E-02	1.98E-01	kg
2,4-Dinitrotoluene	121-14-2	<	6.55E-02	1.99E-01	kg
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	128-37-0	<	6.22E-02	1.89E-01	kg
^{226}Ra	13982-63-3	<	7.14E+01	2.17E+02	Ci
^{228}Ra	15262-20-1	—	7.34E-04	1.33E-03	Ci
^{228}Th	14274-82-9	—	2.06E-01	3.65E-01	Ci
^{229}Th	15594-54-4	<	3.00E-01	9.12E-01	Ci
^{230}Th	14269-63-7	<	2.89E-02	8.79E-02	Ci
^{231}Pa	14331-85-2	<	3.38E+00	1.03E+01	Ci
^{232}Th	N/A	—	7.34E-04	1.33E-03	Ci
^{232}U	14158-29-3	—	1.39E-06	2.34E-06	Ci

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Best Estimate	Upper-Bounding Inventory	Inventory Units*
^{233}U	13968-55-3	—	4.11E-02	7.32E-02	Ci
^{234}U	13966-29-5	<	3.95E-01	1.20E+00	Ci
^{235}U	15117-96-1	—	9.11E-04	1.52E-03	Ci
^{236}U	13982-70-2	<	4.12E-03	1.25E-02	Ci
^{237}Np	13994-20-2	—	1.49E-01	2.29E-01	Ci
^{238}Pu	13981-16-3	—	5.61E+00	8.94E+00	Ci
^{238}U	N/A	—	2.14E-02	3.58E-02	Ci
$^{239/240}Pu$	N/A	—	3.56E+01	5.32E+01	Ci
^{239}Pu	15117-48-3	—	2.86E+01	4.27E+01	Ci
^{240}Pu	14119-33-6	—	7.00E+00	1.05E+01	Ci
^{241}Am	14596-10-2	—	6.95E+01	1.21E+02	Ci
^{241}Pu	14119-32-5	—	2.48E+01	3.63E+01	Ci
^{242}Cm	15510-73-3	—	1.87E-01	3.25E-01	Ci
^{242}Pu	13982-10-0	<	6.92E-03	2.10E-02	Ci
$^{243/244}Cm$	N/A	—	5.36E-01	1.01E+00	Ci
^{243}Am	14993-75-0	—	3.01E-01	4.63E-01	Ci
^{243}Cm	15757-87-6	—	2.99E-02	5.63E-02	Ci
^{244}Cm	13981-15-2	—	5.18E-01	9.75E-01	Ci
2-Butanone	78-93-3	<	1.69E-03	5.14E-03	kg
2-Chlorophenol	95-57-8	<	5.62E-02	1.71E-01	kg
2-Ethoxyethanol	110-80-5	<	4.87E-02	1.48E-01	kg
2-Methylphenol	95-48-7	<	6.11E-02	1.86E-01	kg
2-Nitrophenol	88-75-5	<	5.82E-02	1.77E-01	kg
2-Nitropropane	79-46-9	<	2.09E-03	6.35E-03	kg
^{3}H	15086-10-9	<	7.93E-03	2.41E-02	Ci
4-Chloro-3-methylphenol	59-50-7	<	6.52E-02	1.98E-01	kg
4-Methyl-2-Pentanone	108-10-1	<	2.10E-03	6.38E-03	kg
4-Nitrophenol	100-02-7	<	6.01E-02	1.83E-01	kg
^{60}Co	10198-40-0	<	3.14E+00	9.55E+00	Ci
^{63}Ni	13981-37-8	—	8.79E+01	1.38E+02	Ci
^{79}Se	15758-45-9	<	1.09E-02	3.31E-02	Ci
^{90}Sr	10098-97-2	—	6.70E+04	9.86E+04	Ci

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Best Estimate	Upper-Bounding Inventory	Inventory Units*
^{90}Y	10098-91-6	—	6.70E+04	9.86E+04	Ci
^{94}Nb	14681-63-1	<	3.24E+00	9.85E+00	Ci
^{99}Tc	14133-76-7	—	7.70E-01	1.19E+00	Ci
Acenaphthene	83-32-9	<	7.15E-02	2.17E-01	kg
Acetate	71-50-1	—	1.86E+00	2.70E+00	kg
Acetone	67-64-1	<	3.80E-03	1.16E-02	kg
Ag	7440-22-4	—	2.52E+01	4.38E+01	kg
Al	7429-90-5	—	4.15E+03	6.82E+03	kg
Aroclors (Total PCB)	1336-36-3	<	2.03E-02	6.17E-02	kg
As	7440-38-2	—	5.60E-01	9.17E-01	kg
B	7440-42-8	<	8.26E+00	2.51E+01	kg
Ba	7440-39-3	—	1.24E+01	1.95E+01	kg
Be	7440-41-7	<	1.65E+00	5.02E+00	kg
Benzene	71-43-2	<	1.54E-04	4.68E-04	kg
Benzo(a)pyrene	50-32-8	<	5.26E-02	1.60E-01	kg
Bi	7440-69-9	<	3.51E+00	1.07E+01	kg
Bis(2-ethylhexyl)phthalate	117-81-7	<	3.46E-01	1.05E+00	kg
Br	24959-67-9	<	8.35E-01	2.54E+00	kg
Butylbenzylphthalate	85-68-7	<	9.45E-02	2.87E-01	kg
Ca	7440-70-2	—	1.14E+02	1.55E+02	kg
Carbon disulfide	75-15-0	<	2.11E-04	6.41E-04	kg
Carbon tetrachloride	56-23-5	<	2.82E-04	8.57E-04	kg
Cd	7440-43-9	—	3.54E+00	6.07E+00	kg
Ce	7440-45-1	—	1.13E+01	1.84E+01	kg
Chlorobenzene	108-90-7	<	1.48E-04	4.50E-04	kg
Chloroform	67-66-3	<	1.83E-04	5.56E-04	kg
Cl	16887-00-6	—	1.27E+00	1.92E+00	kg
CN	57-12-5	—	7.71E-02	1.15E-01	kg
Co	7440-48-4	<	1.65E+00	5.02E+00	kg
Cr	7440-47-3	—	2.04E+02	3.65E+02	kg
Cr^{+6}	18540-29-9	—	5.32E+00	8.01E+00	kg
Cresol (m & p)	1319-77-3	<	6.22E-02	1.89E-01	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Best Estimate	Upper-Bounding Inventory	Inventory Units*
Cu	7440-50-8	—	7.10E+00	1.14E+01	kg
Cyclohexanone	108-94-1	<	5.00E-02	1.52E-01	kg
Dibenz[a,h]anthracene	N/A	<	5.78E-02	1.76E-01	Ci
Diethylphthalate	84-66-2	<	1.07E-01	3.25E-01	kg
Di-n-butylphthalate	84-74-2	<	4.52E-01	1.37E+00	kg
Di-n-octylphthalate	117-84-0	<	6.18E-02	1.88E-01	kg
Ethyl acetate	141-78-6	<	1.05E-03	3.19E-03	kg
Ethyl ether	60-29-7	<	3.07E-04	9.33E-04	kg
Ethylbenzene	100-41-4	<	1.92E-04	5.84E-04	kg
Eu	7440-53-1	<	2.17E+00	6.60E+00	kg
F	16984-48-8	—	1.38E+01	2.51E+01	kg
Fe	7439-89-6	—	2.09E+03	3.76E+03	kg
Fluoranthene	206-44-0	<	6.66E-02	2.02E-01	kg
Formate	12311-97-6	<	1.45E+00	4.41E+00	kg
Free OH	N/A	—	8.87E-02	1.36E-01	kg
Glycolate	666-14-8	<	4.39E-01	1.33E+00	kg
Hexachlorobenzene	118-74-1	<	7.43E-02	2.26E-01	kg
Hexachlorobutadiene	87-68-3	<	3.81E-04	1.16E-03	kg
Hexachloroethane	67-72-1	<	1.71E-04	5.20E-04	kg
Hg	7439-97-6	—	8.15E+00	1.27E+01	kg
Isobutanol	78-83-1	<	1.66E-01	5.05E-01	kg
K	7440-09-7	<	2.39E+01	7.27E+01	kg
La	7439-91-0	—	6.00E+00	1.06E+01	kg
Li	7439-93-2	<	3.41E+00	1.04E+01	kg
Methylenechloride	75-09-2	<	1.14E-04	3.47E-04	kg
Mg	7439-95-4	—	1.75E+01	2.42E+01	kg
Mn	7439-96-5	—	9.91E+01	1.54E+02	kg
Mo	7439-98-7	<	2.79E+00	8.48E+00	kg
Morpholine, 4-nitroso-	59-89-2	<	5.99E-02	1.82E-01	kg
Na	7440-23-5	—	8.94E+02	2.72E+03	kg
Naphthalene	91-20-3	<	6.00E-02	1.82E-01	kg
Nb	7440-03-1	<	1.96E+00	5.96E+00	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Best Estimate	Upper-Bounding Inventory	Inventory Units*
Nd	7440-00-8	—	1.78E+01	3.02E+01	kg
NH_3	7664-41-7	—	7.93E-02	1.17E-01	kg
Ni	7440-02-0	—	5.46E+01	9.00E+01	kg
Nitrobenzene	98-95-3	<	5.60E-02	1.70E-01	kg
N-Nitrosodimethylamine	62-75-9	<	4.57E-02	1.39E-01	kg
N-Nitroso-di-n-propylamine	621-64-7	<	6.29E-02	1.91E-01	kg
NO_2	14797-65-0	—	3.05E+01	4.19E+01	kg
NO_3	14797-55-8	—	4.21E+01	1.28E+02	kg
Oxalate	338-70-5	—	2.81E+02	4.80E+02	kg
Pb	7439-92-1	—	1.76E+02	3.12E+02	kg
Pd	7440-05-3	<	5.78E+00	1.76E+01	kg
Pentachlorophenol	87-86-5	<	6.74E-02	2.05E-01	kg
Phenol	108-95-2	<	5.97E-02	1.81E-01	kg
PO_4	14265-44-2	—	3.51E+02	5.24E+02	kg
Pr	7440-10-0	—	3.55E+00	5.82E+00	kg
Pyrene	129-00-0	<	4.78E-02	1.45E-01	kg
Pyridine	110-86-1	<	3.88E-02	1.18E-01	kg
Rb	7440-17-7	<	2.65E+01	8.06E+01	kg
Rh	7440-16-6	—	2.92E+00	4.70E+00	kg
Ru	7440-18-8	—	3.67E+01	5.64E+01	kg
Sb	7440-36-0	—	1.20E-01	3.65E-01	kg
Se	7782-49-2	<	3.33E-01	1.01E+00	kg
Si	7440-21-3	<	9.10E+02	2.77E+03	kg
Sm	7440-19-9	—	3.73E+00	6.06E+00	kg
Sn	7440-31-5	<	3.41E+00	1.04E+01	kg
SO_4	14808-79-8	—	4.11E+01	6.79E+01	kg
Sr	7440-24-6	—	2.95E+00	4.09E+00	kg
Ta	7440-25-7	<	2.45E+01	7.45E+01	kg
Te	13494-80-9	<	5.00E+00	1.52E+01	kg
Tetrachloroethene	127-18-4	<	2.87E-04	8.72E-04	kg
Th	7440-29-1	—	6.67E+00	1.19E+01	kg
Thiosulfate	14383-50-7	<	7.91E-01	2.40E+00	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-AX-103 Residual Solids. (7 sheets)

Constituent	CAS Number	< Detection Limit	Best Estimate	Upper-Bounding Inventory	Inventory Units*
Ti	7440-32-6	—	2.86E+00	4.07E+00	kg
Tl	7440-28-0	—	3.20E+00	9.73E+00	kg
Toluene	108-88-3	<	1.51E-04	4.59E-04	kg
Trans-1,3-Dichloropropene	10061-02-6	<	3.42E-04	1.04E-03	kg
Tributyl phosphate	126-73-8	<	8.01E-02	2.44E-01	kg
Trichloroethene	79-01-6	<	1.54E-04	4.68E-04	kg
Trichlorofluoromethane	75-69-4	<	1.49E-04	4.53E-04	kg
U_{TOTAL}	N/A	<	6.44E+01	1.08E+02	Ci
V	7440-62-2	—	1.96E+00	5.96E+00	kg
Vinyl chloride	75-01-4	<	2.53E-04	7.69E-04	kg
W	7440-33-7	<	4.11E+00	6.05E+00	kg
Xylene (m & p)	108-28-3M	—	4.18E-04	1.27E-03	kg
Xylene	95-47-6	<	1.75E-04	5.32E-04	kg
Xylenes(total)	1330-20-7	<	5.93E-04	1.80E-03	kg
Y	7440-65-5	<	3.29E+00	5.03E+00	kg
Zn	7440-66-6	—	2.82E+00	4.29E+00	kg
Zr	7440-67-7	<	2.29E+00	6.96E+00	kg

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

*Radionuclide concentrations are decay corrected to January 1, 2022.

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

4. RETRIEVAL SYSTEM PERFORMANCE

This section documents the tank AX-103 waste retrieval system performance in terms of residual waste, retrieval duration, and water use. In addition, this section compares the achieved waste retrieval results against predicted performance. The residual tank waste volume at the end of retrieval is described in Section 2. Retrieval system performance is described in more detail in RPP-RPT-63691 and RPP-RPT-63929.

DOE deployed two technologies at tank AX-103: (1) modified sluicing via ERSS, and (2) HPW via ERSS. Sluicing operations started on August 5, 2021, with an initial waste volume of 112,300 gal (15,012 ft^3), which included retrieval system construction water additions. Retrieval ended on February 14, 2022, when operations reached the limits of the modified sluicing and HPW technologies. Recirculated water and supernate generated from the dissolved tank AX-103 saltcake was the carrier fluid for the modified sluicing technology. The second retrieval technology (HPW) was used concurrently with modified sluicing.

An estimated 106,425 gal (14,227 ft^3) of waste (solids and supernate) was retrieved from tank AX-103 to tank 241-AZ-102 (AZ-102), leaving 5,875 gal (785 ft^3) of residual waste (see Section 2.0).

4.1 WASTE RETRIEVAL PROCESS DESCRIPTION

The sluicing system in tank AX-103 consisted of three extended reach sluicers (ERSs) used to remove the waste. Before retrieval, the tank contained approximately 112,300 gal of waste consisting of saltcake, sludge, and supernate from retrieval system construction water additions (RPP-RPT-63691). Water was added during construction to soften the waste so that equipment could be installed without being put into the waste as well as for leak testing of the newly installed components. Some dissolution occurred but could not be quantified. Water was added to tank AX-103 through an ERS with the sluicer directed toward the waste surface. The water added was used to break up the waste. After the desired amount of water was added, the liquid was recirculated for a minimum amount of time. The resulting supernate was then pumped from tank AX-103 to double-shell tank (DST) AZ-102.

The ERS is different from a standard sluicer in that it has a boom, as well as a mast, which can be used to place the sluicer nozzle closer to the waste and increase the effectiveness of dissolving saltcake waste in the tank. The ERS boom is designed to extend and retract and elevate approximately 90° along the vertical. The mast rotates ±180°, from side-to-side and vertically, relative to the boom. This range of motion can be used to bring the nozzle closer to the waste in the tank than is possible with a fixed-elevation sluicer. The nozzle on the sluicers is capable of continuous rotation of 360°. Each ERS in tank AX-103 is equipped with two HPW nozzles that deliver water up to ~5,000 psi at 5 gal per minute to break up hard waste material.

A variable-depth slurry pump was located in the middle of the tank and could be adjusted to extend to the bottom of the tank. The adjustable height slurry pump was lowered as the waste retrieval progressed and the waste level receded. The pump was capable of pumping down to less than an inch during retrieval transfers prior to stalling. Closed-circuit video cameras were installed to support sluicing. The ERSS and slurry pump were controlled from a control trailer near the tank.

4.2 RETRIEVAL SYSTEM PERFORMANCE

Retrieval operations were performed over 95 operating days starting on August 5, 2021, and ending February 14, 2022. Before starting retrieval, 8,900 gal of water were added during retrieval preparation and construction. Each retrieval activity was performed in batches: sluicing with the water addition, followed by recirculation. Several batches included additional sluicing to entrain solids during transfer to tank AZ-102. Table 4-1 shows the retrieval chronology.

The first batch of waste retrieved was sluiced by recirculating the liquids added during construction. Each subsequent batch included sluicing with the water addition and then recirculating as a method to continue sluicing.

For Batches 1–11, water was added to dissolve the salts in tank AX-103. As a result, 80% of starting waste was retrieved in these first 11 batches (RPP-CALC-65050). After water additions, waste visibly broke up during the recirculated sluicing. The waste continued to be responsive to water, dissolving and breaking apart solid piles through October. Even with the waste continuing to move well, the densities started to decrease during the month of October. Washing of the tank walls and ALCs began in an attempt to dislodge material adhered to the equipment so that it could be retrieved. Sluicing progress continued until the beginning of November. The third consecutive batch, with a density less than 1.20 g/mL (Batch 15), ended on November 4. Upon achieving a density less than 1.20 g/mL in the retrieved waste, the decision was made to incorporate the use of HPW.

HPW was first used on November 9, 2021, at the beginning of Batch 16. HPW readily broke apart the visible waste, leaving distinct lines where it had passed. HPW was used during Batches 16, 17, 19, 21, and 23. All three sluicers were used over the course of these batches to apply HPW. No waste agglomerates were found during HPW use.

Tank AX-103 was retrieved over the course of 24 batches, summarized in Table 4-2. Eleven of the 24 batches incorporated a split slurry stream that transferred approximately 50% of the slurry stream to tank AZ-102, with the other 50% returned to tank AX-103 to help keep any solids suspended in the supernate so they could be transferred to tank AZ-102.

Ventilation to tank AX-103 was maintained after retrieval operations ceased in order to allow waste to dry. Final waste volume calculations were performed after the liquid had mostly evaporated.

Table 4-1. Tank 241-AX-103 Retrieval Chronology. (2 sheets)

Date(s)	Description
August 5 to September 2, 2021 (Batches 1 through 6)	Six batches were completed during this time period, all reaching a density ranging from 1.30 g/mL to 1.34 g/mL. Recirculation time varied between 22 and 40 hours to maximize the density with each batch. Each batch pumped significantly more volume than added for recirculation, indicating removal of interstitial liquids. 42,000 gallons of tank 241-AX-103 (AX-103) waste were retrieved between the six batches.
September 2 to 16, 2021 (Batch 7 & 8)	Batch 7 and 8 reached a density of 1.27 g/mL after each recirculation for 40 and 42 hours, respectively. These batches continued to pump significantly more volume than what was added for recirculation, indicating removal of interstitial liquids. A waste volume displacement was performed at the end of Batch 8, updating the waste volume retrieved from tank AX-103 as of September 16 to 78,000 gallons.
September 16 to 21, 2021	Retrieval paused for maintenance work in 241-AX Tank Farm. This pause provided time to troubleshoot sluicer 1, which was limited to only wrist manipulation.
September 21 to 30, 2021 (Batch 9)	Batch 9 reached 1.31 g/mL after 8 hours of recirculation. Batch 9 had a short recirculation duration due to the down time required for sluicer 1 work, to restore its full range of motion. This batch continued to pump significantly more volume than water was added for recirculation, indicating removal of interstitial liquids, retrieving 3,000 gallons of tank AX-103 waste.
September 28 to 30, 2021 (Batch 10)	Batch 10 reached 1.28 g/mL after 9 hours of recirculation. The short recirculation duration was due to the need to transfer waste by September 30 for winterization work. This batch continued to pump significantly more volume than water added for recirculation, indicating removal of interstitial liquids, retrieving 6,000 gallons of tank AX-103 waste.
September 30 to October 6, 2021	No retrieval operations during winterization of retrieval system.
October 6 to 14, 2021 (Batch 11 & 12)	Batch 11 reached 1.30 g/mL after 26 hours of recirculation and Batch 12 reached 1.21 g/mL after 32 hours of recirculation. Batch 12 was the last batch to reach a density above 1.20 g/mL, indicating the end of bulk retrieval. Between the two batches, 4,800 gallons of waste were retrieved from tank AX-103.
October 14 to 27, 2021 (Batch 13 & 14)	Batch 13 and 14 reached densities of 1.19 g/mL and 1.17 g/mL, respectively. Batch 13 had a long recirculation period of 86 hours due to water supply issues. The extended recirculation time appeared to form a mound of waste around the pump, inhibiting liquid flow. This lower liquid flow caused Batch 13 to have a small transfer volume. Batch 14 was used predominately as a sluicing method to clear the solid accumulation immediately surrounding the pump. Between the two batches, 7,000 gallons of waste were retrieved from tank AX-103.
October 28 to 31, 2021	Retrieval paused for a safety stand-down regarding updated COVID-19 controls.
November 1 to 4, 2021 (Batch 15)	Batch 15 reached a density of 1.17 g/mL after 43 hours of recirculation, and it retrieved 1,200 gal of waste from tank AX-103.
November 4 to 9, 2021	Retrieval was paused during an electrical outage in the 241-AZ Tank Farm, which provided an opportunity to replace broken lights and a camera that had degraded from radiological exposure.

Table 4-1. Tank 241-AX-103 Retrieval Chronology. (2 sheets)

Date(s)	Description
November 9 to 16, 2021 (Batch 16)	Batch 16 had the first use of high-pressure water (HPW) to reduce waste piles to the southwest and west of the pump for 1.5 hours. This batch reached 1.10 g/mL after 47 hours of recirculation and retrieved 1,300 gallons of tank AX-103 waste.
November 16 to 29, 2021 (Batch 17 & 18)	Batch 17 used HPW for 1.75 hours to reduce waste to the north of the pump and a section of the northeast tank wall. Both Batches 17 and 18 reached 1.06 g/mL. Batch 18 was used predominately as a sluicing method to clear the solid accumulation immediately surrounding the pump. Between the two batches, 900 gallons of waste were retrieved from tank AX-103.
November 30 to December 16, 2021 (Batch 19)	Batch 19 used HPW for 1.3 hours to reduce waste piles to the west of the pump. This batch had an extended recirculation time of 128 hours due to tank 702-AZ ventilation maintenance preventing transfers to tank 241-AZ-102 (AZ-102). Batch 19 reached 1.08 g/mL, retrieving 1,100 gallons of tank AX-103 waste.
December 20, 2021, to January 12, 2022 (Batch 20)	Batch 20 reached 1.07 g/mL after recirculating for 55 hours. Low pit temperatures required a weeklong shutdown before Batch 20 could be transferred to tank AZ-102. Approximately 400 gallons of waste were retrieved from tank AX-103.
January 12 to 18, 2022 (Batch 21)	Batch 21 used HPW for 19 minutes before pooling quickly, where it then obstructed direct access to the waste surface. Batch 21 reached 1.06 g/mL after recirculating for 39 hours; it retrieved approximately 500 gallons of waste.
January 18 to 25, 2022 (Batch 22)	Batch 22 reached 1.04 g/mL after recirculating for 58 hours. This was the first batch with a density less than 1.05 g/mL, allowing it to be considered "ineffective." Approximately 400 gallons of waste were retrieved from tank AX-103.
January 27 to February 2, 2022 (Batch 23)	Batch 23 used HPW for 30 minutes before pooling quickly obstructed direct access to the waste surface. Batch 23 reached 1.02 g/mL after 44 hours of recirculation. This was the second batch with a density less than 1.05 g/mL, allowing it to be considered "ineffective." Approximately 100 gallons of waste were retrieved from tank AX-103.
February 3 to 14, 2022 (Batch 24)	Batch 24 reached 1.02 g/mL after 40 hours of recirculation. This was the third batch with a density less than 1.05 g/mL, allowing it to be considered "ineffective." Water was added at the end of this batch to submerge the waste to allow for a waste volume displacement measurement, which reduced the final density to 1.01 g/mL. The waste volume displacement identified 9,300 gallons of waste remaining in tank AX-103, resulting in a total waste retrieved volume of 103,000 gallons.
February 17, 2022	Final flush added 700 gallons of water to tank AX-103 and 200 gallons of water to tank AZ-102. Based on retrieval tracking and waste volume displacement measurements, the waste volume, upon ceasing retrieval operations in tank AX-103, was estimated at 9,952 gallons. Note: as discussed in Section 2.0, laser scans later showed a final waste volume of 5,875 gallons, including waste on the tank bottom, walls, stiffener rings and equipment.

Table 4-2. Tank 241-AX-103 Batch Progress Summary (2 sheets).

Batch Number	Water Added (gallons)	Recirculation Time (hours)	Final Density (g/mL)
1	3,000	40	1.34
2	5,500	30	1.31

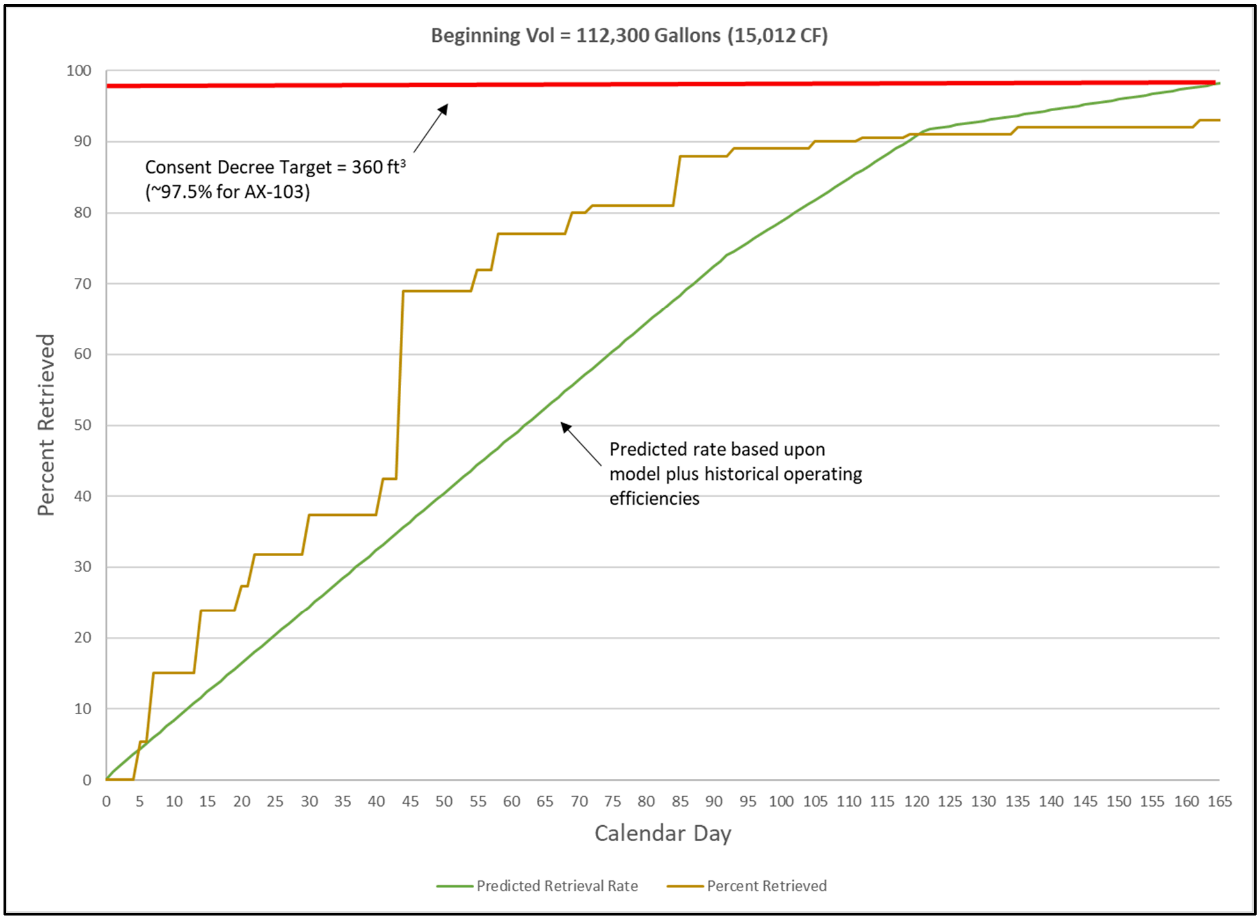
Table 4-2. Tank 241-AX-103 Batch Progress Summary (2 sheets).

Batch Number	Water Added (gallons)	Recirculation Time (hours)	Final Density (g/mL)
3	9,000	36	1.32
4	5,000	29	1.31
5	5,000	23	1.33
6	8,100	47	1.30
7	8,100	40	1.27
8	8,000	42	1.26
9	3,500	8	1.31
10	4,500	9	1.28
11	3,500	27	1.30
12	4,000	32	1.21
13	8,100	86	1.19
14	2,000	–	1.17
15	5,100	44	1.17
16	700 (HPW) 9,200	47	1.10
17	700 (HPW) 4,000	51	1.06
18	4,300	1	1.06
19	500(HPW) 6,000	128	1.08
20	4,500	56	1.07
21	192 (HPW) 7,500	39	1.06
22	6,500	58	1.04
23	200 (HPW) 6,300	44	1.02
24	10,900	40	1.01

4.3 WASTE RETRIEVAL EFFICIENCY

The rate of waste retrieval was high through the first 12 batches. Approximately 80% of retrieved waste occurred over these batches and is considered “bulk retrieval.” Progress began to slow past 80% retrieved as the readily soluble saltcake was removed, leaving less soluble waste material. This remaining dissolved waste started to plateau at lower densities. Transfers of lower-density slurry subsequently retrieved less waste, as shown in Figure 4-1. HPW was used but showed little to no change due to the already fine waste form and lack of waste agglomerations.

Figure 4-1. Retrieval Progress.



CF = cubic feet

Based on the final waste residual volume of 5,875 gal (785 ft^3), and a starting solids volume of 95,900 gal of saltcake and 7,900 gal of sludge, 97,925 gal of solids were retrieved from tank AX-103. Approximately 147,000 gal of water were used to retrieve this volume, or 1.5 gal of water per gallon of tank AX-103 solids retrieved.

4.4 RETRIEVAL DURATION

Retrieval of tank AX-103 using modified sluicing was predicted to take 111 operating days at four 8-hr shifts per day, seven days per week, and 41% efficiency (RPP-RPT-58934, Table 3-2). Retrieval operations ceased after 95 operating days due to ineffective retrieval. Approximately 97,925 gal of solids were removed from tank AX-103 over 95 operating days with two shifts per day (day and swing shifts), four days a week, from August 5, 2021, to February 14, 2022, 193 calendar days.

5. POST-RETRIEVAL SINGLE-SHELL TANK 241-AX-103 RISK ASSESSMENT

The potential impacts to human health from residual waste left in tank AX-103 at closure were estimated using the model developed for the Waste Management Area (WMA) A-AX performance assessment (PA) (RPP-ENV-61497, *Preliminary Performance Assessment of Waste Management Area A-AX, Hanford Site, Washington*), the justification for which has been established in the Environmental Model Calculation Files written to support that effort. The WMA A-AX PA methodology represents the current approach being used to support the assessment of long-term impacts to human health from tank residuals left in SSTs at WMA A-AX.

The system model documented in RPP-CALC-65649, *Potential Groundwater Impacts and Inadvertent Intruder Doses from Tank 241-AX-103 Using Post-Retrieval Inventories* evaluates releases from residual wastes left in tank AX-103 after closure. Evaluation of the COPCs released into the environment depends on the residual waste inventory, the tank system, contaminant transport through the vadose zone, and transport through the saturated zone to the point of calculation at the WMA fenceline for subsequent estimation of cancer risks and non-cancer hazards to humans from the potential use of the contaminated water at the point of calculation. The system model was developed by abstracting process modeling results and capturing key features, events, and processes related to safety functions, while maintaining computational efficiency.

The results obtained from the system model related to the groundwater pathway include the COPC concentration in the saturated zone at the WMA fenceline from which both cancer risks from chemicals and non-cancer hazards can be calculated using the U.S. Environmental Protection Agency (EPA)'s residential tap water scenario. These concentrations are also used to demonstrate compliance with the Model Toxics Control Act (MTCA, *Revised Code of Washington* 70A.305, "Hazardous Waste Cleanup—Model Toxics Control Act") by comparing them to groundwater cleanup levels specified in the January 2023 edition of Cleanup Levels and Risk Calculation (CLARC) (Cleanup Levels and Risk Calculation [CLARC], Queried 5/08/2023, [CLARC data tables and other technical information], https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables). Radionuclide groundwater concentrations are used to evaluate compliance with the regulatory standard for a beta/photon-emitter dose of 4 mrem/yr. using the dose coefficients reported in DOE-STD-1196-2021, *Derived Concentration Technical Standard*.

5.1 GROUNDWATER

To fulfill requirements set forth in the HFFACO (Ecology et al. 1989) Action Plan, Appendix I, risk assessment RPP-CALC-65649 analyzes impacts from hazardous chemical and dangerous waste constituents which are anticipated to remain in tank AX-103 at closure.

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

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

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

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

Inhalation of aerosolized COPCs while showering is included in the analysis using the mass-balance model from EPA/600/R-15/271, *Incorporating a Capability for Estimating Inhalation Doses in TEVA-SPOT*, as recommended by Ecology in their comments on RPP-ENV-62206, *Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington*.

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

Cancer risks and hazard quotients from groundwater use are based on equations and exposure assumptions presented in RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington* using a target risk level of 1×10^{-6} and a cumulative risk level of 1×10^{-5} for carcinogens or a Hazard Quotient (HQ) of 1 and Hazard Index (HI) of 1 for noncarcinogens.

The mathematical model used to calculate cancer and non-cancer risks from exposure to hazardous chemicals from tank AX-103 residuals is detailed in Section 3.3 of RPP-CALC-63600, *Calculation of Groundwater Impacts from Hazardous Chemicals in Residual Wastes Left in Tanks and Ancillary Equipment at Waste Management Area A-AX*.

It is possible to have impacts from chemicals that have not been considered in estimated residual wastes inventories for Tank AX-103 in this analysis. These impacts cannot be assessed without characterization data from the tank waste. However, as described in RPP-CALC-65649, Attachment 11, persistent chemicals left in the residual waste at closure that have a soil-water partition coefficient greater than 1 mL/g will not be expected to impact groundwater because the transport time to groundwater exceeds 10,000 years.

Hexavalent chromium is a potent oral and inhalation carcinogen, and tank AX-103 is the first 241-AX Farm tank to have a bounding inventory for hexavalent chromium calculated from post-retrieval sampling (RPP-RPT-64056, Appendix D). The resulting inventory was then subtracted from that of total chromium to obtain an inventory for trivalent chromium. The inventories used in this analysis include the 95% UCL inventory, which tends to be an overestimation and, as such, would provide a nearly upper bound to the results. In addition, hexavalent chromium's potency as an inhalation carcinogen is addressed through the adoption of an EPA mass-balance model for inhalation while showering (EPA/600/R-15/271).

Ecology has raised concerns about the potential presence of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in residual tank waste based on detections in the groundwater near WMA A-AX. PCDDs and PCDFs that may be present in residual waste, such as 2,3,7,8 tetrachloro dibenzo-p-dioxin, cannot be evaluated for impacts on groundwater because there is no characterization data for these chemicals in the BBI or post-retrieval samples. Using the organic carbon-water partition coefficients (K_{oc}) for PCDDs and PCDFs found in EPA's Superfund Chemical Data Matrix (EPA Superfund, Queried 10/11/2022, [Superfund Chemical Data Matrix Query], https://www.epa.gov/superfund/superfund-chemical-data-matrix-scdm-query), and the organic carbon fraction of Hanford sediments for various 200 East Area and 200 West Area wells (PNNL-30443, *Sediment Mineralogy Data Review for the Hanford Central Plateau*), the lowest distribution coefficient (K_d) that can be calculated with these data is 14 mL/g. The WMA A-AX PA (RPP-ENV-61497) showed that contaminants in residual waste in an intact, retrieved tank with a K_d greater than 0.6 mL/g would not be expected to reach the groundwater within 10,000 years. Furthermore, RPP-RPT-59197, *Analysis of Impacts of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington*, identified chemicals that are not sufficiently mobile to reach groundwater within 10,000 years after tank closure. WMA C is near WMA A-AX and has similar hydrostratigraphic units, making it a suitable analogue for this analysis. The screening in RPP-RPT-59197 used hydraulic properties that yielded maximum transport rates and used net infiltration rates that were greater than those used in RPP-RPT-61497. The screening analysis in RPP-RPT-59197 showed that chemicals with K_d values greater than 2 mL/g would not reach groundwater within 10,000 years post-closure. Since the lowest estimated K_d calculated for PCDDs and PCDFs is 14 mL/g, it is reasonable to assume that PCDDs and PCDFs would not impact groundwater within 10,000 years post-closure, using the increased net recharge of the WMA C screening analysis. Tank AX-103 is an intact tank, therefore, it is unlikely that PCDD and PCDF detections in groundwater could have originated from this tank.

5.2 INADVERTENT INTRUDER

The risk assessment also evaluates the radiological doses and dose rates from hypothetical inadvertent intrusion for one acute scenario (i.e. well driller) and three chronic scenarios (i.e. rural pasture, suburban garden and commercial farm) for comparison to the relevant regulatory standards of 500 mrem for acute inadvertent intrusion dose and 100 mrem/yr. for chronic inadvertent intrusion dose rate. Of all the inadvertent intruder scenarios, the acute Well Driller scenario has among the fewest sources of uncertainty because of the absence of environmental transport and partitioning mechanisms, such as crop uptake or fodder uptake, that are found in the chronic scenarios. The equations used in the models for the Inadvertent Intruder scenarios are identified in RPP-CALC-65649.

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

5.3 ASSUMPTIONS AND INPUTS

RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment* lists assumptions and inputs for the groundwater pathway calculations as well as the inadvertent intruder scenarios. The assumptions related to the residential tap water scenario, the acute well driller inadvertent intrusion scenario and the chronic suburban garden, commercial farm and rural pasture inadvertent intrusion scenarios are also detailed in RPP-RPT-63634, *Model Package Report System Model for Tank Farms Inadvertent Intruder Scenarios*. RPP-RPT-63634 corrects errors in the inadvertent intruder section of RPP-ENV-58813, and therefore correctly describes the inadvertent intruder scenarios.

The residual inventory estimates used in this evaluation were based on tank residual waste samples laboratory analysis results and the residual waste volumes estimated by the RVMS or laser scanning and in-tank video (RPP-RPT-63817).

5.3.1 Constituents Evaluated

Two inventories were calculated: an average inventory based on mean concentrations, density, and waste volume and an upper bounding inventory that is an estimate of inventory parameters (e.g., concentration, density, and waste volume) at the 95% UCL (RPP-RPT-64056).

The average and 95% UCL inventories for the residual solids are shown in Table 3-4. Note that the symbol "<" indicates that the inventory was calculated based on the analytical method detection limit because the analyte was not detected in the samples. Radionuclide inventories in RPP-RPT-64056 are decay-corrected to January 1, 2022.

5.4 RESULTS FOR INDIVIDUAL CONTAMINANTS FOR POST-RETRIEVAL SINGLE-SHELL TANK 241-AX-103

This section presents the groundwater transport results at WMA A-AX that include contaminant concentrations along with the results of the cancer risk and non-cancer hazard calculations for the closed tank AX-103 using EPA's residential tap water exposure scenario. For carcinogens, the target risk level is 1×10^{-6} with a target cumulative risk level of 1×10^{-5}. For noncarcinogens the target is an HQ of 1 and an HI of 1. This section presents results for two time periods: the 0- to 1,000-year period (years 2050 to 3050) and 1,000- to 10,000-year period (years 3051 to 12050) post-closure. Results are provided for the receptor located at the WMA A-AX fenceline.

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

Additionally, there were several analytes in the inventory estimates that have not been considered in the WMA A-AX PA or chemical impacts analysis. Only thirty of these additional analytes were detected, of which five have a Federal or Washington State maximum concentration level (MCL): arsenic, barium, cadmium, copper and antimony. These 5 analytes have K_d values far greater than 1 mL/g, most an order of magnitude greater. Analytes with a K_d value of 1 mL/g have been determined to only reach the groundwater in insignificant levels (e.g., about twenty-two orders of magnitude or greater below the MCL) in 10,000 years (RPP-CALC-65649, Attachment 11). Therefore these five analytes were screened out of further analysis. Although the remaining constituents had non-detect values, modeling them using their 95% UCL inventories showed that no constituent had a fenceline concentration greater than three orders of magnitude below its MCL in 10,000 years (RPP-CALC-65649, Attachment 11).

5.4.1 Groundwater Impacts

This analysis estimates the potential future radiological dose from contaminants regulated under the *Atomic Energy Act of 1954*, as amended (uranium, ^{99}Tc, ^{90}Sr, ^{137}Cs and actinides). The potential impacts to human health posed by the residual waste in tank AX-103 were evaluated in isolation from other sources using the methodology documented in RPP-ENV-61497. The WMA A-AX PA methodology represents the current approach being used to support the assessment of long-term human health impacts from tank residuals.

The human health impacts from existing residual wastes after two retrieval technologies have been applied, considering that COPCs for the groundwater pathway were evaluated with a variety of performance metrics. This analysis uses the maximum modeled groundwater concentrations for COPCs at the WMA A-AX fenceline, which were estimated using one-dimensional modeling of vadose zone and groundwater flow and transport. For example, the peak concentration at the fenceline for ^{99}Tc for the existing inventory estimate is estimated at about 1.8 pCi/L. Using the 95% UCL inventory from the post-retrieval samples, the peak simulated groundwater concentration at the fenceline is about 2.8 pCi/L. Note that the 95% UCL inventory for ^{99}Tc is 54% greater than the average inventory; due to linearity in the release and transport processes, the peak groundwater concentration is also 54% higher. The ^{99}Tc concentration that the EPA determined is equivalent to the 4 mrem/yr. drinking water standard is 900 pCi/L. However, in 2021 DOE published updated dosimetry values; based on the updated dosimetry a concentration of 10,400 pCi/L of ^{99}Tc would yield a 4 mrem/yr. drinking water dose (derived from dose conversion factors reported in DOE-STD-1196-2021).

Table 5-1 shows estimated WMA A-AX peak fenceline concentrations for the three detected radionuclides with fenceline groundwater concentrations greater than 1×10^{-9} pCi/L (^{99}Tc, ^{126}Sn and ^{129}I), the corresponding inventories, Federal MCLs, beta/photon dose rate equivalent, and groundwater pathway dose rate to an all-pathways representative person associated with residual waste left after retrieval (both average and 95% UCL inventory estimates). The groundwater radiological dose from drinking water is evaluated using the residual waste inventories and the all-pathways representative person scenario. Simulated groundwater concentration levels for the selected analytes indicate that the impacts from residual waste left in tank AX-103 after retrieval are about two to three orders of magnitude below the EPA's derived concentrations for the MCL. Beta/photon dose rate equivalents from these three radionuclides are about two to three orders of magnitude below the 4 mrem/yr. regulatory standard. If non-detected results are considered and evaluated at one-half the detection limit, ^{99}Tc, ^{126}Sn and ^{129}I are still over 1×10^{-9} pCi/L and, of the non-detects, only ^{79}Se has a peak fenceline concentration greater than 1×10^{-9} pCi/L: 2.3×10^{-3} pCi/L (average inventory) and about 7.0×10^{-3} pCi/L (upper-bound inventory). There is an insignificant increase in the peak beta/photon dose rate equivalent from the addition of ^{79}Se. The peak total beta/photon dose rate equivalent is about two orders of magnitude below the regulatory standard, even when using upper-bound inventories with non-detects at one-half the detection limit.

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

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

Table 5-1. Estimated Groundwater Concentrations and Radiological Dose at Peak Year for Technetium-99, Tin-126 and Iodine-129 from Residual Inventories Remaining in Single-Shell Tank 241-AX-103 at Closure.

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

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

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

[c] 40 CFR 141.66, Maximum contaminant levels for radionuclides.

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

Table 5-2 shows estimated inventory and related peak fenceline concentrations, Federal MCLs, CLARC MTCA Method A or B groundwater cleanup levels, and HQs associated with detected chemicals in residual waste left after retrieval.

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

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

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

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

1.0, and about three orders of magnitude below for nitrite. After retrieval, groundwater hazard impacts from nitrate and nitrite are significantly below the regulatory standards.

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

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

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

5.4.2 Inadvertent Intruder Impact

This analysis evaluates the radiological doses and dose rates from hypothetical inadvertent intrusion scenarios for an acute well driller scenario and chronic suburban garden, rural pasture and commercial farm scenarios. This section presents detailed results from these scenarios, including contributions of exposure pathways and contributing radionuclides. Of all the inadvertent intruder scenarios, the acute well driller scenario has among the fewest sources of uncertainty because of the absence of environmental transport and partitioning mechanisms, such as crop uptake or fodder uptake, that are found in the chronic scenarios.

Inadvertent intruder doses and dose rates are estimated between 500 and 1,000 years post-closure. Intrusion into a tank without recognition by the driller before 500 years is not considered a credible event (RPP-ENV-61497) due to the thick grout layer poured into the tank to isolate the waste. NUREG-1854, *NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations – Draft Final Report for Interim Use* concludes that for deeper wastes when robust intruder barriers exist, it is appropriate to assume that intrusion is prevented for at least 500 years. Additionally, the Modified RCRA Subtitle C Barrier design described by DOE/RL-93-33, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas* is assumed to meet the requirements for disposal of Class C waste established in Title 10, CFR, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste" (10 CFR 61), Subpart D—Technical Requirements for Land Disposal Facilities, § 61.55, Waste classification. This assumption is made because "the thicknesses of one or more of the barrier layers (e.g., grading fill [Layer 8] or topsoil [Layers 1 and/or 2]) could be modified (i.e., increased) to conform to" a 5-m (16.4-ft) depth that would preclude an excavation scenario into the waste.

Table 5-2. Hazard Quotient and Groundwater Concentrations at Peak Year for Key Chemical Constituents Related to Residual Inventories Remaining in Single-Shell Tank 241-AX-103 at Closure Based on Best-Basis Inventory. (2 sheets)

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

Table 5-2. Hazard Quotient and Groundwater Concentrations at Peak Year for Key Chemical Constituents Related to Residual Inventories Remaining in Single-Shell Tank 241-AX-103 at Closure Based on Best-Basis Inventory. (2 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kilograms)	Time of Peak (Years Post-Closure)	Waste Management Area A-AX Fenceline Concentration (µg/L)	K_d[a] (mL/g)	Federal Maximum Concentration Level (µg/L)	CLARC[b] MTCA Method A or B (non-cancer) Groundwater Cleanup Levels (µg/L)	Hazard Quotient Residential Tap Water Scenario[c]	Cancer Risk Residential Tap Water Scenario[c]
Nitrate	Yes	1.28E+02	2,350	2.94E+00	0	44,300[h]	115,100[h]	2.05E-05	0.00E+00
Nitrite	Yes	4.19E+01	2,350	9.63E-01	0	3,300[h]	5,300[h]	1.59E-04	0.00E+00
Nitrate-N	Yes	2.89E+01	2,350	6.64E-01	0	10,000	26,000	2.05E-05	0.00E+00
Nitrite-N	Yes	1.28E+01	2,350	2.93E-01	0	1,000	1,600	1.59E-04	0.00E+00
Regulatory Standard								**1**	**1.00E-06**

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

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

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

[c] All exposure scenarios are described in RPP-ENV-58813, *Exposure Scenarios for Risk and Performance Assessments in Tank Farms at the Hanford Site, Washington*.

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

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

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

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

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

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

Table 5-3 shows the peak post-closure dose to a receptor from tank AX-103 residual waste using different inadvertent intruder exposure scenarios.

Table 5-3. Potential Future Inadvertent Intruder Dose for Residual Waste Remaining in Tank 241-AX-103 at Closure for All Intruder Scenarios.

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

[1] Regulatory Standard = 500 mrem.
[2] Regulatory Standard = 100 mrem/year.

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

Table 5-4 shows the relative fraction of exposure pathways contributing to total dose or dose rate for each intruder scenario. These pathway contributions are evaluated at the year of peak potential exposure (i.e., 500 years post-closure). Overall dose decreases with the passage of time, and because of differing decay rates between radionuclides contributing to dose or dose rate, the pathway contribution fractions may change over time as well. The contributions of the various exposure pathways to the exposure scenarios are about the same when using either inventory. The soil inhalation pathway contributes the most dose in the well driller scenario, while the external exposure pathway contributes the highest dose rate in the rural pasture and commercial farm scenarios. The suburban garden scenario gets most of the total dose rate from the vegetable ingestion exposure pathway.

Table 5-4. Relative Fraction of Exposure Pathways to Total Dose or Dose Rate at Year of Peak Potential Exposure for Inadvertent Intruder Scenarios.

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

N/A = Not applicable

Table 5-5 illustrates how eight key radionuclides contribute to the majority of dose or dose rate in each exposure scenario for the average inventory case. The table shows the percentage of dose or dose rate that each radionuclide contributes to both the primary exposure pathway and the total (all exposure pathways) for each exposure scenario at the time of peak potential exposure (500 years post-closure). In terms of the total dose or dose rate, three radionuclides are the primary contributors: for the well driller and suburban garden scenarios, ^{239}Pu contributes the most dose or dose rate and ^{126}Sn is the third highest contributor, while for the rural pasture and commercial farm scenarios the contributions are switched with ^{126}Sn contributing the most and ^{239}Pu is the third highest contributor. In all scenarios, ^{241}Am contributes the second highest total dose or dose rate.

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

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

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

When considering the primary exposure pathways, ^{239}Pu contributes the majority of dose or dose rate in the well driller and suburban garden scenarios as shown in Table 5-5. For these scenarios ^{240}Pu is the third highest contributor. Tin-126 is the dominant contributor to the primary exposure pathways in the rural pasture and commercial farm scenarios, while ^{239}Pu is the third highest contributor. In all scenarios' primary exposure pathways, ^{241}Am is the second highest contributing radionuclide. The acute well driller and chronic commercial farm scenarios have only ^{241}Am, ^{239}Pu, ^{240}Pu and ^{126}Sn making up more than 98% of both the total dose/dose rate and primary pathway dose/dose rate. Strontium-90 contributes a negligible amount of dose/dose rate to the well driller and commercial farm scenarios. The chronic suburban garden scenario includes these five radionuclides, but ^{90}Sr is a more substantial contributor, and ^{99}Tc contributes more than 2% of the total dose rate. The chronic rural pasture scenario is different from the other three scenarios in that all of the key radionuclides except ^{126}Sn contribute to the total dose rate, but are not significant contributors to the primary pathway's dose rate. This is because ^{63}Ni,

^{90}Sr, ^{99}Tc and ^{129}I are the primary contributors to the Milk Ingestion pathway's dose rate, while ^{239}Pu, ^{241}Am, and ^{240}Pu are the primary contributors to the Soil Ingestion pathway's dose rate.

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

5.5 RISK ASSESSMENT SUMMARY

The following conclusions are based on the risk assessment results.

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

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

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

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

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

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

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

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

6. LEAK DETECTION, MONITORING, AND MITIGATION

The LDMM program was implemented to protect the workers, public, and environment from leaks of mixed radioactive liquid waste. The LDMM program includes technologies and methods used prior to, during, and after waste retrieval to detect leaks, reduce the potential for a leak to occur, and/or minimize leak volumes.

The operational history and decades of waste and liquid level monitoring indicate that tank AX-103 had not leaked and was sound before starting retrieval (HNF-EP-0182, *Waste Tank Summary Report for Month Ending January 31, 2023*). Additionally, there was no evidence of a leak during retrieval of waste from tank AX-103.

The following sections describe the LDMM requirements, leak detection monitoring implementation, mitigative approach, chronology, and results. The major results for the LDMM program during tank AX-103 waste retrieval were as follows.

a. Drywell moisture and gamma logging showed no indication of leaks during the tank AX-103 waste retrieval.

b. Modified static level monitoring demonstrated no indication to support leakage during retrieval.

c. A high-resolution resistivity (HRR) system was deployed with drywells and the tank thermocouple as electrodes and detected no changes indicative of a leak.

LDMM of tank AX-103 waste was performed to RPP-RPT-58934.

6.1 REQUIREMENTS

RPP-RPT-58934 presents the details of the LDMM program during the waste retrieval period. Leak detection and monitoring methods are described in HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements*, Section 6.0, “Design Features” and OSD-T-151-00010, *Operating Specifications for Pressure Testing and Leak Detection for Tank Farm Transfer Systems and for Control and Use of Temporary Transfer Lines.* The primary procedures governing notification and reporting of leaks are TFC-OPS-OPER-C-24, “Occurrence Reporting” and TFC-ESHQ-ENV_FS-C-01, “Environmental Notification.” Table 6-1 presents the tank AX-103 leak detection and monitoring functions and requirements.

6.2 LEAK DETECTION AND TANK MONITORING

During the sluicing retrieval of tank AX-103, HRR was used as the primary leak detection method with drywell moisture logging as a backup. Moisture logging is used when the tank is in retrieval status, but not in active retrieval and the HRR system has been shut off for greater than seven calendar days. Figure 6-1 is a timeline of the leak detection methods used during retrieval operations. Leak detection and monitoring was accomplished by using HRR, drywell monitoring, visual inspection, pit leak detectors, radiological monitoring and Enraf®[5] gauges in waste accepting tank AZ-102, as shown in Table 6-2 and discussed in Sections 6.2.1 through 6.2.5.

Table 6-1. Tank 241-AX-103 Leak Detection and Monitoring Functions and Requirements.

Function	Requirement	Basis	Key Elements
Detect leaks during waste removal from tank 241-AX-103	The leak detection and monitoring system shall be capable of detecting liquid waste releases during all waste removal operations.	WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.	Utilize leak detection and monitoring technologies to detect loss of liquid from a tank; see Section 6.2.
Monitor for leaks from tank 241-AX-103 during waste removal	The waste retrieval system shall be capable of providing data to support quantifying leak volumes from the tanks in the event a release is detected during waste retrieval operations.		Utilize both ex-tank leak detection and monitoring technologies and process data that will allow estimate of leak volume and migration rate to be developed to the extent practical in the event of a leak.
Mitigate leaks during tank 241-AX-103 waste retrieval	The integrated retrieval and leak detection and monitoring system shall be designed and operated to mitigate leaks as the primary means of minimizing environmental impacts from leaks during waste retrieval if they occur.		Leak mitigation strategy described in Section 6.3.

6.2.1 High-Resolution Resistivity and Drywell Logging

The basic resistivity measurement concept utilizes the existing drywells and a tank electrode (normally the tank thermocouple) as measurement electrodes. There are reference transmitters and receiver electrodes located a nominal 1,500 ft or more from the tank farm. Power is applied to a drywell-reference transmitter electrode pair and an amperage measurement obtained. Concurrently, a voltage measurement is obtained at another electrode-reference receiver electrode pair. Soil resistivity is calculated by dividing the voltage measured across the receiver electrode pair by the current measured across the transmitter pair. These measurements are repeated almost continuously, and the subsequent resistivity data analyzed for changes with time.

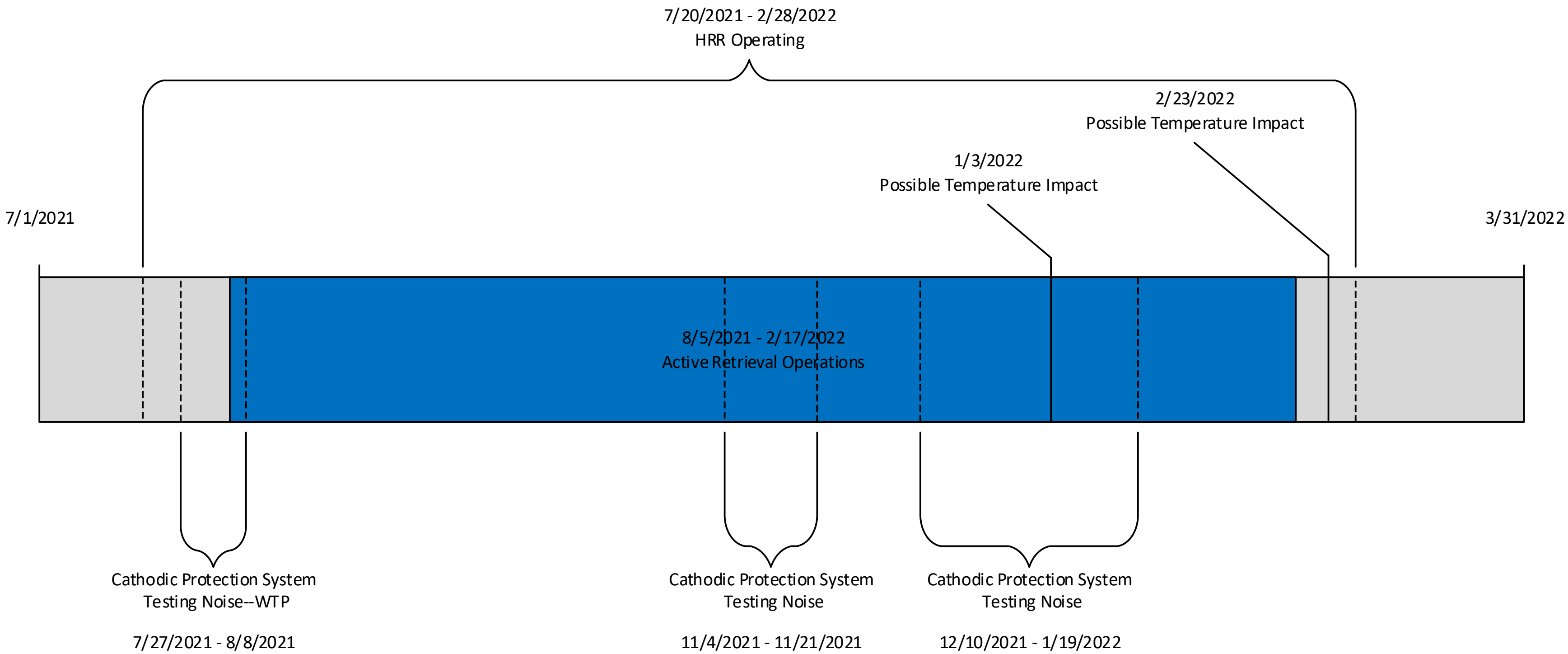
The HRR data is divided into two groups for analysis; the data groups are called well to tank (WTT) and well to well (WTW). The WTT data is the measurements of soil resistance between drywells and the tank electrode. For AX-103 the tank electrode was the tank thermocouple assembly. The WTW data is the measurements of soil resistance between drywells. Ideally, both WTT and WTW resistivity measurements are available to review. When the waste level in the tank is low the thermocouple may not be in contact with the waste, so the WTT data has less

[5] Honeywell Enraf® is a registered trademark of Honeywell International Inc., Morristown, New Jersey.

credibility. It cannot be proven that an electrical pathway exists through the thermocouple and tank structure, although a pathway may exist through structural rebar. No changes were observed in the data when the thermocouple was not in contact with the waste.

The HRR leak detection system was started just before active retrieval operations and continued operating for a short time after active retrieval was discontinued. Figure 6-1 is a timeline of retrieval operations and shows when the HRR system was operational. The system is susceptible to environmental conditions. Towards the end of active retrieval some temperature change impacts were noted.

Figure 6-1. Tank 241-AX-103 High-Resolution Resistivity Timeline.



HRR = high-resolution resistivity

WTP = Waste Treatment Plant

Table 6-2. Leak Detection and Monitoring Methods for Each Waste Retrieval System Component.

Component	Leak Detection and Monitoring Method
Single-shell tank 241-AX-103 (retrieval tank)	Drywells, visual inspection, and high-resolution resistivity
Double-shell tank 241-AZ-102 (receiving tank)	Liquid level indicators, annulus leak detectors, radiation monitoring for annulus exhaust air
Ancillary equipment (hose-in-hose transfer line)	Secondary containment, leak detectors, radiation monitoring

There was one HRR anomaly evaluation record created while the tank AX-103 HRR system was operational. Table 6-3 shows details of the HRR anomaly that occurred and the anomaly disposition. The anomaly occurred just prior to the start of retrieval operations and was caused by cathodic protection system testing at the Waste Treatment Plant (WTP) operated by a separate contractor. It is possible that testing at the WTP impacted the HRR system in the past and was not noticed due to distance from the tank farms and no connecting infrastructure to transmit the electrical noise. In late July 2021, waste transfer piping from the 241-AP Tank Farm was connected to the WTP. This connection allowed electrical noise from WTP cathodic protection system testing to be readily transmitted to the tank farm infrastructure causing much higher than normal readings in the HRR system.

Table 6-3. High-Resolution Resistivity Anomaly Evaluation.

Number	Date	Anomaly Description	Resolution/Comments
2021-01	7/28/21	WTT and WTW leak potential numbers were at greater than 30%.	The high potential values were caused by cathodic protection system test and the Waste Treatment Plant.

WTT = drywell-to-tank WTW = drywell-to-drywell

6.2.2 Neutron Moisture and Gamma Drywell Logging

Drywells were installed for leak detection around the perimeter of the tank after the tank was constructed. The drywells are vertical encased wells that range from approximately 100 to 120 ft deep. Leaks descend both vertically and horizontally in the soil depending on the size and extent of the leak. A leak that expands near the drywell can be detected with either a neutron moisture detector or a gamma detector. The gamma-emitting radionuclides tend to bind with the soil and changes to the gamma logging profile of the drywell provide another indication of whether a waste leak occurred.

Neutron moisture and gamma drywell logging results conclude that none of the drywells around tank AX-103 show evidence of significant changes in moisture content. Handheld neutron moisture (HHNM) data acquired during and after retrieval are within uncertainty, with certain exceptions that were addressed as described in Section 6 of HGLP-MBL-026, *Hanford Geophysical Logging Project 241-AX-103 Post-Retrieval Drywell Monitoring Report*. The gamma and moisture measurements in the drywells provide no evidence of any leak or contaminant movement having encountered the drywells during or after tank AX-103 retrieval operations. The pre-retrieval HHNM data collected upon retrieval of tank AX-103 compared well to the neutron moisture logging system profiles collected in 2014.

6.2.3 Single-Shell Tank 241-AX-103

In-tank mitigative actions to minimize the risk of a leak were taken before and during tank AX-103 retrieval. Mitigative actions of tank AX-103 in-tank monitoring were performed during stagnant periods by liquid level measurements, mass balance calculations and video inspections.

6.2.3.1 Liquid Level Monitoring. The overall waste retrieval operating strategy for tank AX-103 was to reduce the tank liquid inventory and minimize liquid additions during waste retrieval operations. Liquid levels were monitored to evaluate liquid inventories and indicate potential leaks in the system.

No active retrieval actions occurred after February 14, 2022, and the last flush and rinses were pumped to tank AZ-102 by February 17, 2022.[6] During the stagnant periods in between waste transfers, liquid levels in tank AZ-102 did not decrease abnormally, indicating that no leaks occurred.

6.2.3.2 Visual Inspection. Before initiating waste retrieval operations, a visual assessment documented in-tank conditions in tank AX-103 with an in-tank video camera. Throughout waste retrieval, the closed-circuit television system was used to identify the waste surface condition, qualitatively assess the amount of liquid in the tank, observe any significant changes, and implement the mitigation strategy of minimizing liquid pools.

6.2.4 Double-Shell Tank 241-AZ-102

In-tank monitoring of tank AZ-102 was performed by liquid level monitoring, an annulus leak detection system, radiation monitoring[7], and leak detectors in ancillary equipment. The following is a summary of leak mitigation actions for tank AZ-102. More detailed information can be found in HNF-3484, *Double-Shell Tank Emergency Pumping Guide* and RPP-5842, *Time Deployment Study for Annulus Pumping*.

6.2.4.1 Liquid Level Monitoring. The waste level in the DST was monitored using an Enraf® gauge located in the primary tank space during waste transfers, as described in Section 2.0 of OSD-T-151-00031, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection*. Enraf® gauge operation is based on displacement (buoyancy).

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[6] After February 17, 2022, ventilation demister flushes continued to be performed. The water from these flushes went to tank AX-103. Since evaporation during this time period exceeded the amount of water added during this time period, the liquid level in tank AX-103 actually decreased. These flushes continued until operations were switched over to tank AX-101.

[7] The waste contains radioactive elements that can be readily detected, so radiation monitors are used for waste leak detection.

A liquid leak from the primary waste storage tank into the annulus tank would cause a change in buoyancy of displacer to occur.

There was no evidence of a release from primary tank AZ-102 during waste retrieval, based on liquid level monitoring and material balance results. The tank AZ-102 liquid level increase corresponded with the waste transfer from tank AX-103.

6.2.4.2 Leak Detection. Tank AZ-102 was monitored for leaks in the inner shell by three Enraf® gauges installed in the annulus. A change of 0.25 in. of liquid in the annulus tank displacer would activate an alarm at the tank farm instrument building and the tank monitor and control system. Throughout the tank AX-103 waste retrieval operations, no liquid level changes were detected by any of the gauges in the annulus at tank AZ-102.

6.2.4.3 Radiation Monitoring. A continuous air monitor operated to detect airborne radionuclides entrained in the ventilation exhaust stream of the annulus of tank AZ-102. Detection of radiation exceeding a set limit in the annulus of the DST would have activated an audible alarm and an annunciator panel light, initiating mitigative action.

The continuous air monitor for the tank AZ-102 annulus detected no radiation levels above background during retrieval that could have been attributed to leak-induced airborne radionuclides.

6.2.4.4 Ancillary Equipment. Leak detectors were installed in the valve pits to detect the presence of liquid through conductivity, which would have activated alarms and shut down the waste retrieval system.

In accordance with RPP-12711, *Temporary Waste Transfer Line Management Program Plan*, the hose-in-hose transfer line system underwent radiation monitoring and was equipped with leak detectors as part of the leak detection program.

6.3 MITIGATION

Leak mitigation was accomplished through design features and the operational strategy developed for the retrieval system. Mitigation included actions that reduced the chance of a leak and the environmental impact of a leak should one have occurred. Potential leaks were proactively prevented throughout the waste retrieval operations.

The leak mitigation strategy (i.e., reduction of leak loss potential) was to minimize the liquid volume within the tank during waste retrieval operations.

6.3.1 Single-Shell Tank 241-AX-103

A summary of the tank AX-103 mitigation actions to minimize or prevent a leak were as follows.

a. The addition of water to the retrieval tank was minimized to the extent practical.

b. Waste was retrieved to the extent practical by working from the center of the tank outwards. In the center-out waste retrieval strategy, mobilized waste and interstitial liquids drain quickly into a central pool and could have been rapidly pumped from the tank had a leak been detected.

c. Waste sluicing activities were performed only while a video camera was in place to observe the sluicing operation and the waste surface.

d. Equipment handling controls were used to minimize the potential for dropping equipment into the tank, which could have penetrated the tank bottom during installation.

e. A benchmark level was maintained to ensure a low head of introduced liquid. The waste level did not exceed this benchmark.

The mitigative approach was implemented to ensure that potential leakage from tank AX-103 was monitored. Key mitigative actions that would have been taken in the event of a leak are described in RPP-RPT-58934, Sections 4.6.1 and 4.6.2.

6.3.2 Double-Shell Tank 241-AZ-102

Mitigating actions for a leak from AX-103 primary tank piping into the secondary DST containment system during a waste transfer from tank AX-103 would have included (1) stopping the flow of waste into the tank system (stopping the transfer), (2) pumping waste in the primary tank to another DST until the liquid level in the secondary containment was no longer increasing, and (3) removing the waste from the secondary containment system as soon as practicable. Transfer line leakage would have drained to a common point for collection, detection, and removal.

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7. OPPORTUNITIES AND ACTIONS BEING TAKEN TO REFINE OR DEVELOP TANK WASTE RETRIEVAL TECHNOLOGIES, BASED ON LESSONS LEARNED

This section discusses aspects of the tank AX-103 waste retrieval operations and provides recommendations for further actions and opportunities to refine waste retrieval technologies based on lessons learned from the tank AX-103 retrieval operation. The format of this section is to provide brief discussions of the major Lessons-Learned topic areas.

7.1 TANK 241-AX-103 ENHANCEMENTS

Tank AX-103 used ERSS for retrieving tank waste. The tank AX-103 ERSS is different from a standard sluicer in that it has a boom, as well as a mast, which can be used to place the sluicer nozzle closer to the waste and increase the effectiveness in breaking up solid waste in the tank.

The tank AX-103 slurry pump had several key differences from those used to retrieve 241-C Tank Farm tanks, including in-line dilution, low draw-down pumping capability and functional submergence for salt-based retrievals.

- In-line dilution on the slurry pump was available to allow control of the slurry density as it was being pumped to tank AZ-102. However, the specific gravity reached a maximum of 1.34 g/mL therefore, the transfers did not require in-line dilution.

- Tank AX-103 was constructed with a flat bottom. Design changes included modifying the pump suction housing, allowing for low draw down. This modification lowered the stall height to approximately half an inch during retrieval transfers.

- Additional retrieval techniques were deployed during tank AX-103 operations including a technique where the stream was split. This technique was referred to as a recirc transfer where approximately half of the stream was transferred to tank AZ-102 and the other half was returned to tank AX-103 to use for sluicing. This technique was utilized to conserve tank AZ-102 space.

During past retrieval activities at tank AX-102, ERS #2 developed a leak at the PUREX connection on the top of the sluicer. The cause of the leak was determined to be due to movement ("rocking") of the ERS during operations. Movement of the boom, especially when extended, caused the center of gravity to shift and loosened the connection (EDT-882456, *AX Retrieval: Updated AX-104 ERSS Mech Installations for Chem Joint Connections* and EDT-882476, *AX Retrieval: Update AX-101/103 Mechanical Installations for Chem Joint Connections*). Engineering analysis determined that the best fix was to replace the PUREX joint with a Chemjoint™[8] connection and shortened the length of the secondary hose. The sluicers for tank AX-104, tank AX-103, and tank AX-101 were modified to remove the PUREX connectors and installed Chemjoint™ connections.

[8] Chemjoint™ is a trademark of Campbell Fittings, Boyerton, Pennsylvania.

During past retrieval activities at tanks AX-102 and AX-104, in-tank camera lenses would develop an exterior film resulting in visual degradation that would require camera removal and repairs/replacement. A spray ring assembly (EDT-883151, *AX Retrieval: Add Spray Rings to Camera Top Hat Assemblies*) was designed, fabricated, and installed below the camera top hat assemblies. This allowed the camera lenses to be cleaned without removal from the tank, resulting in extended camera life and reduced "down time" for camera replacements. The spray rings also reduced the dose levels on the cameras and lights when replacement was required.

7.2 FUTURE ENHANCEMENT RECOMMENDATIONS

The lessons learned from tank AX-103 that are recommended to extend to future retrieval activities include the following.

- Data collection prior to retrieval activities should include additional soil drywell moisture measurements. Soil moisture data, prior to retrieval, defines the baseline used throughout active retrieval of tank AX-103 to determine if leaks occur during waste transfer activities. More than one set of the pre-retrieval moisture measurements should be obtained for future retrievals, due to anomalies that can occur in drywell data collection.

- To improve in-tank lighting to aid operators during movement of equipment and inspection of residual waste, develop alternative in-tank lighting technologies that would increase visibility during retrieval operations and post-retrieval residual waste characterization.

- To minimize the impacts from low pit temperatures, develop additional methods to prevent air leakage into pits and evaluate the existing pit heater design and fabrication methods.

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APPENDIX A

SINGLE-SHELL TANK 241-AX-103 PRE-RETRIEVAL AND POST-RETRIEVAL INVENTORIES

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Table A-1. Single-Shell Tank 241-AX-103 Best-Basis Inventory Pre-Retrieval and Post-Retrieval Inventories. (2 sheets)

Constituent Name[a]	Pre-Retrieval[b] Inventory	Post-Retrieval[c] Inventory	Unit	Constituent Name[a]	Pre-Retrieval[b] Inventory	Post-Retrieval[c] Inventory	Unit
Al	1.43E+04	4.15E+03	kg	^{106}Ru	1.16E-08	8.12E-11[d]	Ci
Bi	9.50E+00	3.51E+00	kg	^{113m}Cd	1.12E+01	1.86E-01[d]	Ci
Ca	3.41E+02	1.14E+02	kg	^{125}Sb	1.33E+00	1.39E+01	Ci
Cl	3.03E+03	1.27E+00	kg	^{126}Sn	1.21E+00	1.34E+00	Ci
Cr	2.00E+03	2.04E+02	kg	^{129}I	6.41E-02	6.66E-03	Ci
F	5.01E+02	1.38E+01	kg	^{134}Cs	1.55E-03	2.95E+01	Ci
Fe	4.53E+03	2.09E+03	kg	^{137}Cs	8.45E+04	3.08E+03	Ci
Hg	5.21E+00	8.15E+00	kg	^{137m}Ba	7.97E+04	2.91E+03	Ci
K	1.90E+03	2.39E+01	kg	^{151}Sm	1.93E+04	2.66E+03	Ci
La	5.51E+01	6.00E+00	kg	^{152}Eu	9.03E+00	1.12E+01	Ci
Mn	6.15E+02	9.91E+01	kg	^{154}Eu	7.59E+02	1.48E+01	Ci
Na	1.00E+05	8.94E+02	kg	^{155}Eu	1.00E+02	1.36E+01	Ci
Ni	2.69E+02	5.46E+01	kg	^{226}Ra	1.93E-05	7.14E+01	Ci
NO_2	5.06E+04	3.05E+01	kg	^{227}Ac	8.27E-03	1.24E-06[d]	Ci
NO_3	6.45E+04	4.21E+01	kg	^{228}Ra	1.13E-04	7.34E-04	Ci
Oxalate	3.36E+03	2.81E+02	kg	^{229}Th	8.08E-06	3.00E-01	Ci
Pb	3.85E+02	1.76E+02	kg	^{231}Pa	2.21E-02	3.38E+00	Ci
PO_4	3.32E+03	3.51E+02	kg	^{232}Th	1.13E-04	7.34E-04	Ci
Si	1.15E+03	9.10E+02	kg	^{232}U	8.83E-03	1.39E-06	Ci
SO_4	7.78E+03	4.11E+01	kg	^{233}U	8.48E-02	4.11E-02	Ci
Sr	4.58E+01	2.95E+00	kg	^{234}U	9.98E-02	3.95E-01	Ci
TIC as CO_3	3.07E+04	2.88E+02	kg	^{235}U	2.68E-03	9.11E-04	Ci
U_{TOTAL}	1.88E+02	6.44E+01	kg	^{236}U	3.48E-03	4.12E-03	Ci
Zr	1.53E+02	2.29E+00	kg	^{237}Np	4.54E-02	1.49E-01	Ci
^{3}H	2.52E+00	7.93E-03	Ci	^{238}Pu	3.95E+00	5.61E+00	Ci
^{14}C	1.61E+00	7.58E-03	Ci	^{238}U	6.28E-02	2.14E-02	Ci
^{59}Ni	4.81E+00	1.08E+00[d]	Ci	^{239}Pu	9.23E+01	2.86E+01	Ci
^{60}Co	1.54E+01	3.14E+00	Ci	^{240}Pu	2.32E+01	7.00E+00	Ci

Table A-1. Single-Shell Tank 241-AX-103 Best-Basis Inventory Pre-Retrieval and Post-Retrieval Inventories. (2 sheets)

Constituent Name[a]	Pre-Retrieval[b] Inventory	Post-Retrieval[c] Inventory	Unit	Constituent Name[a]	Pre-Retrieval[b] Inventory	Post-Retrieval[c] Inventory	Unit
^{63}Ni	4.16E+02	8.79E+01	Ci	^{241}Am	7.16E+02	6.95E+01	Ci
^{79}Se	4.13E-01	1.09E-02	Ci	^{241}Pu	1.00E+02	2.48E+01	Ci
^{90}Sr	3.37E+05	6.70E+04	Ci	^{242}Cm	6.11E-01	1.87E-01	Ci
^{90}Y	3.37E+05	6.70E+04	Ci	^{242}Pu	1.64E-03	6.92E-03	Ci
^{93m}Nb	1.02E+01	2.55E-01[d]	Ci	^{243}Am	3.90E-01	3.01E-01	Ci
^{93}Zr	1.14E+01	4.52E-01[d]	Ci	^{243}Cm	2.75E-02	2.99E-02	Ci
^{99}Tc	6.68E+01	7.70E-01	Ci	^{244}Cm	5.23E-01	5.18E-01	Ci

Note: Shaded cells are less-than-detect values.

[a] Radionuclides decayed to January 1, 2022.

[b] Data are from RPP-RPT-59854, 2020, *Derivation of Best-Basis Inventory for Tank 241-AX-103 as of July 1, 2020*, Revision 1. Note that Revision 1 of the Best-Basis Inventory predates retrieval activities, which commenced on August 5, 2021. There were no waste transfer activities (only water additions) during this period; hence, inventories in Revision 1 represent pre-retrieval inventories. The pre-retrieval inventory is the sum of all waste phases present at the time.

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

[d] No post-retrieval analysis for this constituent. Estimated value from RPP-RPT-59854, 2023, *Derivation of Best-Basis Inventory for Tank 241-AX-103 as of April 1, 2023*, Revision 5.

TIC = total inorganic carbon

U_{TOTAL} = total uranium

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APPENDIX B

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR TANK 241-AX-103 RESIDUAL SOLIDS

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Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-AX-103 Residual Solids. (6 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration[1]	Units	RSD[2]
1,1,1-Trichloroethane	71-55-6	<	1.23E-02	µg/g	1.00E+00
1,1,2,2-Tetrachloroethane	79-34-5	<	5.41E-03	µg/g	1.00E+00
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	<	5.37E-03	µg/g	1.00E+00
1,1,2-Trichloroethane	79-00-5	<	1.54E-02	µg/g	1.00E+00
1,1-Dichloroethene	75-35-4	<	7.25E-03	µg/g	1.00E+00
1,2,4-Trichlorobenzene	120-82-1	<	8.75E-03	µg/g	1.00E+00
1,2-Dichlorobenzene	95-50-1	<	5.22E-03	µg/g	1.00E+00
1,2-Dichloroethane	107-06-2	<	1.08E-02	µg/g	1.00E+00
1,4-Dichlorobenzene	106-46-7	<	5.70E-03	µg/g	1.00E+00
^{125}Sb	14234-35-6	<	6.14E-01	µCi/g	1.00E+00
^{126}Sn	15832-50-5	—	5.93E-02	µCi/g	3.00E-01
^{129}I	15046-84-1	—	2.94E-04	µCi/g	3.33E-01
^{134}Cs	13967-70-9	<	1.30E+00	µCi/g	1.00E+00
^{137}Cs	10045-97-3	—	1.36E+02	µCi/g	3.25E-01
^{137m}Ba[3]	—	—	1.28E+02	µCi/g	3.25E-01
^{14}C	14762-75-5	—	3.34E-04	µCi/g	3.71E-01
^{151}Sm	15715-94-3	—	1.17E+02	µCi/g	2.79E-01
^{152}Eu[3]	14683-23-9	<	4.92E-01	µCi/g	1.00E+00
^{154}Eu	15585-10-1	—	6.51E-01	µCi/g	1.94E-01
^{155}Eu[3]	14391-16-3	<	6.02E-01	µCi/g	1.00E+00
1-Butanol	71-36-3	<	2.54E-01	µg/g	1.00E+00
2,4,5-Trichlorophenol	95-95-4	<	2.85E+00	µg/g	1.00E+00
2,4,6-Trichlorophenol	88-06-2	<	2.87E+00	µg/g	1.00E+00
2,4-Dinitrotoluene	121-14-2	<	2.89E+00	µg/g	1.00E+00
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	128-37-0	<	2.74E+00	µg/g	1.00E+00
^{226}Ra	13982-63-3	<	3.15E+00	µCi/g	1.00E+00
^{228}Ra	15262-20-1	—	3.24E-05	µCi/g	3.65E-01
^{228}Th	14274-82-9	—	9.08E-03	µCi/g	3.43E-01
^{229}Th	15594-54-4	<	1.32E-02	µCi/g	1.00E+00
^{230}Th	14269-63-7	<	1.28E-03	µCi/g	1.00E+00
^{231}Pa	14331-85-2	<	1.49E-01	µCi/g	1.00E+00

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-AX-103 Residual Solids. (6 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration[1]	Units	RSD[2]
^{232}Th	N/A	—	3.24E-05	µCi/g	3.65E-01
^{232}U[3]	14158-29-3	—	6.14E-08	µCi/g	2.91E-01
^{233}U	13968-55-3	—	1.82E-03	µCi/g	3.48E-01
^{234}U	13966-29-5	<	1.74E-02	µCi/g	1.00E+00
^{235}U	15117-96-1	—	4.02E-05	µCi/g	2.82E-01
^{236}U	13982-70-2	<	1.82E-04	µCi/g	1.00E+00
^{237}Np	13994-20-2	—	6.57E-03	µCi/g	2.02E-01
^{238}Pu	13981-16-3	—	2.48E-01	µCi/g	2.40E-01
^{238}U	N/A	—	9.46E-04	µCi/g	2.87E-01
$^{239/240}$Pu	N/A	—	1.57E+00	µCi/g	1.75E-01
^{239}Pu[3]	15117-48-3	—	1.26E+00	µCi/g	1.75E-01
^{240}Pu[3]	14119-33-6	—	3.09E-01	µCi/g	1.75E-01
^{241}Am	14596-10-2	—	3.07E+00	µCi/g	3.25E-01
^{241}Pu	14119-32-5	—	1.10E+00	µCi/g	1.50E-01
^{242}Cm	15510-73-3	—	8.27E-03	µCi/g	3.24E-01
^{242}Pu[3]	13982-10-0	<	3.05E-04	uCi/g	1.00E+00
$^{243/244}$Cm	N/A	—	2.41E-02	µCi/g	4.05E-01
^{243}Am	14993-75-0	—	1.33E-02	µCi/g	2.04E-01
^{243}Cm[3]	15757-87-6	—	1.32E-03	µCi/g	4.05E-01
^{244}Cm[3]	13981-15-2	—	2.28E-02	µCi/g	4.05E-01
2-Butanone	78-93-3	<	7.44E-02	µg/g	1.00E+00
2-Chlorophenol	95-57-8	<	2.48E+00	µg/g	1.00E+00
2-Ethoxyethanol	110-80-5	<	2.15E+00	µg/g	1.00E+00
2-Methylphenol	95-48-7	<	2.69E+00	µg/g	1.00E+00
2-Nitrophenol	88-75-5	<	2.57E+00	µg/g	1.00E+00
2-Nitropropane	79-46-9	<	9.24E-02	µg/g	1.00E+00
^{3}H	15086-10-9	<	3.50E-04	µCi/g	1.00E+00
4-Chloro-3-methylphenol	59-50-7	<	2.88E+00	µg/g	1.00E+00
4-Methyl-2-Pentanone	108-10-1	<	9.29E-02	µg/g	1.00E+00
4-Nitrophenol	100-02-7	<	2.65E+00	µg/g	1.00E+00
^{60}Co	10198-40-0	<	1.39E-01	µCi/g	1.00E+00
^{63}Ni	13981-37-8	—	3.88E+00	µCi/g	2.24E-01

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-AX-103 Residual Solids. (6 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration[1]	Units	RSD[2]
^{79}Se	15758-45-9	<	4.80E-04	µCi/g	1.00E+00
^{90}Sr	10098-97-2	—	2.96E+03	µCi/g	1.59E-01
^{90}Y[3]	10098-91-6	—	2.96E+03	µCi/g	1.59E-01
^{94}Nb	14681-63-1	<	1.43E-01	µCi/g	1.00E+00
^{99}Tc	14133-76-7	—	3.40E-02	µCi/g	2.06E-01
Acenaphthene	83-32-9	<	3.15E+00	µg/g	1.00E+00
Acetate	71-50-1	—	8.19E+01	µg/g	1.44E-01
Acetone	67-64-1	<	1.68E-01	µg/g	1.00E+00
Ag	7440-22-4	—	1.11E+03	µg/g	3.26E-01
Al	7429-90-5	—	1.83E+05	µg/g	2.70E-01
Aroclors (Total PCB)	1336-36-3	<	8.97E-01	µg/g	1.00E+00
As	7440-38-2	—	2.47E+01	µg/g	2.67E-01
B	7440-42-8	<	3.64E+02	µg/g	1.00E+00
Ba	7440-39-3	—	5.47E+02	µg/g	2.29E-01
Be	7440-41-7	<	7.29E+01	µg/g	1.00E+00
Benzene	71-43-2	<	6.81E-03	µg/g	1.00E+00
Benzo(a)pyrene	50-32-8	<	2.32E+00	µg/g	1.00E+00
Bi	7440-69-9	<	1.55E+02	µg/g	1.00E+00
Bis(2-ethylhexyl)phthalate	117-81-7	<	1.52E+01	µg/g	1.00E+00
Br	24959-67-9	<	3.68E+01	µg/g	1.00E+00
Butylbenzylphthalate	85-68-7	<	4.17E+00	µg/g	1.00E+00
Ca	7440-70-2	—	5.04E+03	µg/g	4.24E-02
Carbon disulfide	75-15-0	<	9.33E-03	µg/g	1.00E+00
Carbon tetrachloride	56-23-5	<	1.24E-02	µg/g	1.00E+00
Cd	7440-43-9	—	1.56E+02	µg/g	3.12E-01
Ce	7440-45-1	—	4.97E+02	µg/g	2.61E-01
Chlorobenzene	108-90-7	<	6.54E-03	µg/g	1.00E+00
Chloroform	67-66-3	<	8.08E-03	µg/g	1.00E+00
Cl	16887-00-6	—	5.62E+01	µg/g	1.83E-01
CN	57-12-5	—	3.40E+00	µg/g	1.71E-01
Co	7440-48-4	<	7.29E+01	µg/g	1.00E+00
Cr	7440-47-3	—	9.01E+03	µg/g	3.54E-01

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-AX-103 Residual Solids. (6 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration[1]	Units	RSD[2]
Cr^{+6}	18540-29-9	—	2.32E+02	µg/g	1.56E-01
Cresol (m & p)	1319-77-3	<	2.75E+00	µg/g	1.00E+00
Cu	7440-50-8	—	3.13E+02	µg/g	2.49E-01
Cyclohexanone	108-94-1	<	2.21E+00	µg/g	1.00E+00
Dibenz[a,h]anthracene	N/A	<	2.55E+00	µg/g	1.00E+00
Diethylphthalate	84-66-2	<	4.74E+00	µg/g	1.00E+00
Di-n-butylphthalate	84-74-2	<	1.99E+01	µg/g	1.00E+00
Di-n-octylphthalate	117-84-0	<	2.73E+00	µg/g	1.00E+00
Ethyl acetate	141-78-6	<	4.65E-02	µg/g	1.00E+00
Ethyl ether	60-29-7	<	1.36E-02	µg/g	1.00E+00
Ethylbenzene	100-41-4	<	8.48E-03	µg/g	1.00E+00
Eu	7440-53-1	<	9.56E+01	µg/g	1.00E+00
F	16984-48-8	—	6.07E+02	µg/g	3.68E-01
Fe	7439-89-6	—	9.21E+04	µg/g	3.58E-01
Fluoranthene	206-44-0	<	2.94E+00	µg/g	1.00E+00
Formate	12311-97-6	<	6.40E+01	µg/g	1.00E+00
Free OH	N/A	—	3.91E+00	µg/g	2.00E-01
Glycolate	666-14-8	<	1.94E+01	µg/g	1.00E+00
Hexachlorobenzene	118-74-1	<	3.28E+00	µg/g	1.00E+00
Hexachlorobutadiene	87-68-3	<	1.68E-02	µg/g	1.00E+00
Hexachloroethane	67-72-1	<	7.54E-03	µg/g	1.00E+00
Hg	7439-97-6	—	3.60E+02	µg/g	2.16E-01
Isobutanol	78-83-1	<	7.32E+00	µg/g	1.00E+00
K	7440-09-7	<	1.06E+03	µg/g	1.00E+00
La	7439-91-0	—	2.65E+02	µg/g	3.44E-01
Li	7439-93-2	<	1.50E+02	µg/g	1.00E+00
Methylene chloride	75-09-2	<	5.03E-03	µg/g	1.00E+00
Mg	7439-95-4	—	7.72E+02	µg/g	7.60E-02
Mn	7439-96-5	—	4.37E+03	µg/g	2.13E-01
Mo	7439-98-7	<	1.23E+02	µg/g	1.00E+00
Morpholine, 4-nitroso-	59-89-2	<	2.64E+00	µg/g	1.00E+00
Na	7440-23-5	—	3.94E+04	µg/g	1.00E+00

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-AX-103 Residual Solids. (6 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration[1]	Units	RSD[2]
Naphthalene	91-20-3	<	2.65E+00	µg/g	1.00E+00
Nb	7440-03-1	<	8.65E+01	µg/g	1.00E+00
Nd	7440-00-8	—	7.84E+02	µg/g	3.00E-01
NH3	7664-41-7	—	3.50E+00	µg/g	1.62E-01
Ni	7440-02-0	—	2.41E+03	µg/g	2.73E-01
Nitrobenzene	98-95-3	<	2.47E+00	µg/g	1.00E+00
N-Nitrosodimethylamine	62-75-9	<	2.02E+00	µg/g	1.00E+00
N-Nitroso-di-n-propylamine	621-64-7	<	2.78E+00	µg/g	1.00E+00
NO_2	14797-65-0	—	1.34E+03	µg/g	6.58E-02
NO_3	14797-55-8	—	1.86E+03	µg/g	1.00E+00
Oxalate	338-70-5	—	1.24E+04	µg/g	3.07E-01
Pb	7439-92-1	—	7.76E+03	µg/g	3.42E-01
Pd	7440-05-3	<	2.55E+02	µg/g	1.00E+00
Pentachlorophenol	87-86-5	<	2.97E+00	µg/g	1.00E+00
Phenol	108-95-2	<	2.63E+00	µg/g	1.00E+00
PO_4	14265-44-2	—	1.55E+04	µg/g	1.74E-01
Pr	7440-10-0	—	1.57E+02	µg/g	2.68E-01
Pyrene	129-00-0	<	2.11E+00	µg/g	1.00E+00
Pyridine	110-86-1	<	1.71E+00	µg/g	1.00E+00
Rb	7440-17-7	<	1.17E+03	µg/g	1.00E+00
Rh	7440-16-6	—	1.29E+02	µg/g	2.49E-01
Ru	7440-18-8	—	1.62E+03	µg/g	2.04E-01
Sb	7440-36-0	—	5.31E+00	µg/g	1.00E+00
Se	7782-49-2	<	1.47E+01	µg/g	1.00E+00
Si	7440-21-3	<	4.02E+04	µg/g	1.00E+00
Sm	7440-19-9	—	1.64E+02	µg/g	2.59E-01
Sn	7440-31-5	<	1.50E+02	µg/g	1.00E+00
SO_4	14808-79-8	—	1.82E+03	µg/g	2.75E-01
Sr	7440-24-6	—	1.30E+02	µg/g	8.40E-02
Ta	7440-25-7	<	1.08E+03	µg/g	1.00E+00
Te	13494-80-9	<	2.20E+02	µg/g	1.00E+00
Tetrachloroethene	127-18-4	<	1.27E-02	µg/g	1.00E+00

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-AX-103 Residual Solids. (6 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration[1]	Units	RSD[2]
Th	7440-29-1	—	2.94E+02	µg/g	3.54E-01
Thiosulfate	14383-50-7	<	3.49E+01	µg/g	1.00E+00
Ti	7440-32-6	—	1.26E+02	µg/g	1.20E-01
Tl	7440-28-0	<	1.41E+02	µg/g	1.00E+00
Toluene	108-88-3	≤	6.68E-03	µg/g	1.00E+00
Trans-1,3-Dichloropropene	10061-02-6	≤	1.51E-02	µg/g	1.00E+00
Tributyl phosphate	126-73-8	≤	3.53E+00	µg/g	1.00E+00
Trichloroethene	79-01-6	≤	6.80E-03	µg/g	1.00E+00
Trichlorofluoromethane	75-69-4	<	6.59E-03	µg/g	1.00E+00
U_{TOTAL}	N/A	—	2.84E+03	µg/g	2.91E-01
V	7440-62-2	≤	8.65E+01	µg/g	1.00E+00
Vinyl chloride	75-01-4	≤	1.12E-02	µg/g	1.00E+00
W	7440-33-7	—	1.81E+02	µg/g	1.59E-01
Xylene (m & p)	108-28-3M	<	1.84E-02	µg/g	1.00E+00
Xylene (o)	95-47-6	≤	7.74E-03	µg/g	1.00E+00
Xylenes (total)	1330-20-7	—	2.62E-02	µg/g	1.00E+00
Y	7440-65-5	—	1.45E+02	µg/g	1.99E-01
Zn	7440-66-6	—	1.24E+02	µg/g	1.94E-01
Zr	7440-67-7	<	1.01E+02	µg/g	1.00E+00

µg/g = micrograms per gram
µCi/g = microcurie per gram
CAS = Chemical Abstract Services
N/A = not available
PCB = polychlorinated biphenyl
RSD = Relative Standard Deviation

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

[2] In accordance with Best-Basis Inventory protocol (RPP-7625, 2019, *Guidelines for Updating Best-Basis Inventory*, Rev. 14, Washington River Protection Solutions, LLC, Richland, Washington), the relative standard deviation is assumed to be 1.00 if the constituent was not detected.

[3] Calculated value (RPP-7625).