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OFFICE OF RIVER PROTECTION
P.O. Box 450, MSIN H6-60
Richland, Washington 99352

AUG 1 1 2017

17-TPD-0018

Ms. Alexandra K. Smith, Program Manager
Nuclear Waste Program
Washington State
Department of Ecology
3100 Port of Benton Blvd.
Richland, Washington 99354

Ms. Smith:

THE U.S. DEPARTMENT OF ENERGY OFFICE OF RIVER PROTECTION SUBMITS THE RETRIEVAL DATA REPORT FOR TANK 241-C-111

Reference: ORP letter from K.W. Smith to A.K. Smith, Ecology, "The U.S. Department of Energy, Office of River Protection Submits the Retrieval Completion Certification Report for Tank 241-C-111," 16-TF-0090, dated August 29, 2016.

1239998

The U.S. Department of Energy, Office of River Protection is transmitting RPP-RPT-60173, *Retrieval Data Report for Single Shell Tank 241-C-111, Rev. 0*, completed in accordance with the requirements of the Hanford Federal Facility Agreement and Consent Order Milestone M-045-86, "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...*" RPP-RPT-60173, Rev. 0, documents completion of waste retrieval and post-retrieval sampling at Tank 241-C-111 using modified sluicing as a first technology, high pressure water as a second retrieval technology, and chemical dissolution as the third technology.

The retrieval completion certification for Tank 241-C-111 was transmitted to the Washington State Department of Ecology on August 29, 2016 (*The U.S. Department of Energy, Office of River Protection Submits The Retrieval Completion Certification Report For Tank 241-C-111*, 16-TF-0090).

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If you have any questions, please contact Glyn D. Trenchard, Assistant Manager for Tank Farms Projects at (509) 373-4016, or R. Doug Greenwell, Manager of Tank Retrievals, Washington River Protection Solutions LLC, at (509) 376-2504.

Kevin W. Smith, Manager
Office of River Protection

TPD:JBB

Attachment

cc w/attach:

R.S. Skeen, CTUIR
J.M. Alzheimer, Ecology
J.J. Lyon, Ecology
N.M. Menard, Ecology
J.B. Price, Ecology
C.L. Whalen, Ecology
D.A. Faulk, EPA
S. Hudson, HAB
C.P. Noonan, MSA
R.E. Piippo, MSA
M.J. Turner, MSA
G. Bohnee, NPT
K. Niles, ODOE
R. Buck, Wanapum
R. Utley, WDOH
R.M. Allen, WRPS
R.D. Cantwell, WRPS
S.B. Cherry, WRPS
N.R. Davis, WRPS
R.E. Gregory, WRPS
R.D. Greenwell, WRPS
J.A. Joyner, WRPS
M.A. Lindholm, WRPS
R.B. McPherson, WRPS
D.L. Parker, WRPS
A.D. Pappas, WRPS
P.L. Rutland, WRPS
K.M. Singleton, WRPS
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RPP-RPT-60173

Transmitting RPP-RPT-60173, Retrieval Data Report for Single Shell Tank 241-C-111, Rev. 0

DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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RPP-RPT-60173
Revision 0

Retrieval Data Report for Single-Shell Tank 241-C-111

Prepared by

A. D. Pappas
J. A. Kadinger
Washington River Protection Solutions, LLC

Date Published
July 2017

washington river protection solutions

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

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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-045-86, due 12 months after the U.S. Department of Energy (DOE) submits a retrieval completion certification 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 *Washington v. DOE*, Case No. CV-08-5085-FVS, as amended[1] (E.D. WA. October 25, 2010). The DOE submitted Revision 00A of its certification of retrieval, RPP-RPT-59363, "*Retrieval Completion Certification Report for Tank 241-C-111*," to Ecology on August 29, 2016 (Letter 16-TF-0090, "The U.S. Department of Energy, Office of River Protection Submits the Retrieval Completion Certification Report for Tank 241-C-111").

This Retrieval Data Report presents information showing that single-shell tank 241-C-111 has undergone waste retrieval using three retrieval technologies, each to its limits of technology, using modified sluicing, high-pressure water, and chemical dissolution deployed with an Extended Reach Sluicing System. The first waste retrieval technology was deployed in 2010 using standard sluicing, which only was able to break up small portions of the crust into chunks – much too large to pass through the pump screen and into the slurry pump (RPP-RPT-59363, Rev. 00A). Waste retrieval was performed with more success using the second and third technologies of high-pressure water and caustic-based chemical dissolution delivered with the Extended Reach Sluicer System.

This Retrieval Data Report also summarizes the potential risk to human health from waste remaining in the tank, provides details on the technologies deployed and their respective performance during the waste removal campaigns, and describes measures taken to prevent and detect leaks during waste retrieval operations.

RPP-RPT-59363, Rev. 00A documents that the three retrieval technologies deployed in tank 241-C-111 retrieved the waste in tank 241-C-111 to the limits of the technologies. The tank 241-C-111 waste retrieval campaign began September 14, 2010 and finished on March 30, 2016. During retrieval, the removed waste from tank 241-C-111 was transferred into double-shell tank 241-AN-101.

The tank 241-C-111 leak detection, monitoring, and mitigation program used during retrieval operations consisted of high-resolution resistivity techniques along with readings from a combination of drywell moisture measurements, waste volume assessments (mass balances), and visual inspection to detect and control potential leaks. No leaks were detected during tank 241-C-111 retrieval operations.

[1] The 2010 Consent Decree has been amended twice. See Amended Consent Decree, Case No. CV-08-5085-RMP (March 11, 2016) and Second Amended Consent Decree, Case No. CV-08-5085-RMP (April 12, 2016). Note that the Amended Consent Decree and Second Amended Consent Decree did not re-publish the provisions of the 2010 Consent Decree but only published those portions of the text that were modified by each decree; consequently, it is necessary to refer to each document to determine whether a particular section has been amended.

Prior to retrieval, after interim stabilization completed in 1994, the best estimate of waste volume remaining was ~57,000 gal (7,700 ft^3). After the initial modified sluicing phase, the estimated upper confidence volume of waste remaining in the tank was revised to ~32,200 gal (4,300 ft^3) (RPP-RPT-59363, Rev. 0). Following deployment of three retrieval technologies, the best estimate of waste remaining in the tank was ~4,890 gal (~654 ft^3) (95% upper confidence level of waste volume, as described in RPP RPT-59363, Rev. 00A).

The inventory of constituents in the residual waste remaining in tank 241-C-111 was determined by laboratory analysis of waste samples, which were taken once it was determined that the requirements of the Consent Decree had been met after the deployment of a third retrieval technology to the limit of technology as described in Appendix C, Part 1 of the Consent Decree. The risk assessment for the residual waste in tank 241-C-111 based on sampling analysis shows that for the groundwater pathway, the estimated risk impacts for tank 241-C-111 are well below performance objectives. For all inadvertent intruder scenarios other than the Suburban Garden and Rural Pasture scenarios (both sensitivity cases) at 100 years after closure, the estimated risk impacts for tank 241-C-111 were below performance objectives. For the Suburban Garden and Rural Pasture scenarios at 500 years after closure, the effects are below performance objectives per DOE M 435.1-1, *Radioactive Waste Management Manual*, Section IV.P.(2)(h).

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TERMS

1C	first cycle waste from the bismuth phosphate process
AEA	alpha energy analysis
AES	atomic emission spectrometry
BBI	best-basis inventory
BBIM	best-basis inventory maintenance
CAD	computer-aided design
CCMS	camera/computer-aided design modeling system
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DOE	U.S. Department of Energy
DOE-ORP	DOE Office of River Protection
DQO	data quality objectives (document)
DST	double-shell tank
ECD	electron capture detection
Ecology	State of Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
ERS	extended reach sluicer
ERSS	Extended Reach Sluicer System
GC	gas chromatography
GEA	gamma energy analysis
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HPW	high-pressure water
HRR	high-resolution resistivity
HTWOS	Hanford Tank Waste Operations Simulator

IC	ion chromatography
ICP	inductively coupled plasma
ILCR	incremental lifetime cancer risk
LDMM	leak detection, monitoring, and mitigation
LSC	liquid scintillation counting
MS	mass spectrometry
MTCA	*Model Toxics Control Act*
PA	performance assessment
PCB	polychlorinated biphenyl
PUREX	Plutonium Uranium Extraction (Plant)
RCW	*Revised Code of Washington*
RDR	Retrieval Data Report
RSD	relative standard deviation
SST	single-shell tank
SVOC	semi-volatile organic compound
TGA	thermogravimetric analysis
TIC	tentatively identified compound
TSR	Technical Safety Requirement
UCL	upper confidence level
VOC	volatile organic compound
WAC	*Washington Administrative Code*
WMA	Waste Management Area
WRS	waste retrieval system
WTT	drywell-to-tank
WTW	drywell-to-drywell

1. INTRODUCTION AND BACKGROUND

Retrieval of single-shell tank (SST) 241-C-111 (C-111) waste occurred in a series of campaigns. At the start of retrieval operations, the tank was reported to contain approximately 57,000 gal (7,700 ft^3) of waste primarily consisting of uranium recovery waste, ferrocyanide waste, Plutonium Uranium Extraction Plant (PUREX) organic wash waste, cladding waste and waste from the Hot Semi-Works Plant. However, during the first stages of hard heel retrieval the starting volume was revised when a supernatant soak and subsequent calculations [SVF-2013, Rev. 0, "C-111 Liquid Displacement (2010-09-30 and 2010-10-29).xlsx"] indicated that the tank only contained approximately 34,900 gal (4,665 ft^3) gal of solid, instead of the assumed 57,000 gal (7,700 ft^3). These wastes are described in RPP-RPT-48459, "*Derivation of Best-Basis Inventory for Tank 241-C-111 as of April 4, 2017.*" Tank C-111 entered service in 1946 when first cycle waste (1C) from the bismuth phosphate process began cascading from tank 241-C-110 into tank C-111. The tank was declared full and the waste cascaded into tank 241-C-112 in November 1946.

Retrieval of tank C-111 stored waste was conducted between September 14, 2010, and March 30, 2016. The three waste retrieval technologies used in tank C-111 for retrieval were modified sluicing, high-pressure water (HPW) using an Extended Reach Sluicer System (ERSS), and chemical dissolution using caustic. Tank C-111 was declared retrieved to the limits of these technologies with a preliminary volume estimate of 7,700 gal (1,029 ft^3) of waste remaining based on liquid displacement measurement and visual evaluation (RPP-CALC-60840, "*Tank 241-C-111 Waste Retrieval Tracking Volume Calculation*"; RPP-RPT-59292, "*Single-Shell Tank 241-C-111 Hard Heel Retrieval Completion Report*").

The first technology of modified sluicing was deployed, from September 14 to September 27, 2010, but was unsuccessful. The sluicing operations were capable of breaking up only small portions of the crust into chunks much too large to pass through the pump screen and into the slurry pump. Tank C-111 waste had been sluiced by September 27 with over 800,000 gal (106,944 ft^3) of supernate with no significant waste retrieval. To aid in the retrieval between October 1 and 22, 2010, about 8,000 gal (1,069 ft^3) of hot water (110 to 126 °F) was added in an attempt to dissolve sodium phosphate and soften or break up the waste. The water was recirculated in the tank from October 25 to 27, 2010. Subsequent sluicing resulted in some additional chunks of waste being broken off, but no significant increase in waste retrieval rates was observed. At the conclusion of modified sluicing operations, approximately 300 gal (40 ft^3) or approximately 1% of the initial, after revision, 32,500 gal (4,340 ft^3) of waste had been retrieved.

The second and third technologies, HPW using an ERSS and chemical dissolution using caustic, respectively, were part of a Hard Heel Retrieval which began on October 5, 2015 and ended on March 30, 2016. The Hard Heel Retrieval process included the following steps: (1) resumption of modified sluicing using the ERSS and HPW, (2) caustic pre-conditioning, (3) sluicing with supernate and HPW, (4) caustic dissolution, and (5) final supernate sluicing and water rinses. Supernate from tank 241-AN-101 (AN-101) or HPW was directed through each extended reach sluicer (ERS) installed in tank C-111. Care was taken when using HPW to position the ERS nozzles close to the waste surface, so each ERS could be more effectively used to break up the

waste surface and mobilize solids towards the slurry pump. The slurry pump in tank C-111 transferred supernate and suspended solids to tank AN-101. The slurry distributor in tank AN-101 distributed the solids across the waste surface and helped prevent transferring suspended solids back to tank C-111.

The first phase of modified sluicing and HPW was intended to retrieve solids as well as break through the waste crust and create as much surface area as possible prior to caustic preconditioning. Caustic preconditioning, while not a retrieval technology, was used to convert insoluble aluminum compounds into sodium aluminate, a significantly more water soluble form, through reaction with a caustic solution. This step was intended to dissolve aluminum compounds and soften the waste crust to make the waste more susceptible to sluicing and HPW activities. A volume of 14,930 gal (2,000 ft^3) of 50 weight percent caustic (approximately 19.4 M) with a temperature range of 80 to 100 °F was added to tank C-111 from trucks through a drop leg (RPP-RPT-59292). The caustic solution was recirculated using the slurry pump and each ERS. During recirculation, the caustic stream was focused on wetting the solids that were not submerged and agitating the caustic pool to promote mixing. After the reaction had gone to its practical end, the solution was diluted using tank AN-101 supernate in an attempt to maximize the solubility of sodium aluminate.

The second round of modified sluicing and HPW were intended to remove the bulk of the remaining solids in tank C-111. It was predicted in RPP-37739, "*241-C-111 Tank Waste Retrieval Work Plan*" that after caustic preconditioning, the solids would be sufficiently softened and/or size-reduced to allow for improved recovery rates. Sluicing was carried out in the same fashion described above. HPW was used in an effort to further size-reduce the residual solids.

When sluicing efficiency decreased, a second round of 50 weight percent sodium hydroxide for caustic dissolution was performed using 16,930 gal (2,260 ft^3) to dissolve aluminum compounds and soften the remaining waste to make it more susceptible to sluicing (RPP-RPT-59292). The dissolution process was similar to caustic preconditioning. Process samples were collected using a sample sleeve and the ERS to direct the stream of caustic to a sample bottle. After the reaction had gone to its practical end, the solution was diluted to approximately 8.0 M using tank AN-101 supernate in an attempt to maximize the solubility of sodium aluminate.

The final sluicing was performed following caustic dissolution to mobilize solids that had been size-reduced or broken up by the caustic dissolution step. A water rinse of residual waste was required to be performed after the final use of supernate in tank C-111, as required by RPP-37739. After consultation with the State of Washington Department of Ecology (Ecology), a continuous rinse of the remaining tank C-111 waste was performed instead of the batch additions specified in RPP-37739. Water was delivered through an ERS and directed onto the waste. After a sufficient pool had built up, the slurry pump was started. After approximately 11,000 gal (1,470 ft^3) of water was used, the system was shut down and a pump-down was performed. The system was then restarted to add an additional 11,000 gal (1,470 ft^3) of water through the other sluicer before performing a final pump-down. The preliminary residual volume was estimated in RPP-CALC-60840 to be approximately 7,700 gal (approximately 1,030 ft^3).

Where information regarding treatment, management, and disposal of the radioactive source, byproduct material, and/or special nuclear components of mixed waste (as defined by the *Atomic Energy Act of 1954*, as amended) 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 Chapter 70.105, "Hazardous Waste Management," *Revised Code of Washington* (RCW) (known as the *Hazardous Waste Management Act*) and its implementing regulations, but is provided for information purposes only.

1.1 PURPOSE

This Retrieval Data Report (RDR) provides information required by *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989) Milestone M-045-86. The report documents the following aspects of tank C-111 retrieval:

- Residual tank waste volume measurement, including associated calculations
- The results of residual tank waste characterization
- Retrieval technology performance documentation
- The U.S. Department of Energy (DOE)'s updated post-retrieval risk assessment
- Opportunities and actions being taken to refine or develop tank waste retrieval technologies based on lessons learned
- Leak detection monitoring and performance results.

1.2 REGULATORY REQUIREMENTS

Retrieval of waste from tank C-111 and submittal of this RDR (in accordance with conditions stated in the HFFACO) are necessary requirements for closing the Hanford SST system. The HFFACO Milestone M-045-86 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;

6) LDMM *[leak detection, monitoring, and mitigation]* monitoring and performance results."

The Tank Waste Retrieval Work Plan for tank C-111 (RPP-37739) establishes the three retrieval technologies that were to be deployed to their respective "limits of technology" in an effort to obtain the Consent Decree waste residue goal of 360 ft^3 or less. The three technologies established by RPP-37739 were deployed to their limits of technology as required by Appendix C, Part 1, of the Consent Decree, resulting in a waste residual volume of 654 ft^3.

1.3 DOCUMENT STRUCTURE

- This tank C-111 RDR is organized to present information required by Milestone M-045-86 of the HFFACO Action Plan.

- Section 1, Introduction and Background discusses the purpose and scope of tank C-111 waste retrieval, presents requirements applicable to this report, and outlines the report structure.

- Section 2, Single-Shell Tank 241-C-111 Residual Waste Volume Measurement describes the method for determining the volume of residual waste in tank C-111 and presents results of the volume measurement process.

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

- Section 4, Retrieval System Performance provides an evaluation of how well the waste retrieval system (WRS) performed and provides a comparison of actual performance against predicted performance.

- Section 5, Post-Retrieval Single-Shell Tank 241-C-111 Risk Assessment describes the potential risk to human health from tank C-111 residual waste. This section identifies and discusses contaminants of potential concern in the waste, describes the effects of waste retrieval and closure on long-term human health risk, presents expected cumulative health effects of source terms, relates calculated risk to residual waste volume, and summarizes overall conclusions of the risk assessment. To satisfy recent requests by Ecology, this section also provides additional risk management information related to how concentrations of constituents remaining in waste residuals within tank C-111 compare against the *Washington Administrative Code* (WAC) 173-340, "Model Toxics Control Act—Cleanup" cleanup standards. These soil cleanup standards are developed to be protective of direct contact exposures and groundwater use.

- Section 6, 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 C-111 and actions being taken based on lessons learned.

- Section 7, Leak Detection, Monitoring, and Mitigation describes leak detection, monitoring, and mitigation (LDMM) methods and procedures, presents an LDMM chronology for tank C-111 waste retrieval, and summarizes LDMM results.

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

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2. SINGLE-SHELL TANK 241-C-111 RESIDUAL WASTE VOLUME MEASUREMENT

This section presents the residual waste volume measurement process and the results for tank C-111. The post-retrieval residual waste volume estimate was performed using a method described in RPP-RPT-59377, "*Post-Retrieval Camera/CAD Modeling System Waste Volume Estimate for Tank 241-C-111.*" The total measured volume of residual waste in tank C-111 was the sum of volumes remaining in the tank dish, on the tank walls, and on the stiffener rings (Table 2-1). The residual waste volume used for all calculations in this RDR is the volume reported as the 95% upper confidence level (UCL) in RPP-RPT-59710, "*Final Report for Tank 241-C-111 Post-Retrieval Waste Solid Samples in Support of Tank Closure.*"

Table 2-1. Tank 241-C-111 Total Waste Volume and Component Waste Volumes.

Component	Waste Volume from CCMS			Actual Volume[a] (ft^3)	Actual Volume (gal)	95% UCL[b] (ft^3)	95% (gal)
	m^3	gal	ft^3				
On the bottom of the tank (solids)	12.17	3,210	429.8	602.9	4,510	623.2	4,660
On the bottom of the tank (liquid pool)	2.99	790	105.5				
On the tank wall and stiffener rings	1.44	380	50.9	50.9	380	50.9	380
Total[c]	16.6	4,380	586	654	4,890	674	5,040

[a]Per RPP-23403, "*Single-Shell Tank Component Closure Data Quality Objectives,*" the actual residual waste volume on the tank bottom is calculated by the formula = 1.125×CCMS + 0.53 ft^3.

[b]Per RPP-23403, the volume at 95% upper confidence level is calculated by the following formula = 1.132×CCMS + 17.09 ft^3.

[c]Total may not equal sum of individual volumes because of rounding.

CCMS = camera/computer-aided design modeling system UCL = upper confidence level

2.1 RESIDUAL WASTE VOLUME MEASUREMENT PROCESS

RPP-RPT-59377 documents the video camera/computer-aided design (CAD) modeling system (CCMS) estimate for the post-hard heel retrieval waste volume in tank C-111. Although all solids were covered for Enraf®[2] volume displacement estimates, the CCMS volume was obtained for comparison with liquid displacement values and to better estimate the volume of waste remaining on the tank walls and stiffener rings.

After the CCMS video was completed, the video was reviewed to develop an AutoCAD®[3] Civil 3D® drawing of tank C-111 and the tank waste residuals and to complete tank bottom volume estimates per TFC-ENG-FACSUP-CD-22, *Post-Retrieval Tank Waste Volume Determination.*

[2] Honeywell Enraf® is a registered trademark of Honeywell International Inc., Corporation Delaware, 101 Columbia Road Morristown, New Jersey.

[3] AutoCAD® and Civil 3D® are trademarks of Autodesk, Inc., 111 McInnis Parkway, San Rafael, California.

The AutoCAD® Civil 3D® software was tested and verified per RPP-52784, "*Video Camera/CAD Modeling System for Retrieval: HISI #3254 Software Management Plan.*"

A template of the 100-series 241-C Tank Farm tanks was developed from tank construction drawings (BPF-73550, *Specifications For Construction of Composite Storage Tanks Bldg. No. 241 Hanford Engineer Works Project 9536*, Drawing D-3). The area and depth of waste and equipment in the tank bottom was estimated based on tank features and the dimensions of equipment and debris observed in the CCMS video (Figure 2-1 shows a mosaic of tank C-111 post-retrieval). The waste contour information was then added to the template drawing to show waste remaining in the tank bottom. After completing the drawings, the AutoCAD® Civil 3D® software calculated a waste volume by integrating between the waste contour lines and the tank bottom profile. These processes are described in more detail below.

2.2 ESTIMATION OF WASTE REMAINING ON TANK BOTTOM

The post-retrieval waste consists of solids piles and a liquid pool. The volume of this waste was estimated using the CCMS method. The estimated volume of waste on the tank bottom, calculated using AutoCAD® Civil 3D®, was 535.3 ft^3 (4,005.8 gal). The waste volume consists of an estimated 429.8 ft^3 (3,210 gal) of solids piles and sand bars and 105.5 ft^3 (790 gal) in pooled liquids (RPP-RPT-59377). The pool is entirely within the dish and is distributed, but mostly to the tank south and tank west. It was conservatively assumed that the waste on the tank bottom remains saturated, and the waste volume was not adjusted for porosity.

2.3 ESTIMATION OF WASTE REMAINING ON TANK SURFACES

The estimated volume of waste on the tank walls and stiffener rings is based on H-14-109874, "CCMS Residual Waste Surface Volume Tank 241-C-111." As documented in BPF-73550, tank C-111 has four stiffener rings located at 4.5-ft intervals from the zero reference elevation (i.e., 4.5 ft, 9 ft, 13.5 ft and 18 ft elevations). The zero reference elevation is at the top of the tank dish, which is 1 ft above the bottom of the tank. Each stiffener ring extends 5 in. from the wall. The topmost stiffener ring is located at the top of the tank liner and is sloped slightly downward from the wall to the inside edge of the ring. The estimated volume of waste on the stiffener rings and tank bottom, calculated using AutoCAD® Civil 3D®, was 50.9 ft^3 (380.8 gal).

2.4 RESIDUAL WASTE VOLUME RESULTS

The total CCMS volume of post-retrieval residual waste in tank C-111 and the waste volumes associated with the various waste components are given in Table 2-1. The best estimate for the total post-retrieval waste volume in tank C-111 is 654 ft^3 (4,890 gal). The 95% UCL is 674 ft^3 (5,040 gal). Figure 2-1 shows a video composite of the residual waste in tank C-111. This final waste volume is above the 360 ft^3 (2,690 gal) retrieval goal specified in the Consent Decree.

Figure 2-1. Tank 241-C-111 Panoramic Image of Residual Tank Waste (Video March 24, 2016).

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3. RESIDUAL TANK WASTE CHARACTERIZATION

This section describes the results of residual tank waste characterization for tank C-111. Presented are the average and upper bound estimates of residual waste inventory based on laboratory analysis of waste samples taken after waste retrieval actions were completed. The calculated inventories are used as input to estimate the potential risk to human health that arises from the residual waste. This risk assessment is discussed in Section 5.

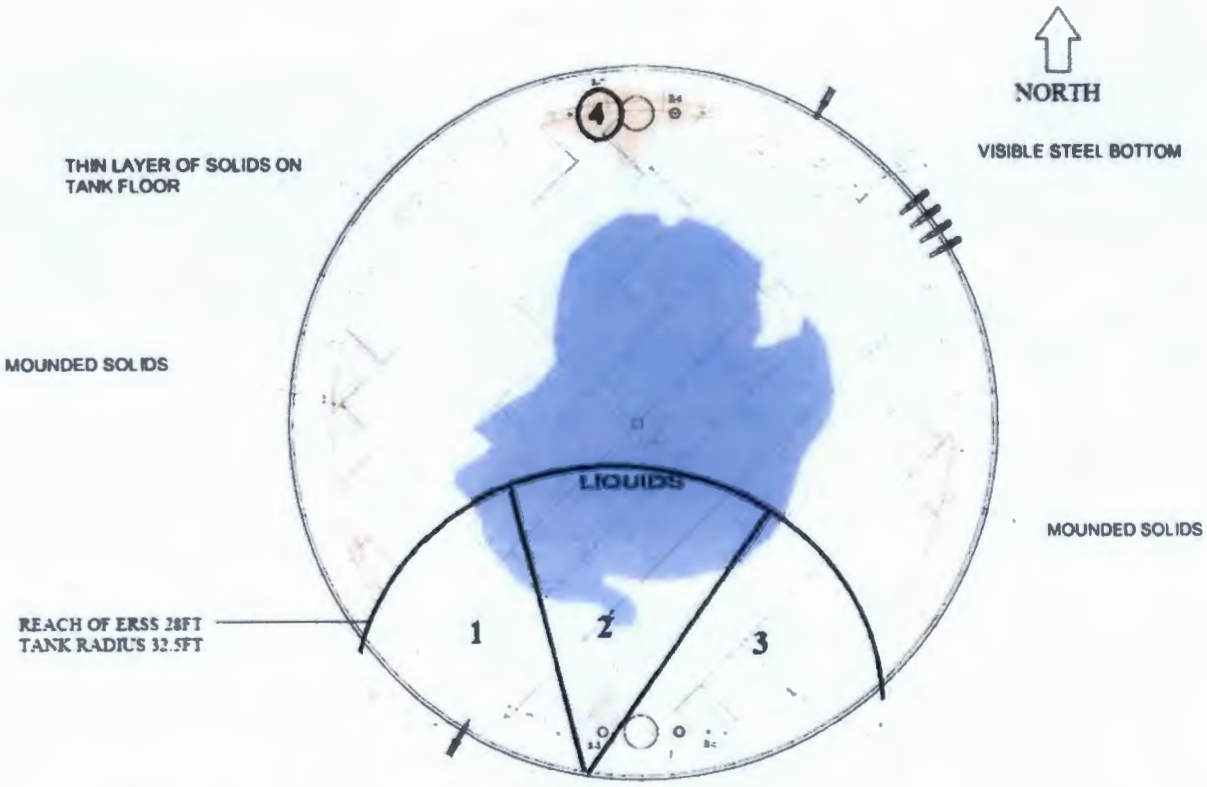
3.1 SAMPLING AND ANALYSIS OF RESIDUAL WASTE

A tank sampling and analysis plan (RPP-PLAN-47778, "*Tank Sampling and Analysis Plan for Residual Waste Solids in Tank 241-C-111*") identified sample collection, laboratory analysis, quality assurance/quality control, and reporting requirements for the characterization of waste solids remaining in tank C-111 after completion of retrieval to support tank closure. The samples were analyzed according to the requirements in RPP-23403, "*Single-Shell Tank Component Closure Data Quality Objectives*" and RPP-PLAN-23827, "*Sampling and Analysis Plan for Single-Shell Tanks Component Closure*."

RPP-PLAN-47778 identified a total of four samples taken; one from the north side of the tank directly under riser 7, and three from the south side using riser 1 as an entry point with the ERSS to guide the clamshell. Approximate sample locations are shown in Figure 3-1. Residual solids in the tank are made up primarily of a loose, sand-like material, with a liquid pool in the center, and some harder material on the outer edges with visible tank floor on the outermost edge. Most of this loose material was found to be adequately soft for the clamshell to be used without a solids crusher; however, in areas in which the material was too hard a solids crusher was utilized. The solids crusher was a 10-pound steel weight which has a bottom that resembles a meat tenderizer. When the solids crusher was used, it was dropped from about 1 to 3 feet above the material. This was repeated as needed. For sampling purposes, the south portion of the tank that was accessible with the installed ERSS was divided into three areas, as shown in Figure 3-1, with one sample taken from each area. A clamshell was lowered through riser 1. To collect a sample, the ERSS was moved so that the clamshell was in the desired sampling location. When the clamshell was in place, it was lowered to collect a sample. After the clamshell collected the sample, the ERSS moved back under the riser so the sample could be retrieved. Multiple "grabs" of a material were needed to provide sufficient solids for a sample.

On the north side of the tank, a solids crusher and clamshell were used to sample directly under riser 7. Because the waste under riser 7 was expected to be too hard for a clamshell to pick up, a solids crusher was deployed first to be used to break up the solids. After the solids were broken up into small pieces (e.g., less than 1 in.), the clamshell was lowered through riser 7 to collect a sample. Multiple "grabs" were needed to provide sufficient solids.

Figure 3-1. Approximate Sample Locations in Tank 241-C-111 Post-Heel Removal (not to scale).



Source: RPP-PLAN-47778, "*Tank Sampling and Analysis Plan for Residual Waste Solids in Tank 241-C-111*," Rev. 1.

3.2 SAMPLING AT SINGLE-SHELL TANK 241-C-111

The tank-specific sampling design in RPP-PLAN-47778 for the tank C-111 post-retrieval sample event divided the remaining solids into four sample areas, one on the north side of the tank directly under Riser 7 and three on the south side of the tank, using Riser 1 as an entry point with the ERSS to guide the clamshell sampler to the approximate locations (RPP-PLAN-47778). The residual solids in the tank are primarily made up of a loose, sand-like material, with a liquid pool in the center, and some harder material on the outer edges, with visible tank floor on the outermost edge. Figure 3-1 shows the approximate sample locations. The locations sampled are approximate, given the limitations of remote video viewing.

The ERSS and a clamshell sampler, along with a solids crusher, were used to collect waste samples from the desired locations. The ERSS consists of a sluicer on the end of a hydraulically-driven, retractable boom that extends down into the tank to attack the waste closer to its surface. For sampling, the ERSS was used to move the clamshell to a selected sample location by catching the cable used for lowering the sampler into the tank and guiding the sampler to the desired location.

Sampling of the residual waste solids in tank C-111 was conducted May 25, 2016 through June 28, 2016. The resulting tank C-111 solid samples were shipped to the 222-S Laboratory for analysis. Descriptions of the solids samples are provided in Table 3-1 as reported in RPP-RPT-59710.

Table 3-1. Description of Tank 241-C-111 Post-Heel Retrieval Samples.

Sample Identification	Date Sampled	Date Received	Solid Weight (g)	Liquid Volume (mL)	Sample Description
C111-16-1	6/28/2016 09:27	6/28/2016 10:35	88.2	None	1/3 full 240-mL container white/tan/dark brown solids. No organic layer visible.
C111-16-2	6/28/2016 08:20	6/28/2016 10:35	92.7	None	1/3 full 240-mL container white/tan/dark brown solids. No organic layer visible.
C111-16-3	6/23/2016 10:00	6/23/2016 11:35	88.6	None	Approximately 80 mL of gray/tan/white solids in a 240-mL Teflon jar. No organic layer visible.
C111-16-4	5/25/2016 10:34	5/25/2016 11:38	191.9	None	Partially full Teflon jar (240 mL) with brown solid material. No organic layer visible.

Source: RPP-RPT-59714, "*Final Report for Tank 241-C-111 Post-Retrieval Waste Solid Samples in Support of Tank Closure*."

3.3 SAMPLE ANALYSES

The samples listed in Table 3-1 were using analysis requirements that were specified in RPP-23403 and RPP-PLAN-47778. The analytical methods performed on the post-retrieval samples are identified in Table 3-2. Tank C-111 had four grab samples taken from it starting May 25, 2016 through June 28, 2016. The approximate locations of the samples are as shown in Figure B-1. The sample results are reported in RPP-RPT-59710. Electronic data were also loaded into the Tank Waste Information Network System.

3.4 CALCULATION OF RESIDUAL INVENTORY

The residual waste inventories were calculated in accordance with the best-basis inventory (BBI) process as described in RPP-7625, "*Guidelines for Updating Best-Basis Inventory*." Two inventories were calculated: an average inventory based on mean concentrations, density, and volume, and an upper bounding inventory that is an estimate of an inventory at the 95% UCL. The inventories are discussed in the following sections.

Table 3-2. Analytical Methods Used in Analysis of Post-Retrieval Samples.

Analysis	SW-846 Reference Method
Inorganic Analyses	
Bulk Density – Gravimetric	Not applicable
pH	9045D
Weight percent water – TGA	Not applicable
Cyanide – Spectrophotometric	9014
Mercury – Cold Vapor Atomic Absorption	7471B
Anions & Organic Acids – IC	9056A
Metals – ICP/AES	6010C
^{99}Tc – ICP/MS	3050B
^{126}Sn, Antimony – ICP/MS	3050B
Actinides – ICP/MS	3050B
Radiochemical Analyses	
GEA	Not applicable
$^{89/90}$Sr – Separation/Beta counting	Not applicable
^{14}C – LSC	Not applicable
^{79}Se – Separation/LSC	Not applicable
^{3}H – LSC	Not applicable
^{63}Ni – Separation/LSC	Not applicable
^{99}Tc – Separation/LSC	Not applicable
^{129}I – Separation/GEA	Not applicable
^{241}Am – Separation/AEA	Not applicable
$^{239/240}$Pu – Separation/AEA	Not applicable
^{241}Pu – Separation/LSC	Not applicable
^{228}Th – Separation/AEA	Not applicable
Organic Analyses	
VOC – GC/MS	8260C
SVOC – GC/MS	8270D
PCB – GC/ECD	8082A

Abbreviations: AEA = alpha energy analysis, EPA = U.S. Environmental Protection Agency, GC/ECD = gas chromatography/electron capture detection, GC/MS = gas chromatography/mass spectrometry, GEA = gamma energy analysis, IC = ion chromatography, ICP/AES = inductively coupled plasma/atomic emission spectrometry, ICP/MS = inductively coupled plasma/mass spectrometry, LSC = liquid scintillation counting, PCB = polychlorinated biphenyls, SVOC = semi-volatile organic compound, TGA = thermogravimetric analysis, VOC = volatile organic compound

Reference: SW-846, 1986. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Third Edition as amended, U.S. Environmental Protection Agency, Washington, District of Columbia.

3.4.1 Average Inventories

The 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). The calculations by the BBIM tool are summarized below.

The BBIM used equations from Variance Components (Searle et al. 1992), to estimate the mean concentration and density, and the associated standard deviation for all constituents that had 50% or more of their reported values greater than the detection limit. These equations are used to compute means by weighting results based on the variance components. Some concentration results were below the detection limits. In these cases, the detection limits were used for calculating the mean concentrations. For a constituent with a majority of results below the detection limit, a simple average of the detection limits was calculated. Note that in accordance with BBI protocol, the relative standard deviations for non-detected constituents were assumed to be "1" (RPP-6924, "*Statistical Methods for Estimating the Uncertainty in the Best Basis Inventories*").

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 Searle et al. (1992) 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.

As shown in Table 2-1, approximately 602.9 ft^3 of waste were left on the bottom of the tank floor which included solids and liquid on the tank floor (RPP RPT-59377). The estimated volume of solids on the rings and side walls was 50.9 ft^3. The total residual volume used for inventory estimates is 654 ft^3 (602.9 + 50.9 = 654 ft^3). There are 7.481 gallons per cubic foot and 3.785 liters per gallon; therefore the solid volume is 18.5 kL used for inventory ([654 ft^3 × 7.481 gal/ft^3 × 3.785 L/gal] × 1 kL/1,000 L ≈ 18.5 kL).

3.4.2 Bounding Inventories

The 95% UCL inventory of each constituent was estimated based on a statistical method described in RPP-6924. This method is based on calculation of the average inventory 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, volume, and density measurements. Standard deviations for the mean concentrations (provided in Appendix B) and density were calculated using the BBIM tool. The standard deviation for waste volume was estimated as described below.

RPP-RPT-59377 provides estimates of post-retrieval residual waste volumes on the tank bottom and on the tank wall and tank stiffener rings (see Table 2-1). The total waste volume was

estimated at 654 ft^3. The upper bounding estimates for the waste volume components added up to 674 ft^3. The estimated error for the total volume may be represented as ± 0.031 ([674-654]/654). 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 0.015 (0.031/2). This RSD was used to approximate the RSD associated with the solids volume.

The BBIM tool calculated the inventory RSD using the equation:

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

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

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

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

where $\hat{I}$ is the inventory estimate and $RSD(\hat{I})$ is the RSD of the inventory estimate. The 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% confidence interval on the mean based on a normal distribution with a known variance (in accordance with the BBI process, which uses a two-sided 95% confidence interval for inventory). The 95% UCL inventories were calculated using the above equation and the average inventory estimates and associated RSDs that were calculated by the BBIM tool.

3.4.3 Evaluation of Sample Data Usability

Tank C-111 residual waste solids were sampled using the ERSS and clamshell sampler (with a solids crusher), an accepted sampling method in the data quality objectives document (DQO) (RPP-23403). A sampling design specific to the residual waste in tank C-111 was developed and documented in the sampling and analysis plan (RPP-PLAN-47778). 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 Table B-1. The solids RSDs in Table B-1 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 program to ensure data quality. The waste samples were analyzed according to quality assurance plans established by the program. In addition, the 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-59710).

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

- Inventories were generated only for constituents specified in the DQO (RPP-23403). Inventories for BBI analytes that are not included in RPP-23403 were not calculated. For the inventories of the BBI analytes, see RPP-RPT-48459.

- 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.

- 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.

- The volume estimate for the residual waste on the tank bottom includes liquids (RPP-RPT-59377). The separate solids and liquid volumes are not estimated; therefore, any liquid is included in the total residual solids volume in the tank.

- Thorium concentration was measured by inductively coupled plasma (ICP)/atomic emission spectrometry (AES) 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.

- Uranium concentration and RSD were based on the concentration means and standard deviations of uranium isotopes detected by ICP/MS (^{235}U, ^{236}U, and ^{238}U).

- Uranium isotope ^{232}U was calculated from total uranium using isotopic distribution ratios.

- Plutonium isotopes (^{239}Pu and ^{240}Pu) were calculated from the $^{239/240}$Pu analytical results, using the isotopic distribution ratios (RPP-8847, "*Best-Basis Inventory Template Compositions of Common Tank Waste Layers*").

- Curium isotopes (^{243}Cm and ^{244}Cm) were calculated from the $^{243/244}$Cm analytical results, using the isotopic distribution ratios (RPP-8847).

- 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 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, tentatively identified compounds (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-59710 are in Table 3-3. The samples contained numerous alkanes.

Bulk density sample results had a range from 1.00 g/mL to 1.90 g/mL (RPP RPT-59710) and a sample mean density of 1.40 g/mL.

3.5 INVENTORY ESTIMATES

The average and upper-bounding inventories for the residual solids are shown in Table 3-4. Note that the symbol "<" indicates 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 July 1, 2015.

Table 3-3. Tentatively Identified Compounds in Tank 241-C-111 Residual Solids.

Laboratory Sample Number	Field Sampling Sample Number	Tentatively Identified Compound	Result (µg/kg)	Retention Time (minutes)	Chemical Abstract Services Number
S16T014968	C111-16-1	Unknown1	2.40E+04	14.09	—
S16T014968	C111-16-1	Unknown2	7.30E+04	15.43	—
S16T014968	C111-16-1	Unknown3	6.10E+05	16.82	—
S16T014968	C111-16-1	Unknown1	1.30E+04	3.18	—
S16T014968	C111-16-1	Unknown2	1.90E+05	16.74	—
S16T014968	C111-16-1	2,5-Cyclohexadien-1-one, 4-[3,	1.80E+04	19.81	2455-14-3
S16T014968	C111-16-1	Unknown1	1.80E+04	3.19	—
S16T014997	C111-16-2	Unknown1	1.90E+03	2.87	—
S16T014997	C111-16-2	Unknown2	1.20E+04	3.18	—
S16T014997	C111-16-2	Unknown1	1.80E+04	3.19	—
S16T015025	C111-16-3	Oxirane, trimethyl-	1.90E+04	2.88	5076-19-7
S16T015025	C111-16-3	Unknown1	1.20E+04	3.41	—
S16T015025	C111-16-3	Oxirane, trimethyl-	1.60E+04	2.88	5076-19-7
S16T015025	C111-16-3	Unknown1	1.50E+04	3.40	—
S16T015025	C111-16-3	Unknown1	1.50E+04	3.40	—
S16T015025	C111-16-3	Triethylene glycol	8.10E+03	9.50	112-27-6
S16T014964	C111-16-1	Unknown1	2.80E+01	12.83	—
S16T014964	C111-16-1	Unknown2	6.90E+01	14.25	—
S16T014964	C111-16-1	Unknown3	9.90E+01	15.56	—
S16T014964	C111-16-1	Unknown4	2.00E+01	17.67	—
S16T014964	C111-16-1	Unknown5	6.90E+02	17.82	—
S16T014993	C111-16-2	Unknown1	2.50E+01	15.57	—
S16T014993	C111-16-2	Unknown2	7.50E+01	17.67	—
S16T014993	C111-16-2	Unknown3	1.50E+02	17.82	—
S16T014993	C111-16-2	Unknown4	8.90E+01	18.51	—
S16T014993	C111-16-2	Unknown5	4.80E+01	18.73	—
S16T015021	C111-16-3	Unknown1	5.70E+01	14.24	—
S16T015021	C111-16-3	Unknown2	2.30E+02	17.82	—
S16T015144	C111-16-4	Unknown1	2.90E+01	10.05	—
S16T015144	C111-16-4	Unknown2	2.90E+02	11.87	—
S16T015144	C111-16-4	Unknown3	3.80E+01	14.24	—
S16T015144	C111-16-4	Unknown4	1.50E+01	15.88	—
S16T015144	C111-16-4	Unknown5	3.20E+01	16.24	—
S16T015144	C111-16-4	Unknown6	2.70E+01	16.99	—
S16T015144	C111-16-4	Unknown7	4.90E+01	17.32	—
S16T015144	C111-16-4	Unknown8	2.60E+01	17.43	—
S16T015144	C111-16-4	Unknown9	9.60E+01	17.67	—
S16T015144	C111-16-4	Unknown10	1.30E+02	17.85	—
S16T015144	C111-16-4	Unknown11	5.00E+01	18.32	—
S16T015144	C111-16-4	Unknown12	8.90E+01	18.51	—
S16T015144	C111-16-4	Unknown13	6.10E+01	18.73	—
S16T015144	C111-16-4	Unknown14	4.70E+01	18.92	—

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-111 Residual Solids. (5 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units*
1,1,1-Trichloroethane	71-55-6	<	2.37E-05	7.16E-05	kg
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	<	3.00E-05	9.06E-05	kg
1,1,2-Trichloroethane	79-00-5	<	4.27E-05	1.29E-04	kg
1,1-Dichloroethene	75-35-4	<	1.09E-04	3.29E-04	kg
1,2,4-Trichlorobenzene	120-82-1	<	4.99E-05	1.51E-04	kg
1,2-Dichlorobenzene	95-50-1	<	3.14E-05	9.48E-05	kg
1,2-Dichloroethane	107-06-2	<	1.39E-05	4.20E-05	kg
1,4-Dichlorobenzene	106-46-7	<	2.31E-05	6.98E-05	kg
^{125}Sb	14234-35-6	<	1.57E+01	4.74E+01	Ci
^{126}Sn	15832-50-5	<	1.40E-02	4.23E-02	Ci
^{129}I	15046-84-1	<	1.46E-03	4.41E-03	Ci
^{137}Cs	10045-97-3	—	1.61E+02	3.55E+02	Ci
^{137m}Ba	N/A	—	1.52E+02	3.35E+02	Ci
^{14}C	14762-75-5	<	3.90E-03	1.18E-02	Ci
^{152}Eu	14683-23-9	<	1.31E+01	3.96E+01	Ci
^{154}Eu	15585-10-1	<	1.26E+01	3.81E+01	Ci
^{155}Eu	14391-16-3	<	2.24E+01	6.76E+01	Ci
1-Butanol	71-36-3	<	2.65E-03	8.00E-03	kg
2,4,5-Trichlorophenol	95-95-4	<	1.08E-02	3.26E-02	kg
2,4,6-Trichlorophenol	88-06-2	<	1.51E-02	4.56E-02	kg
2,4-Dinitrotoluene	121-14-2	<	8.38E-03	2.53E-02	kg
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	128-37-0	<	2.05E-02	6.19E-02	kg
^{228}Th	14274-82-9	<	6.07E-03	1.83E-02	Ci
^{230}Th	14269-63-7	<	1.26E-01	3.81E-01	Ci
^{231}Pa	14331-85-2	<	2.89E-01	8.73E-01	Ci
^{232}Th	N/A	—	2.85E-06	6.91E-06	Ci
^{233}U	13968-55-3	<	5.92E-03	1.79E-02	Ci
^{234}U	13966-29-5	<	2.15E-02	6.49E-02	Ci
^{235}U	15117-96-1	—	2.84E-04	6.85E-04	Ci
^{236}U	13982-70-2	—	2.30E-04	6.02E-04	Ci
^{237}Np	13994-20-2	—	1.31E-03	2.85E-03	Ci
^{238}Pu	13981-16-3	—	8.73E-02	1.63E-01	Ci
^{238}U	N/A	—	6.68E-03	1.62E-02	Ci
^{239}Pu	15117-48-3	<	7.62E-01	2.30E+00	Ci
^{240}Pu	14119-33-6	<	8.29E-02	2.50E-01	Ci
^{241}Am	14596-10-2	—	7.79E+00	1.56E+01	Ci
^{241}Pu	14119-32-5	<	7.14E-01	2.16E+00	Ci
^{242}Cm	15510-73-3	—	3.24E-02	4.53E-02	Ci
^{242}Pu	13982-10-0	<	3.15E-02	9.51E-02	Ci
^{243}Cm	15757-87-6	—	6.80E-03	1.36E-02	Ci
^{244}Cm	13981-15-2	—	1.30E-01	2.61E-01	Ci
2-Butanone	78-93-3	<	1.02E-03	3.08E-03	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-111 Residual Solids. (5 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units*
2-Chlorophenol	95-57-8	<	1.28E-02	3.87E-02	kg
2-Ethoxyethanol	110-80-5	<	1.65E-02	4.98E-02	kg
2-Methylphenol	95-48-7	<	9.65E-03	2.91E-02	kg
2-Nitrophenol	88-75-5	<	1.62E-02	4.89E-02	kg
2-Nitropropane	79-46-9	<	1.52E-04	4.59E-04	kg
^{3}H	15086-10-9	<	6.51E-02	1.97E-01	Ci
4-Chloro-3-methylphenol	59-50-7	<	1.30E-02	3.93E-02	kg
4-Methyl-2-Pentanone	108-10-1	<	4.40E-04	1.33E-03	kg
4-Nitrophenol	100-02-7	<	1.37E-02	4.14E-02	kg
^{60}Co	10198-40-0	<	4.94E+00	1.49E+01	Ci
^{63}Ni	13981-37-8	—	3.55E+00	6.35E+00	Ci
^{79}Se	15758-45-9	<	5.56E-03	1.68E-02	Ci
^{90}Sr	10098-97-2	—	4.53E+04	1.11E+05	Ci
^{90}Y	10098-91-6	—	4.53E+04	1.11E+05	Ci
^{99}Tc	14133-76-7	—	4.97E-02	1.00E-01	Ci
Acenaphthene	83-32-9	<	1.13E-02	3.41E-02	kg
Acetate	71-50-1	—	5.01E+00	8.43E+00	kg
Acetone	67-64-1	<	3.35E-03	1.01E-02	kg
Ag	7440-22-4	—	5.07E+00	1.37E+01	kg
Al	7429-90-5	—	2.08E+03	4.01E+03	kg
Aroclors (Total PCB)	1336-36-3	<	2.96E-04	8.94E-04	kg
As	7440-38-2	<	8.25E-01	2.49E+00	kg
B	7440-42-8	<	1.10E-01	3.32E-01	kg
Ba	7440-39-3	—	3.72E-01	7.22E-01	kg
Be	7440-41-7	<	5.50E-02	1.66E-01	kg
Benzene	71-43-2	<	3.80E-05	1.15E-04	kg
Benzo(a)pyrene	50-32-8	<	1.72E-02	5.19E-02	kg
Bi	7440-69-9	—	7.62E+00	1.20E+01	kg
Bis(2-ethylhexyl)phthalate	117-81-7	—	9.82E-02	1.42E-01	kg
Br	24959-67-9	<	1.85E+00	5.59E+00	kg
Butylbenzylphthalate	85-68-7	—	5.13E-02	6.80E-02	kg
Ca	7440-70-2	—	9.27E+01	2.52E+02	kg
Carbon disulfide	75-15-0	<	4.14E-05	1.25E-04	kg
Carbon tetrachloride	56-23-5	<	2.41E-05	7.28E-05	kg
Cd	7440-43-9	<	8.66E-02	2.62E-01	kg
Ce	7440-45-1	—	5.17E+00	7.68E+00	kg
Chlorobenzene	108-90-7	<	2.23E-05	6.73E-05	kg
Chloroform	67-66-3	<	3.37E-05	1.02E-04	kg
Cl	16887-00-6	<	2.22E+00	6.70E+00	kg
CN	57-12-5	—	4.39E-01	9.93E-01	kg
Co	7440-48-4	<	7.62E-02	2.30E-01	kg
Cr	7440-47-3	—	1.46E+00	2.73E+00	kg
Cresol (m & p)	1319-77-3	<	1.22E-02	3.68E-02	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-111 Residual Solids. (5 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units*
Cu	7440-50-8	—	4.97E-01	8.26E-01	kg
Cyclohexanone	108-94-1	<	1.60E-02	4.83E-02	kg
Dibenz[a,h]anthracene	N/A	<	8.18E-03	2.47E-02	kg
Diethylphthalate	84-66-2	<	1.51E-02	4.56E-02	kg
Di-n-butylphthalate	84-74-2	<	4.93E-02	1.49E-01	kg
Di-n-octylphthalate	117-84-0	<	1.01E-02	3.05E-02	kg
Diphenyl amine	122-39-4	<	7.82E-03	2.36E-02	kg
Ethyl acetate	141-78-6	<	1.51E-04	4.56E-04	kg
Ethyl ether	60-29-7	<	6.60E-05	1.99E-04	kg
Ethylbenzene	100-41-4	<	2.76E-05	8.34E-05	kg
Eu	7440-53-1	<	6.15E-02	1.86E-01	kg
F	16984-48-8	—	2.54E+02	3.33E+02	kg
Fe	7439-89-6	—	2.69E+02	4.99E+02	kg
Fluoranthene	206-44-0	<	4.45E-02	1.34E-01	kg
Formate	12311-97-6	<	6.20E+00	1.87E+01	kg
Free OH	N/A	—	6.28E+00	1.41E+01	kg
Glycolate	666-14-8	<	1.97E+00	5.95E+00	kg
Hexachlorobenzene	118-74-1	<	7.36E-03	2.22E-02	kg
Hexachlorobutadiene	87-68-3	<	1.48E-02	4.47E-02	kg
Hexachloroethane	67-72-1	<	3.62E-05	1.09E-04	kg
Hg	7439-97-6	—	7.19E-02	1.32E-01	kg
Isobutanol	78-83-1	<	1.79E-01	5.41E-01	kg
K	7440-09-7	<	1.79E+00	5.41E+00	kg
La	7439-91-0	—	1.38E+00	2.52E+00	kg
Li	7439-93-2	<	6.83E-02	2.06E-01	kg
Methylenechloride	75-09-2	<	1.65E-05	4.98E-05	kg
Mg	7439-95-4	—	2.83E+00	7.22E+00	kg
Mn	7439-96-5	—	1.34E+00	2.66E+00	kg
Mo	7439-98-7	<	1.16E-01	3.50E-01	kg
Morpholine, 4-nitroso-	59-89-2	<	1.47E-02	4.44E-02	kg
Na	7440-23-5	—	4.96E+03	6.56E+03	kg
Naphthalene	91-20-3	<	1.24E-02	3.74E-02	kg
Nb	7440-03-1	<	3.30E-01	9.97E-01	kg
Nd	7440-00-8	—	2.40E+00	4.30E+00	kg
NH_3	7664-41-7	—	7.54E-02	1.37E-01	kg
Ni	7440-02-0	—	1.58E+02	3.09E+02	kg
Nitrobenzene	98-95-3	<	1.27E-02	3.84E-02	kg
N-Nitrosodimethylamine	62-75-9	<	1.37E-02	4.14E-02	kg
N-Nitroso-di-n-propylamine	621-64-7	<	1.32E-02	3.99E-02	kg
NO_2	14797-65-0	—	2.96E+01	7.45E+01	kg
NO_3	14797-55-8	—	6.12E+01	1.57E+02	kg
Oxalate	338-70-5	<	5.41E+00	1.63E+01	kg
Pb	7439-92-1	—	6.85E+01	1.42E+02	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-111 Residual Solids. (5 sheets)

Constituent	CAS Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units*
Pd	7440-05-3	<	6.60E-01	1.99E+00	kg
Pentachlorophenol	87-86-5	<	7.46E-03	2.25E-02	kg
Phenol	108-95-2	<	1.33E-02	4.02E-02	kg
PO_4	14265-44-2	—	4.94E+03	6.72E+03	kg
Pr	7440-10-0	<	1.46E+00	4.41E+00	kg
Pyrene	129-00-0	<	2.49E-02	7.52E-02	kg
Pyridine	110-86-1	<	1.64E-02	4.95E-02	kg
Rb	7440-17-7	<	3.13E+00	9.45E+00	kg
Rh	7440-16-6	<	6.60E-01	1.99E+00	kg
Ru	7440-18-8	<	2.75E-01	8.31E-01	kg
Sb	7440-36-0	<	9.89E-01	2.99E+00	kg
Se	7782-49-2	<	1.65E+00	4.98E+00	kg
Si	7440-21-3	—	9.11E+01	1.53E+02	kg
Sm	7440-19-9	—	1.47E+00	2.24E+00	kg
Sn	7440-31-5	<	4.40E-01	1.33E+00	kg
SO_4	14808-79-8	—	1.47E+01	2.66E+01	kg
Sr	7440-24-6	—	2.06E+00	4.17E+00	kg
Ta	7440-25-7	<	2.81E-01	8.49E-01	kg
Te	13494-80-9	<	4.95E-01	1.49E+00	kg
Tetrachloroethene	127-18-4	<	2.83E-05	8.55E-05	kg
Th	7440-29-1	—	2.59E-02	6.28E-02	kg
Thiosulfate	14383-50-7	<	3.20E+00	9.66E+00	kg
Ti	7440-32-6	—	1.08E+00	3.06E+00	kg
Tl	7440-28-0	<	8.25E-01	2.49E+00	kg
Toluene	108-88-3	<	2.07E-05	6.25E-05	kg
Trans-1,3-Dichloropropene	10061-02-6	<	6.98E-05	2.11E-04	kg
Tributyl phosphate	126-73-8	—	3.25E-02	5.67E-02	kg
Trichloroethene	79-01-6	<	3.12E-05	9.42E-05	kg
Trichlorofluoromethane	75-69-4	<	2.42E-05	7.31E-05	kg
U	7440-61-1	—	2.00E+01	4.84E+01	kg
V	7440-62-2	—	1.87E-01	2.70E-01	kg
Vinyl chloride	75-01-4	<	4.47E-05	1.35E-04	kg
W	7440-33-7	<	8.80E-01	2.66E+00	kg
Xylene (m & p)	108-28-3M	<	4.31E-05	1.30E-04	kg
Xylene (o)	95-47-6	<	2.37E-05	7.16E-05	kg
Xylenes (total)	1330-20-7	<	1.05E-05	3.17E-05	kg
Y	7440-65-5	—	2.39E-01	3.96E-01	kg
Zn	7440-66-6	<	1.98E+00	5.98E+00	kg
Zr	7440-67-7	—	1.07E+00	2.02E+00	kg

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

* Radionuclide concentrations are decay corrected to July 1, 2015.

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4. RETRIEVAL SYSTEM PERFORMANCE

This section discusses the tank C-111 WRS 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 DOE Office of River Protection (DOE-ORP) has deployed three approved technologies at tank C-111: (1) modified sluicing, (2) HPW, and (3) chemical dissolution deployed with an ERSS using an array of rationale (RPP-37739). Sluicing operations started on September 14, 2010 with an initial waste volume of approximately 4,665 ft^3 (34,900 gal), revised from 7,700 ft^3 (57,000 gal) at the commencement of activities, and completed on November 4, 2010, reaching the limits of technology. Approximately 40 ft^3 (300 gal) of waste was removed by the first retrieval technology; 4,300 ft^3 (32,200 gal) remained in the tank. During hard heel retrieval, the supernatant liquor was the primary carrier fluid during this period with a total of 299,440 ft^3 (2.24 million gal) of supernate recirculated from tank AN-101 to tank C-111. The second and third retrieval technologies (caustic chemical dissolution and HPW deployed using an ERSS) reached the limits of technology on March 30, 2016 having removed approximately 3,680 ft^3 (27,500 gal). The residual waste solids volume remaining in the tank was estimated at 623.2 ft^3 (4,660 gal) (95% UCL, RPP-RPT-59377).

4.1 WASTE RETRIEVAL PROCESS DESCRIPTION

The WRSs deployed at tank C-111 using the ERSS were designed to mobilize, size-reduce, and dissolve portions of the sludge waste so it could be transferred to tank AN-101. Descriptions of WRSs may be found in RPP-37739. The WRSs used supernate from the double-shell tank (DST) to break up and fluidize the waste, and transfer it to tank AN-101. Supernate from tank AN-101 was recycled continuously. The volume of supernate transferred to tank C-111 was monitored and balanced by the volume pumped out of tank C-111. The flow rate of the recycled supernate was roughly the same as the flow rate of the slurry pumped to the DST. The bulk sluicing operation directed the supernate toward the tank C-111 waste using the ERS end effector, eroding and moving the waste toward the center transfer pump so pumpable material could be transferred to the DST.

Modified sluicing was selected because it requires less DST supernate storage and management along with an anticipated shorter retrieval duration than the Mobile Retrieval System. Modified sluicing was used for bulk retrieval of waste from September 14, 2010 to November 4, 2010. Supernate from tank AN-101was used as the sluicing fluid in an attempt to mobilize the waste in tank C-111. The resulting slurry was pumped from tank C-111 to tank AN-101 where the solids settled and the supernate was then recycled for sluicing. The sluicing system in tank C-111 consisted of two sluicers located at the north and south ends of the tank and a variable-depth slurry pump located in the middle of the tank. Two closed-circuit video cameras were installed to support sluicing. The hydraulic sluicers, slurry pump, and a motor-operated valve to control the supernatant flow rate were controlled from a control trailer near the tank.

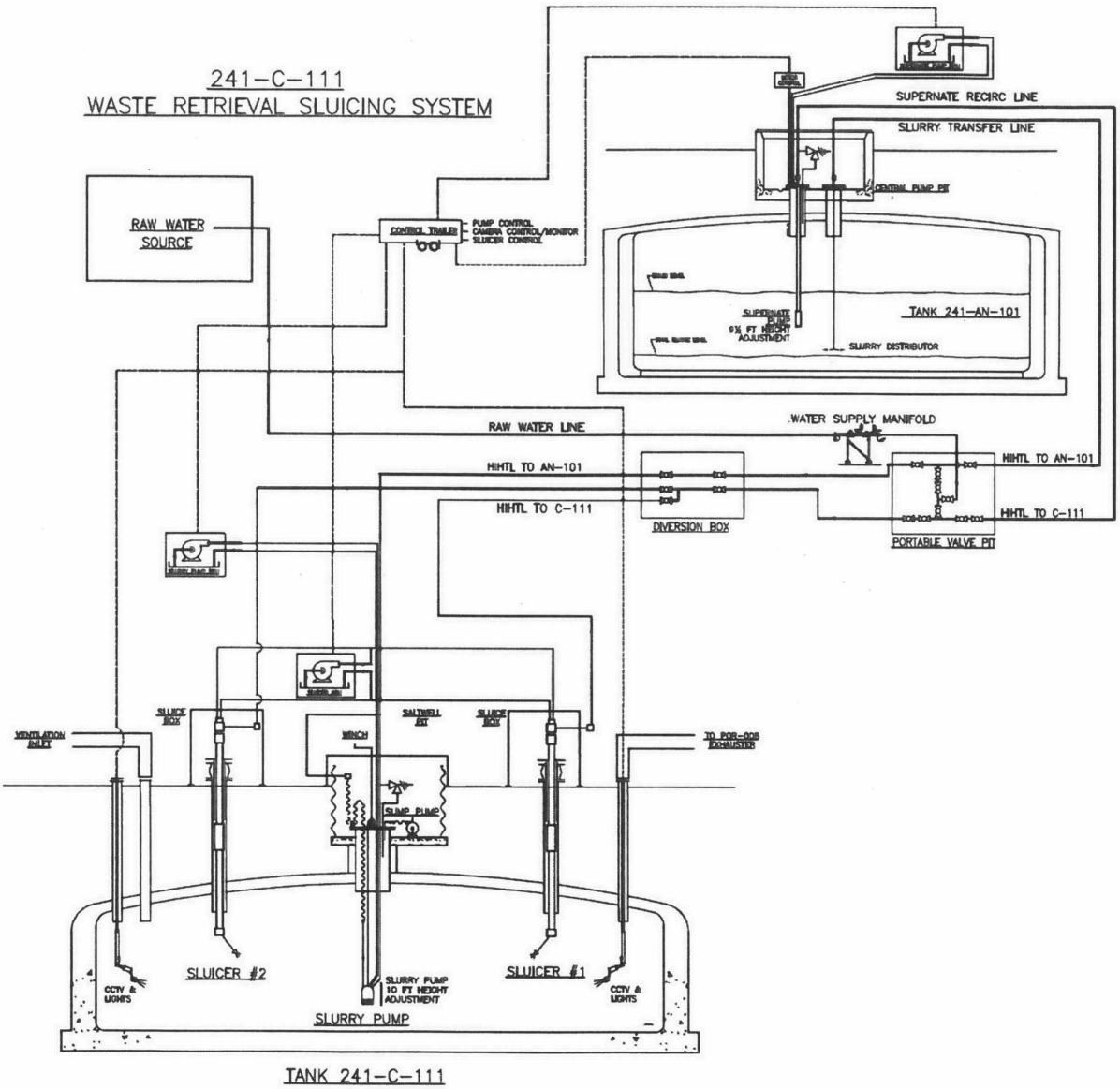
Following the bulk retrieval campaign, which consisted of modified sluicing, hard heel retrieval began in October 2015 after the installation of the ERSS. Hard heel retrieval included the second and third technologies deployed, which included HPW using an ERSS and chemical dissolution using caustic. ERSS and HPW were selected as they can be deployed in less time than an in-tank vehicle technology when the first technology is no longer effective and the tank retrieval goal of 360 ft^3 has not been reached.

To prepare the hard heel for retrieval and to minimize the amount of caustic needed for dissolution, the following steps were used: (1) sluicing using the ERSS and HPW, (2) caustic preconditioning, and (3) sluicing with supernate and HPW. Waste solids were then dissolved with caustic followed by sluicing with supernate and rinsing the residual solids with water. Caustic dissolution complements the mechanical technologies and has been shown to be effective for waste forms resistant to size reduction by mechanical methods. These methods were determined to be the best methods for retrieving tank C-111 based on the experiences from the bulk retrieval operations performed in tanks 241-C-101, 241-C-102, and 241-C-112 and heel retrieval operations performed in tanks 241-C-108, 241-C-109, and 241-C-104. The order was determined to be optimal because it allows for more efficient use of the caustic. Splitting the total allotted volume of caustic across two strikes that are separated by sluicing operations allows new surface area to be exposed and potentially react with the caustic solution.

The hard heel retrieval system in tank C-111 consisted of a variable speed and depth slurry pump located in the middle of the tank and two ERSs located at opposite ends of the tank. Each ERS was fitted with two HPW fan nozzles, capable of delivering water at approximately 5,000 psi at 10 gpm. The hydraulically-powered adjustable-height slurry pump was lowered as the waste retrieval progressed and the waste level receded. The hydraulic sluicers, slurry pump and supernate pump were controlled from a control trailer near the tank.

The retrieval system used tank AN-101 as the receiver tank and its system consisted of an adjustable-height slurry distributor and a supernate pump. The supernate pump was positioned near the center of the tank and was used to transfer the motive fluid used during sluicing operations to tank C-111. The slurry from tank C-111 was pumped through the slurry distributor in tank AN-101. The slurry distributor allowed the solids to settle out across more of the settled solids surface area. The height was adjustable to ensure adequate clearance for both the settled solids layer and the supernate pump inlet (see Figure 4-1).

Figure 4-1. Retrieval System Diagram.



CCTV = closed-circuit television HIHTL = Hose-in-Hose Transfer Line

4.2 RETRIEVAL SYSTEM PERFORMANCE

In tank C-111, the waste primarily consisted of uranium recovery waste, ferrocyanide waste, PUREX organic wash waste, cladding waste and waste from the Hot Semi-Works Plant. The rationale for selection of the three approved retrieval technologies can be found in RPP-37739. Modified sluicing was selected because it requires less DST supernate storage and management along with an anticipated shorter retrieval duration over the Mobile Retrieval System. ERSS and HPW were selected as they can be deployed in less time than an in-tank vehicle technology. As

the first technology reaches a point where it is no longer effective and the tank residual waste volume in the Decree is exceeded, the second technology can be deployed.

The modified sluicing system in tank C-111 consisted of two sluicers located at the north and south ends of the tank and a variable-depth slurry pump located in the middle of the tank. The HPW and ERSS system in tank C-111 consisted of a variable speed and depth slurry pump located in the middle of the tank and two ERSs located at opposite ends of the tank. Each ERS was fitted with two HPW fan nozzles, capable of delivering water at approximately 5,000 psi at 10 gpm. The hydraulically-powered adjustable-height slurry pump was lowered as the waste retrieval progressed and the waste level receded.

With most tanks that have been retrieved by modified sluicing, the rate of waste retrieval is initially high and begins to fall off as the easily-retrieved sludge is removed, and waste consisting of larger-sized particles remains. However, this was not the case with tank C-111 retrieval. The modified sluicing retrieval rate for tank C-111 remained inconsistent throughout the retrieval, being only slightly higher after the first ~1.4 million gal of slurry pumped. At the conclusion of standard sluicing operations approximately 40 ft^3 (300 gal) of solids had been retrieved.

The first phase of HPW combined modified sluicing, intended to retrieve solids as well as break through the waste crust and create as much surface area as possible prior to caustic preconditioning, retrieved approximately 260 ft^3 (1,930 gal) of solids. Caustic preconditioning was used to convert insoluble aluminum compounds into sodium aluminate. The second phase of modified sluicing and HPW were intended to remove the bulk of the remaining solids in tank C-111 and retrieved approximately 1,820 ft^3 (13,590 gal) of solids. Caustic dissolution was performed to retrieve aluminum compounds in the waste, with specific emphasis on gibbsite. This step was intended to dissolve aluminum compounds and soften the remaining waste to make it more susceptible to sluicing. The final sluicing was performed following caustic dissolution to mobilize solids that had potentially been size-reduced or broken up by the caustic dissolution step and retrieved approximately 460 ft^3 (3,420 gal) of solids.

Based on the performance metrics examined with the implementation of the modified sluicing, HPW, and chemical dissolution deployed with an ERSS and consideration of the factors specified in the Consent Decree, DOE-ORP concluded that these retrieval technologies had been deployed to the limits of technology at tank C-111 (RPP-RPT-59363, "*Retrieval Completion Certification Report for Tank 241-C-111*," Rev. 00A).

4.3 RETRIEVAL DURATION

Modified sluicing operations were performed during 26 operating days (53 shifts) starting on September 14, 2010 and ending on November 4, 2010 (Letter WRPS-1003927, "Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Completion of Performance Based Incentive 2.14, Fee Bearing Milestone PBI-2.14.3, "Complete Bulk Retrieval of Tank 241-C-111" – Request For Incremental Fee Approval," Enclosure, "FY 2011 Performance Expectation Completion Notice"). At the conclusion of modified sluicing

operations, approximately 40 ft^3 (300 gal) of waste had been retrieved; the total volume of waste left in tank C-111 was approximately 4,300 ft^3 (32,200 gal). Operations using modified sluicing, HPW and chemical dissolution deployed with an ERSS were performed over approximately 83 operating days (131 shifts) starting on October 4, 2015 and ending on March 30, 2016. The preliminary residual volume from these activities was estimated in RPP-CALC-60840 to be approximately 1,030 ft^3 (7,700 gal).

4.4 CONCLUSION

Based on the information contained in Section 4 above, DOE-ORP concluded that waste retrieval operations were performed to the limits of the modified sluicing, HPW, and chemical dissolution deployed with an ERSS (RPP-RPT-59363, Rev. 00A). The waste residual volume estimate of 674 ft^3 (5,040 gal) at the 95% UCL (RPP-RPT-59714, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment*") is greater than the Consent Decree retrieval goal of 360 ft^3 (2,693 gal) after deploying the three technologies.

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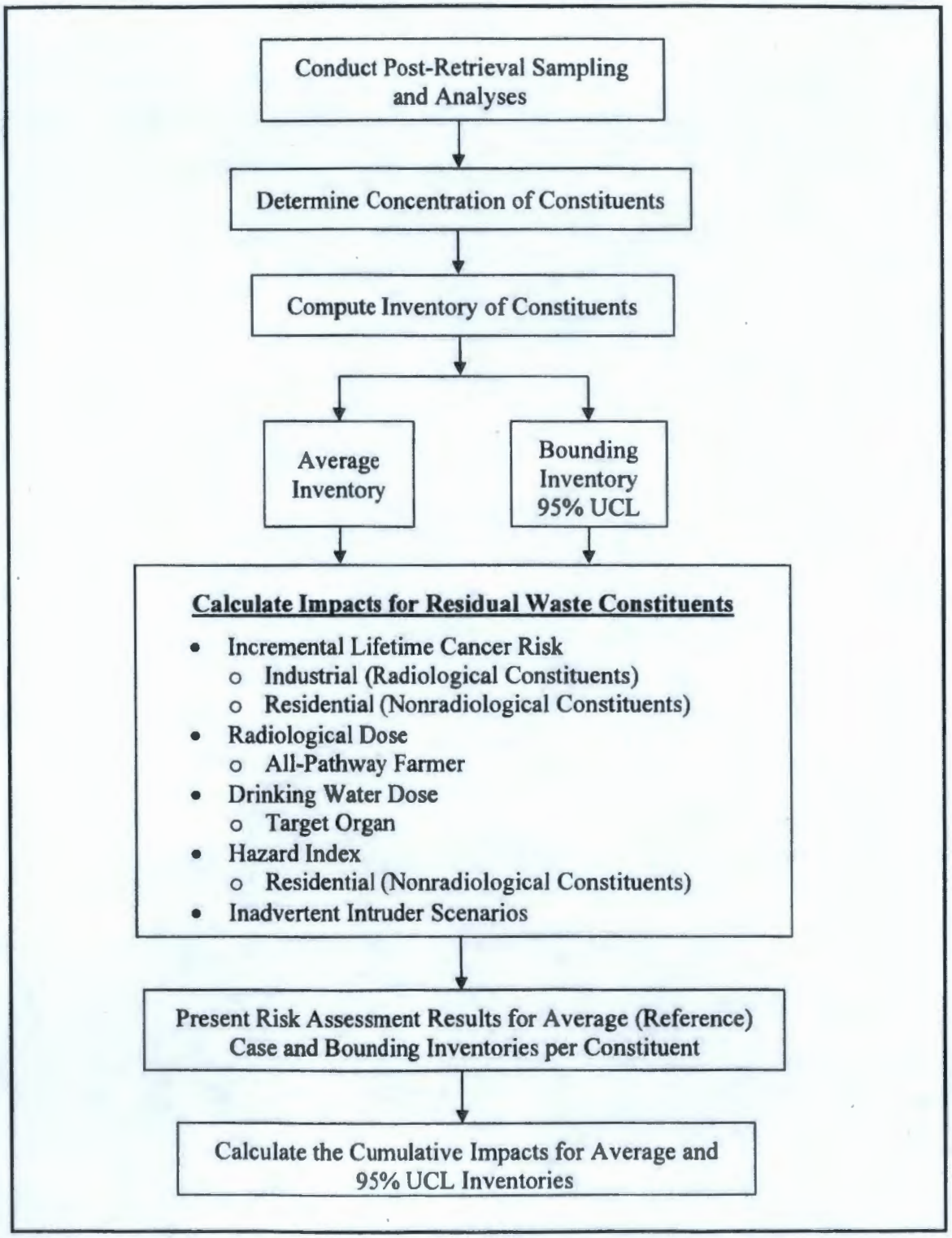
5. POST-RETRIEVAL SINGLE-SHELL TANK 241-C-111 RISK ASSESSMENT

The potential impacts to human health posed by the residual waste in SST C-111 were evaluated using the methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*. Figure 5-1 provides a schematic of the process used for the tank C-111 risk assessment, and this methodology is described in detail in Chapter 3 of DOE/ORP-2005-01. The SST performance assessment (PA) methodology represents the current approach being used to support the assessment of long-term impacts to human health from tank residuals left in individual SSTs in RDRs. Decisions on final closure of tank C-111, all other SSTs, ancillary facilities and equipment within Waste Management Area (WMA) C will be supported by a site-specific PA as outlined in Appendix I of the HFFACO. That single Appendix I PA will evaluate whether closure conditions at WMA C will be protective of human health and the environment for all contaminants of concern, both radiological and nonradiological. The DOE intends that the PA will document by reference relevant performance requirements defined by the Resource Conservation and Recovery Act, 42 U.S.C. §6901 *et seq.*, the Hazardous Waste Management Act, RCW 70.105 *et seq.*, the Federal Water Pollution Control Act (Clean Water Act), 33 U.S.C. §1251 *et seq.*, the Safe Drinking Water Act, 42 U.S.C.§ 300f *et seq.*, and the Atomic Energy Act of 1954, 42 U.S.C. §2011 *et seq.*, as well as any other performance requirements that might be Applicable or Relevant and Appropriate Requirements under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), 42 U.S.C. §9601. *et seq.*

The inventory used in this tank C-111 risk assessment was derived from post-retrieval residual inventory samples (see Section 3.0). A comparison of post-retrieval inventory to the inventory used in DOE/ORP-2005-01 is provided in Appendix C for information purposes. The inventory used in DOE/ORP-2005-01 is based on RPP-RPT-23412, "*Hanford Tank Waste Operations Simulator Model Data Package for the Development Run for the Refined Target Case*." The post-retrieval inventory used in this RDR provides a more accurate representation of tank residuals than RPP-RPT-23412, and will be incorporated in the WMA C PA.

Results of the potential impacts to human health were calculated using the average and 95% UCL inventories. Results show that for the groundwater pathway, the effects associated with tank C-111 are one to three orders of magnitude below the current lower end of the range for incremental lifetime cancer risk (ILCR) performance objectives (1.0×10^{-6} to 1.0×10^{-4}) for radioactive analytes, and one to 13 orders of magnitude below the ILCR performance objectives (1.0×10^{-5}) for nonradioactive analytes. The hazard indices for the tank C-111 groundwater pathway are two to four orders of magnitude below the performance objective (1.0). For the inadvertent intruder scenarios of the suburban garden scenario and rural pasture scenario (both sensitivity cases) at 100 years after closure, the effects associated with tank C-111 exceeded the 100 mrem/yr performance objective for chronic exposure. For all other sensitivity cases, the results were below the performance objectives for both the acute and chronic exposure at both 100 and 500 years after closure. Details of these results are provided in Sections 5.2 through 5.4.

Figure 5-1. Single-Shell Tank 241-C-111 Residual Waste Inventory and Risk Assessment Process.



UCL = upper confidence level

This section also provides additional risk management information related to concentrations of constituents remaining in waste residuals within tank C-111 compared against the WAC 173-340 cleanup standards. The soil cleanup standards evaluated are developed for direct contact exposures and for groundwater protection. Selected constituent concentrations estimated for the average and 95% UCL inventories of tank residuals are specifically compared against soil direct contact cleanup levels for unrestricted land use (Method B), soil direct contact cleanup levels for industrial land use (Method C), and soil cleanup levels protective of groundwater using the fixed parameter three-phase partitioning model given in WAC 173-340-747, "Deriving Soil Concentrations for Groundwater Protection," subsection (4), "Fixed parameter three-phase partitioning model." Results of these comparisons are found in Section 5.5.1.

Section 5.5 also includes a discussion of the appropriateness of comparisons for constituent concentrations remaining in waste residuals within tank C-111 against cleanup standards protective of ecological risk found in WAC 173-340. Because footnotes in tables containing the cleanup standards protective of ecological concerns indicate these standards are not intended to be used for evaluation of sludges or wastes, specific comparisons of concentrations of constituents remaining in waste residuals within tank C-111 against the WAC 173-340 cleanup standards related to ecosystem risk are not provided.

5.1 CONSTITUENTS EVALUATED

Following retrieval, the residual waste was sampled and analyzed. This risk assessment is based on the analytical results from the post-retrieval sample (Section 3.0).

Analytical data for tank C-111 were collected and analyzed as defined by the closure DQOs. The post-retrieval samples were analyzed for 167 constituents (i.e., radionuclides, volatile organic compounds, semi-volatile organic compounds, polychlorinated biphenyls, and inorganics [including metals and conventional parameters]) in accordance with approved 222-S Laboratory procedures based on U.S. Environmental Protection Agency (EPA) approved methods. Only 166 of these constituents were evaluated for risk. However, 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*. Table 5-1 presents a complete listing of the analytes evaluated, whether the analyte was detected, and whether a cancer potency factor (also called a cancer slope factor), dose factor, or reference dose is published for that analyte.

Table 5-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]	Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]
^{125}Sb	Antimony-125*	U	DFR/CPF	7440-47-3	Chromium, Total*	—	–
^{126}Sn	Tin-126	U	DFR/CPF	1319-77-3	Cresylic acid (cresol, mixed isomers)*	U	–
^{129}I	Iodine-129	U	DFR/CPF	7440-50-8	Copper	—	RfD
^{137}Cs	Cesium-137 + Daughters	—	DFR/CPF	108-94-1	Cyclohexanone	U	RfD
^{137m}Ba	Barium-137m*	—	–	53-70-3	Dibenz[a, h]anthracene*	U	CPF
^{14}C	Carbon-14	U	DFR/CPF	84-66-2	Diethyl phthalate *	U	RfD
^{152}Eu	Europium-152	U	DFR/CPF	84-74-2	Di-n-butylphthalate*	U	RfD
^{154}Eu	Europium-154	U	DFR/CPF	117-84-0	Di-n-octylphthalate*	U	RfD
^{155}Eu	Europium-155	U	DFR/CPF	122-39-4	N, N-Diphenylamine*	U	RfD
^{228}Th	Thorium-228 + D	U	DFR/CPF	141-78-6	Ethyl Acetate	U	RfD
^{230}Th	Thorium-230	U	DFR/CPF	60-29-7	Diethyl ether	U	RfD
^{231}Pa	Protactinium-231	U	DFR/CPF	100-41-4	Ethylbenzene	U	RfD/CPF
^{232}Th	Thorium-232	—	DFR/CPF	7440-53-1	Europium	U	–
^{233}U	Uranium-233	U	DFR/CPF	16984-48-8	Fluoride	—	RfD
^{234}U	Uranium-234	U	DFR/CPF	7439-89-6	Iron	—	RfD
^{235}U	Uranium-235 + D	—	DFR/CPF	206-44-0	Fluoranthene*	U	RfD
^{236}U	Uranium-236	—	DFR/CPF	12311-97-6	Formate+A2	U	–
^{237}Np	Neptunium-237 + D	—	DFR/CPF	OHDEMAND	Hydroxide OH	—	–
^{238}Pu	Plutonium-238	—	DFR/CPF	Glycolate	Glycolate C2H3O3	U	–
^{238}U	Uranium-238 + D	—	DFR/CPF	118-74-1	Hexachlorobenzene*	U	RfD/CPF

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Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]	Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]
^{239}Pu	Plutonium-239	U	DFR/CPF	87-68-3	Hexachlorobutadiene*	U	RfD/CPF
^{240}Pu	Plutonium-240	U	DFR/CPF	67-72-1	Hexachloroethane*	U	RfD/CPF
^{241}Am	Americium-241	—	DFR/CPF	7439-97-6	Mercury*	—	RfD
^{241}Pu	Plutonium-241 + D	U	DFR/CPF	78-83-1	Isobutanol	U	RfD
^{242}Cm	Curium-242	—	DFR/CPF	7440-09-7	Potassium	U	–
^{242}Pu	Plutonium-242	U	DFR/CPF	7439-91-0	Lanthanum		–
^{243}Cm	Curium-243	—	DFR/CPF	7439-93-2	Lithium	U	RfD
^{244}Cm	Curium-244	—	DFR/CPF	75-09-2	Dichloromethane (methylene chloride)*	U	RfD/CPF
^{3}H	Tritium	U	DFR/CPF	7439-95-4	Magnesium	—	–
^{60}Co	Cobalt-60	U	DFR/CPF	7439-96-5	Manganese	—	RfD
^{63}Ni	Nickel-63*		DFR/CPF	7439-98-7	Molybdenum	U	RfD
^{79}Se	Selenium-79*	U	DFR/CPF	59-89-2	n-Nitrosomorpholine*	U	–
^{90}Sr	Strontium-90 + D	—	DFR/CPF	7440-23-5	Sodium	—	–
^{90}Y	Yttrium-90	—	–	91-20-3	Naphthalene*	U	RfD
^{99}Tc	Technetium-99	—	DFR/CPF	7440-03-1	Niobium	U	–
71-55-6	1, 1, 1-Trichloroethane*	U	RfD	7440-00-8	Neodymium	—	–
76-13-1	1, 1, 2-Trichloro-1, 2, 2-trifluoroethane	U	RfD	7664-41-7	Ammonia	—	RfD
79-00-5	1, 1, 2-Trichloroethane*	U	RfD/CPF	7440-02-0	Nickel*	—	RfD
75-35-4	1, 1-Dichloroethene*	U	RfD	98-95-3	Nitrobenzene*	U	RfD
120-82-1	1, 2, 4-Trichlorobenzene*	U	RfD	62-75-9	N-Nitroso-N, N-dimethylamine*	U	RfD/CPF

Table 5-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]	Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]
95-50-1	o-Dichlorobenzene*	U	RfD	621-64-7	N-nitroso-di-n-propylamine	U	CPF
107-06-2	1, 2-Dichloroethane*	U	RfD/CPF	14797-65-0	Nitrite	—	RfD
106-46-7	1, 4-Dichlorobenzene	U	RfD/CPF	14797-55-8	Nitrate	—	RfD
71-36-3	n-Butyl alcohol (1-butanol)	U	RfD	338-70-5	Oxalate	U	–
95-95-4	2, 4, 5-Trichlorophenol*	U	RfD	7439-92-1	Lead*	—	–
88-06-2	2, 4, 6-Trichlorophenol	U	RfD/CPF	7440-05-3	Palladium	U	–
121-14-2	2, 4-Dinitrotoluene*	U	RfD	87-86-5	Pentachlorophenol*	U	RfD/CPF
128-37-0	2, 6-Bis (tert-butyl)-4-methylphenol	U	–	108-95-2	Phenol*	U	RfD
78-93-3	2-Butanone(MEK)	U	RfD	14265-44-2	Phosphate	—	–
95-57-8	2-Chlorophenol*	U	RfD	7440-10-0	Praseodymium	U	–
110-80-5	2-Ethoxyethanol	U	RfD	129-00-0	Pyrene	U	RfD
95-48-7	2-Methylphenol (o-cresol)	U	RfD	110-86-1	Pyridine*	U	RfD
88-75-5	o-Nitrophenol	U	–	7440-17-7	Rubidium	U	–
79-46-9	2-Nitropropane*	U	RfD/CPF	7440-16-6	Rhodium	U	–
59-50-7	p-Chloro-m-cresol (4-Chloro-3-methylphenol)*	U	–	7440-18-8	Ruthenium	U	–
108-10-1	4-Methyl-2-pentanone (MIBK)	U	RfD	7440-36-0	Antimony*	U	RfD
88-75-5	o-Nitrophenol	U	–	7782-49-2	Selenium*	U	RfD
83-32-9	Acenaphthene	U	RfD	7440-21-3	Silicon	—	–

Table 5-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]	Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]
71-50-1	Acetate	—	–	7440-19-9	Samarium	—	–
67-64-1	2-Propanone (Acetone)	U	RfD	7440-31-5	Tin	U	RfD
7440-22-4	Silver*	—	RfD	14808-79-8	Sulfate	—	–
7429-90-5	Aluminum	—	RfD	7440-24-6	Strontium	—	RfD
1336-36-3	Polychlorinated Biphenyls*	U	CPF	7440-25-7	Tantalum	U	–
7440-38-2	Arsenic*	U	RfD/CPF	13494-80-9	Tellurium	U	–
7440-42-8	Boron	U	RfD	127-18-4	Tetrachloroethylene*	U	RfD/CPF
7440-39-3	Barium*	—	RfD	7440-29-1	Thorium	—	–
7440-41-7	Beryllium*	U	RfD/CPF	7440-32-6	Titanium	—	–
71-43-2	Benzene*	U	RfD/CPF	7440-28-0	Thallium*	U	RfD
50-32-8	Benzo[a]pyrene*	U	CPF	108-88-3	Toluene*	U	RfD
7440-69-9	Bismuth	—	–	542-75-6	1,3-Dichloropropene (cis & trans)*	U	RfD/CPF
117-81-7	Di (2-ethylhexyl) phthalate (DEHP)	—	RfD/CPF	126-73-8	Tributyl phosphate	—	RfD/CPF
24959-67-9	Bromide	U	–	79-01-6	1, 1, 2-Trichloroethylene	U	RfD/CPF
85-68-7	Butylbenzylphthalate*	—	RfD	75-69-4	Trichlorofluoromethane*	U	RfD
7440-70-2	Calcium	—	–	7440-61-1	Uranium	—	–
75-15-0	Carbon disulfide*	U	RfD	7440-62-2	Vanadium	—	RfD
56-23-5	Carbon tetrachloride*	U	RfD/CPF	75-01-4	Chloroethene(vinyl chloride)*	U	RfD/CPF
7440-43-9	Cadmium*	U	RfD/CPF	7440-33-7	Tungsten	U	–
7440-45-1	Cerium	—	RfD	108-38-3	m-Xylene	U	RfD

Table 5-1. List of Analytes and Available Toxicity Information. (5 sheets)

Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]	Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]
108-90-7	Chlorobenzene*	U	RfD	95-47-6	o-Xylene	U	RfD
67-66-3	Chloroform*	U	RfD/CPF	1330-20-7	Xylenes	U	RfD
16887-00-6	Chloride	U	–	7440-65-5	Yttrium	—	–
57-12-5	Cyanide*	—	RfD	7440-66-6	Zinc	U	RfD
7440-48-4	Cobalt	U	RfD/CPF	7440-67-7	Zirconium	—	–

[a] RPP-RPT-59714, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*"
[b] HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments.*

CAS = Chemical Abstracts Service
CPF = Cancer potency factor
– = No available toxicity value (dose factor, reference dose, or cancer potency factor)
DFR = Dose factor
RfD = Reference dose
U = Analyte not detected in residual wastes

Gray shaded area indicates non-detect for this analyte.

*Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List."

5.2 RESULTS FOR INDIVIDUAL CONTAMINANTS FOR POST-RETRIEVAL SINGLE-SHELL TANK 241-C-111

Table 5-2 identifies the main contributors to the ILCR (industrial and residential scenarios), groundwater dose (all-pathways farmer scenario), and drinking water dose for radiological components of the residual waste remaining in tank C-111. Table 5-3 identifies the primary hazardous chemicals that contribute to ILCR and the Hazard Quotient. These results are provided for the average residual waste inventory for SST C-111. A more complete listing of all analytes for the same average inventory is provided in Tables D-1 and D-2 of Appendix D. A similar set of tables based on the 95% UCL inventory is provided in Tables D-3 and D-4 of Appendix D. In each of these tables, the following columns are provided.

a. **Analyte Name**.

b. **Detected in Residual Wastes** is an indicator as to whether an analyte was detected in the laboratory.

c. **Inventory** as shown here for non-detects is calculated at one-half the detection limit.

d. **WMA C Fenceline Concentration** is the maximum modeled concentration for a constituent at the WMA C fenceline over the modeling period. In the methodology used in DOE/ORP-2005-01, this concentration was estimated using cross-sectional modeling of vadose zone and groundwater flow and transport. In some cases, individual analytes may not have a corresponding concentration at the fenceline because short-lived radionuclides will decay away before the contaminant can arrive at the WMA C fenceline. Relatively immobile contaminants (i.e., K_d greater than 0.6 mg/L) will also result in a zero concentration at the fenceline as they will not reach the fenceline within 10,000 years (based on assumptions and transport modeling approach used).

e. **Peak Year** is the year in which the simulation estimates that peak concentration for a given analyte arrives at the fenceline.

f. **K_d** is the mobility factor used in the groundwater modeling for the analyte. The smaller the K_d, the more mobile the contaminant; if the K_d is zero, the contaminant moves with the groundwater.

g. **Half-life** is the duration in years for a radionuclide to decay to half its activity. Organic compounds were assumed not to decay (radionuclides only).

h. **Incremental Lifetime Cancer Risk** (groundwater) is described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments* for the industrial and residential exposure scenarios [including WAC 173-340, Method B (residential)].

i. **Radiological Dose** is the estimated drinking water dose for the all-pathways farmer exposure scenario (radionuclides only).

j. **Radiological Dose – Beta/Photon** is the drinking water dose from beta/photon-emitting radionuclides using equivalent dose (radionuclides only).

k. **Hazard Quotient** (groundwater) – Hazard quotients calculated for residential and industrial scenarios described in HNF-SD-WM-TI-707.

5.3 CUMULATIVE ANALYSIS RESULTS FOR SINGLE-SHELL TANK 241-C-111 AND WASTE MANAGEMENT AREA C

The cumulative analysis (i.e., sum of the risk metrics) for tank C-111 residual average and 95% UCL risk levels was calculated and results are provided in this section.

- **Average Inventory**—best estimate of the residual waste inventory computed using mean sample concentrations, mean sample density, and best estimate of the residual volume.
- **95% UCL Inventory**—considered the bounding inventory. The 95% UCL of the average inventory was calculated based on uncertainties associated with the concentration, volume, and density (for solids) measurements (see Section 3.0).

The impacts for the groundwater pathway associated with each residual waste inventory are evaluated with a variety of performance metrics. The ILCRs are evaluated for radiological analytes using the average and 95% UCL inventories and industrial and residential exposure scenarios. The ILCR and hazard indices are examined for the same inventories using a residential exposure scenario.

Radiological doses using the same two inventories are also evaluated for an all-pathways farmer and a drinking water only exposure scenario. Estimated concentration levels of some selected analytes are also provided and compared against current maximum concentration levels.

A comparison of impacts from the average and the 95% UCL inventories and current performance metrics for ILCR, hazard indices, and maximum concentration limits are summarized in Table 5-4.

5.4 INADVERTENT INTRUDER

The DOE recognizes that an inadvertent intruder may be onsite and not be discovered until after exposure has occurred. The radiological dose to an inadvertent intruder is therefore estimated as a part of this risk assessment.

The scenarios considered in this assessment for radiological doses from inadvertent intrusions included: 1) a well driller scenario that was used as a reference case for acute exposure in the SST PA and 2) a rural pasture scenario that was used as a reference case for chronic exposure in the SST PA. This assessment of doses from inadvertent intrusions also evaluated chronic exposure scenarios that included: 1) a suburban garden scenario and 2) a commercial farm scenario that were used as sensitivity cases for chronic exposure in the SST PA.

Table 5-2. Estimated Maximum Incremental Lifetime Cancer Risk/Radiological Dose During the Modeling Period for Primary Radionuclides Related to Average Residual Waste Inventory in Single-Shell Tank 241-C-111.

Analyte	Above Detection Limits in Residual Waste	Inventory (Ci)	Waste Management Area C Fenceline Concentration (pCi/L)	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Lifetime Cancer Risk		Radiological Dose (mrem/yr) All-Pathways Farmer Scenario[b]	Radiological Dose – Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
^{14}C	No	1.95E-03	3.00E-03	9.78E+03	0.00E+00	5.73E+03	2.33E-11	1.69E-10	1.46E-05	6.01E-06
^{99}Tc	Yes	4.97E-02	1.98E-01	1.05E+04	0.00E+00	2.11E+05	2.73E-09	6.66E-08	3.48E-04	8.82E-04
^{129}I	No	7.30E-04	<1.00E-03	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
^{234}U	No	1.08E-02	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	N/A
^{235}U	Yes	2.84E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	N/A
^{236}U	Yes	2.30E-04	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	N/A
^{238}U	Yes	6.68E-03	0.00E+00	DNA	6.00E-01	4.47E+09	NE	NE	NE	N/A
Performance Objective[c]							**1-0E-6 to 1.0E-4[d]**	**1-0E-6 to 1.0E-4[d]**	**25[e]**	**4[f]**

[a] See PNNL-13895, "*Hanford Contaminant Distribution Coefficient Database and Users Guide*," Rev. 1, for the basis for the K_d values listed for the radionuclides.

[b] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*.

[c] Performance objectives apply to the cumulative (i.e., all contaminants) for the entire waste management area.

[d] EPA 540/R/99/006, *Radiation Risk Assessment At CERCLA Sites: Q & A*, Directive 9200.4-31P.

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

[f] 65 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

DNA = did not arrive at fenceline within the modeling period
N/A = not applicable
NE = constituent analyzed, but this risk metric was not calculated because the analyte was predicted to have a concentration less than 0.001 pCi/L, which is well below the ability of standard laboratory methods to detect it

[a]

Shaded cell indicates non-detects in sludge or supernate, and the inventory used in the risk assessment is calculated at one-half the minimum detection limit.

Table 5-3. Estimated Maximum Value for Incremental Lifetime Cancer Risk and Hazard Quotient for Selected Nonradiological Analytes Related to Average Residual Waste Inventory in Single-Shell Tank 241-C-111.

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[a]	Incremental Lifetime Cancer Risk Scenarios (Groundwater)[b]	Hazard Quotient (Groundwater)[b]
						WAC 173-340 Method B	
Chromium, Total*	Yes	1.46E+00	5.99E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Fluoride	Yes	2.54E+02	1.04E+00	1.05E+04	0.00E+00	No CPF	1.09E-03
Nitrate	Yes	6.12E+01	2.51E-01	1.05E+04	0.00E+00	No CPF	9.81E-06
Nitrite	Yes	2.96E+01	1.22E-01	1.05E+04	0.00E+00	No CPF	7.60E-05
Uranium	Yes	2.00E+01	0.00E+00	DNA	6.00E-01	NE	NE
Performance Objective[c]						**1.0E-06[d]**	**1.0[e]**

[a] See PNNL-13895, "*Hanford Contaminant Distribution Coefficient Database and Users Guide*," Rev. 1, for the basis for the K_d values listed for chromium and nitrate The K_d values listed for the organic chemical compounds are determined from the chemicals' organic carbon/water partitioning coefficient and an estimate of 0.03% for the Hanford Site sediments fraction of organic content (PNNL-13895, Rev. 1, page 11, paragraph 3).

[b] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*.

[c] Single Analyte Performance objectives apply to entire waste management area, not just a single component of the waste management area.

[d] *Washington Administrative Code* (WAC) 173-340-705, "Use of Method B" subsection (2)(c)(ii).

[e] WAC 173-340-705 (2)(c)(i).

DNA = did not arrive at fenceline within the modeling period
NE = constituent analyzed, but this risk metric was not calculated because the analyte was predicted to have a concentration less than 0.001 µg/L, which is well below the ability of standard laboratory methods to detect it
No CPF = no cancer potency factor available
No Rfd = no reference data for analyte

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III) insoluble salts.

Table 5-4. Comparison of Cumulative Incremental Lifetime Cancer Risk, Hazard Index, and Groundwater Concentration at Peak Waste Management Area C Fenceline for Average and 95% Upper Confidence Level Residual Waste Inventories in Single-Shell Tank 241-C-111. (2 sheets)

Metric[a]	Industrial Receptor		Residential Receptor		Performance Objective[b]
ILCR from Radioactive Analytes (unitless)	**Average Inventory**	**95% UCL Inventory**	**Average Inventory**	**95% UCL Inventory**	
Total without non-detects[c]	2.73E-09	5.50E-09	6.66E-08	1.34E-07	1.0E-06 to 1.0E-4[e]
Total with non-detects[d]	2.76E-09	5.57E-09	6.68E-08	1.35E-07	
ILCR from Nonradioactive Analytes (unitless)	**Average Inventory**	**95% UCL Inventory**	**Average Inventory**	**95% UCL Inventory**	**Performance Objective[b]**
Total without non-detects[c]	3.39E-18	5.91E-18	2.37E-17	4.13E-17	1.0E-5[f]
Total with non-detects[d]	7.67E-09	2.32E-08	1.00E-06	3.03E-06	
Hazard Index (unitless)	**Average Inventory**	**95% UCL Inventory**	**Average Inventory**	**95% UCL Inventory**	**Performance Objective[b]**
Total without non-detects[c]	1.88E-04	2.63E-04	1.30E-03	1.81E-03	1.0[f]
Total with non-detects[d]	2.28E-04	3.84E-04	7.00E-03	1.90E-02	
Radiological Dose (mrem/yr)	**All Pathways**		**Drinking Water**		**Performance Objective[b]**
	Average Inventory	**95% UCL Inventory**	**Average Inventory**	**95% UCL Inventory**	
Total without non-detects[c]	3.48E-04	6.99E-04	8.82E-04	1.77E-03	25 and 4 mrem
Total with non-detects[d]	3.62E-04	7.42E-04	8.88E-04	1.79E-03	

Table 5-4. Comparison of Cumulative Incremental Lifetime Cancer Risk, Hazard Index, and Groundwater Concentration at Peak Waste Management Area C Fenceline for Average and 95% Upper Confidence Level Residual Waste Inventories in Single-Shell Tank 241-C-111. (2 sheets)

Waste Management Area C Fenceline Concentration[c, d]					
Analyte	**Detected In Residual Wastes**	**Average Inventory**	**95% UCL Inventory**	**Maximum Concentration Limit**	**Units**
Technetium-99	Yes	1.98E-01	3.99E-01	900	pCi/L
Iodine-129	No	<1.00E-03	<1.00E-03	1	pCi/L
Carbon-14	No	3.00E-03	9.09E-03	2,000	pCi/L
Chromium, Total*	Yes	5.99E-03	1.12E-02	100	µg/L
Uranium	Yes	0.00E+00	0.00E+00	30	µg/L

[a] Incremental lifetime cancer risks (ILCRs) of radioactive analytes were evaluated using industrial and residential land use scenarios described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*. ILCRs and hazard indices for nonradiological analytes were evaluated using *Washington Administrative Code* (WAC) 173-340-705, "Use of Method B," subsection (4) "Multiple hazardous substances or pathways" (residential).

[b] Performance objectives apply to entire waste management area (WMA), not just a single component of the WMA.

[c] If detected, fenceline concentration is based on an inventory that is calculated from actual laboratory results. Analytes with a fenceline concentration of less than either 0.001 pCi/L (radioactive) or 0.001 µg/L (nonradioactive), which is a value that is well below the minimum detection limit for standard analytical methods, are reported as less than 1.00E-03 pCi/L or µg/L.

[d] If not detected, fenceline concentration is based on an inventory that is calculated at half the detection limits of analytical results. Concentrations that are less than either 0.001 pCi/L (radioactive) or 0.001 µg/L (nonradioactive), which is a value that is well below the minimum detection limit for standard analytical methods, are reported as less than 1.00E-03 pCi/L or µg/L.

[e] EPA 540/R/99/006, *Radiation Risk Assessment At CERCLA Sites: Q & A*, Directive 9200.4-31P.

[f] WAC 173-340-705(4).

UCL = upper confidence level

Gray shaded cells are non-detects and the inventory used in the risk assessment is calculated at one-half the minimum detection limit.

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III) insoluble salts.

A summary of doses calculated for each of the intruder scenarios for the average and 95% UCL inventories remaining at SST C-111 at 100 years and 500 years after closure for tank C-111 are provided in Table 5-6. A summary of doses calculated for each of the intruder scenarios for the average and 95% UCL inventories at 100-year intervals between 100 and 1,000 years after closure for tank C-111 are provided in Table 5-7. Tables and plots of doses related to individual radioactive analytes are provided in Tables D-5 through D-8 and Figures D-1 through D-4 in Appendix D.

Table 5-6. Comparison of Intruder Doses at 100 and 500 years after Closure from Residual Waste for Single-Shell Tank 241-C-111.

Years after Closure[1]	Inventory	SST PA Reference Cases		SST PA Sensitivity Cases	
		Well Driller[2] (mrem)	Rural Pasture[3] (mrem/yr)	Suburban Garden[3] (mrem/yr)	Commercial Farmer[3] (mrem/yr)
100	Average	6.45	275	3,896	3.17E-02
	95% UCL	15.39	673	9,545	7.54E-02
500	Average	0.32	0.101	2.09	2.43E-03
	95% UCL	0.75	0.236	4.87	5.67E-03

PA = performance assessment SST = single-shell tank UCL = upper confidence level

Notes:

[1] Site closure is assumed to occur on January 1, 2032.

[2] Performance Objective (Acute Exposure) – 500 mrem.

[3] Performance Objective (Chronic Exposure) – 100 mrem/yr.

A review of detailed results and plots in Appendix D (Tables D-5 through D-8 and Figures D-1 through D-4) resulted in observations about key analytes for inadvertent intruder impacts as given in Table 5-8.

At 100 years after closure (see Table 5-6 and 5-7), doses for the well driller scenario were estimated to be ~1.3% and 3.1% of the 500 mrem acute exposure performance objective for the average and the 95% UCL inventories, respectively. At 100 years after closure, doses with the rural pasture scenario were estimated to be ~275% and 673% of the 100 mrem/yr chronic exposure performance objective for the average and 95% UCL inventories, respectively. However, doses resulting from chronic exposure in the suburban garden scenario were ~3,896% and 9,545% of the 100 mrem/yr chronic exposure performance objective for the average and 95% UCL inventories, respectively (see Table 5-6). Doses resulting from the commercial farm were well below (e.g., 0.03% and 0.08%) the 100 mrem/yr chronic exposure performance objective for the average and 95% UCL inventories, respectively (see Table 5-6).

By 500 years after closure (see Tables 5-6 and 5-7), the estimated doses for the well driller scenario for the average and 95% UCL inventories was 0.06% and 0.15% of the acute exposure performance objective of 500 mrem, respectively. At 500 years after closure, doses for all inadvertent intruder scenarios used to evaluate the doses from chronic exposure were well below

the chronic exposure performance objective of 100 mrem/yr. The highest estimated dose at 500 yrs after closure was for the suburban garden scenario using the 95% UCL inventory, which yielded a dose that was estimated to be 0.5% of the 100 mrem/yr performance objective (see Table 5-6).

5.5 COMPARISON OF TANK RESIDUALS WITH MODEL TOXICS CONTROL ACT SOIL CLEANUP LEVELS

This section provides additional risk management information related to concentrations of constituents remaining in waste residuals within tank C-111 compared against the Model Toxics Control Act (MTCA), RCW 70.105D, "Hazardous Waste Cleanup—Model Toxics Control Act," WAC 173-340, cleanup standards. In this section, specific comparisons are made between the concentrations of constituents remaining in tank C-111 against the MTCA cleanup standards for soil direct contact unrestricted land use (Method B), industrial land use (Method C), and soil concentrations protective of groundwater using the fixed parameter three-phase partitioning model given in WAC 173-340-747(4).

Per WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards," for soil cleanup levels based on human exposure via direct contact or other exposure pathways where contact with the soil is required to complete the pathway, the point of compliance shall be established in the soils throughout the site from the ground surface to 15 ft below the ground surface. Under a closure configuration, waste residuals left in tank C-111 and other SSTs in WMA C would be expected to be below 15 ft below ground surface.

Implicit in the use of the fixed parameter three-phase partitioning model given in WAC 173-340-747 deriving soil cleanup levels for groundwater protection is the assumption that constituents of interest are found in soils and are immediately available to be leached by infiltrating precipitation. Under a closure configuration, constituents associated with waste residuals left in tank C-111 and other SSTs in WMA C would be contained within a grout-filled tank, a steel tank liner, and an underlying concrete pad below the liner and would not be immediately available for leaching by infiltrating water.

5.5.1 WAC 173-340 Direct Contact and Soil Concentrations Protective of Groundwater

Table 5-9 contains the average and 95% UCL concentrations of detected constituents estimated in residual waste for tank C-111 on a mass basis for comparison against WAC 173-340 cleanup levels for soil direct contact unrestricted land use (Method B), industrial land use (Method C), and soil concentration protective of groundwater. Table 5-9 also provides Hanford Site-specific 90th percentile background concentrations, and identifies analytes that are dangerous waste constituents per WAC 173-303-9905, "Dangerous Waste Constituents List." A more detailed list of background concentrations and references is provided in Table D-11 of Appendix D.

Table 5-7. Potential Future Impact from Inadvertent Intrusion into Residual Waste for Average and 95% Upper Confidence Level Inventories.

Years After Closure[1]	100	200	300	400	500	600	700	800	900	1,000
Inadvertent Intrusion Acute Dose[2] (mrem) – Well Driller Scenario										
Average Inventory	6.4	1.0	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2
95% Upper Confidence Level Inventory	15.4	2.3	1.0	0.8	0.8	0.7	0.6	0.6	0.6	0.5
Inadvertent Intrusion Acute Dose[3] (mrem/yr) – Rural Pasture Scenario										
Average Inventory	275	23.5	2.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1
95% Upper Confidence Level Inventory	673	57.6	5.1	0.6	0.2	0.2	0.2	0.2	0.1	0.1
Inadvertent Intrusion Chronic Dose[3] (mrem/yr) – Suburban Gardener Scenario										
Average Inventory	3,896	334	30.6	4.5	2.1	1.7	1.5	1.4	1.3	1.2
95% Upper Confidence Level Inventory	9,545	819	74.6	10.7	4.9	4.0	3.7	3.4	3.2	3.0
Inadvertent Intrusion Chronic Dose[3] (mrem/yr) – Commercial Farm Scenario										
Average Inventory	3.2E-02	5.9E-03	3.3E-03	2.7E-03	2.4E-03	2.2E-03	2.0E-03	1.8E-03	1.7E-03	1.5E-03
95% Upper Confidence Level Inventory	7.5E-02	1.4E-02	7.4E-03	6.3E-03	5.7E-03	5.2E-03	4.8E-03	4.4E-03	4.1E-03	3.9E-03

[1] Site closure is assumed to occur on January 1, 2032.

[2] Performance Objective (Acute Exposure) – 500 mrem.

[3] Performance Objective (Chronic Exposure) – 100 mrem/yr.

Table 5-8. Impact Results of Key Analytes for an Inadvertent Intruder.

Inadvertent Intrusion Scenario	Key Radionuclides			
	^{137}Cs	^{90}Sr	^{239}Pu	^{241}Am
Well Driller	Secondary contributor to dose up to ~150 years after closure	Primary contributor to dose up to ~200 years after closure	Secondary contributor to dose after ~300 years after closure	Primary contributor to dose ~200 years after closure
Rural Pasture	Secondary contributor to dose up to ~150 years after closure	Primary contributor to dose up to ~450 years after closure, secondary up to ~500 years after closure	Secondary contributor to dose after ~500 years closure	Secondary contributor to dose after ~150 years, primary contributor to dose ~450 years after closure.
Suburban Gardener	Secondary contributor to dose up to ~100 years after closure	Primary contributor to dose up to ~400 years after closure, secondary up to ~500 years after closure	Secondary contributor to dose after ~500 years post-closure	Secondary contributor from ~100 to ~400 years, Primary contributor to dose after ~400 years
Commercial Farm	Secondary contributor to dose up to ~125 years post-closure	Primary contributor to dose up to ~200 years after closure, secondary up to ~250 years after closure	Secondary contributor to dose after ~250 years post-closure	Secondary contributor from ~150 to ~200 years, Primary contributor to dose after ~200 years

Ratios of the average and 95% UCL concentrations to cleanup levels for soil direct contact (Method B and Method C) and soil concentrations protective of groundwater are provided in Tables 5-10 and 5-11, respectively. The ratios are obtained by dividing the analyte concentration by the soil direct contact cleanup level or the soil concentration protective of groundwater. The level of exceedance (ratio) corresponds to the level of residual waste concentration remaining in tank C-111 above or below the cleanup level. A level of exceedance greater than 1 corresponds to a residual waste concentration greater than the cleanup level. Tables 5-10 and 5-11 also identify analytes that are dangerous waste constituents per WAC 173-303-9905 and analytes with concentrations that exceed 90th percentile background concentrations. Expanded lists of nonradioactive analytes that were not detected are provided in Tables D-10 and D-11 in Appendix D.

The results for waste residual concentrations estimated for the average residual waste inventory from detected analytes are briefly summarized below.

- For direct contact under an unrestricted land use scenario, only aluminum, fluoride, silver, and uranium are above the cleanup levels. Arsenic had a concentration more than 9 times the soil cleanup level. Arsenic is listed as a dangerous constituent per WAC 173-303-9905.

- For direct contact under an industrial land use scenario, all constituents are reported at concentrations less than the soil cleanup level.

- For soil concentrations protective of groundwater, fluoride, tributyl phosphate, lead, cadmium, cyanide, iron, mercury, nitrate, nitrite, silver, and uranium are all above the concentration predicted by the MTCA fixed parameter three-phase model. The estimated average arsenic concentration was 182 times above the concentration protective of groundwater. Arsenic, cadmium, cyanide, mercury, and silver are listed as dangerous constituents per WAC 173-303-9905.

5.5.2 WAC 173-340 Ecological Risk

WAC 173-340-900, "Tables" includes the following tables:

- Table 749-2, "Priority Contaminants of Ecological Concern for Sites that Qualify for the Simplified Terrestrial Ecological Evaluation Procedure"

- Table 749-3, "Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals."

Each of these tables contains a footnote stating that it is not intended for the purpose of evaluating sludges or waste, as follows (key statement bolded for this report).

- Table 749-2, footnote a: "Caution on misusing these chemical concentration numbers. These values have been developed for use at sites where a site-specific terrestrial ecological evaluation is not required. They are not intended to be protective of terrestrial ecological receptors at every site. Exceedances of the values in this table do not necessarily trigger requirements for cleanup action under this chapter. **The table is not intended for purposes such as evaluating sludges or wastes.**
  This list does not imply that sampling must be conducted for each of these chemicals at every site. Sampling should be conducted for those chemicals that might be present based on available information, such as current and past uses of chemicals at the site."

- Table 749-3, footnote a: "Caution on misusing ecological indicator concentrations. Exceedances of the values in this table do not necessarily trigger requirements for cleanup action under this chapter. Natural background concentrations may be substituted for ecological indicator concentrations provided in this table. **The table is not intended for purposes such as evaluating sludges or wastes.**
  This list does not imply that sampling must be conducted for each of these chemicals at every site. Sampling should be conducted for those chemicals that might be present based on available information, such as current and past uses of chemicals at the site."

Table 5-9. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (3 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Lognormal 90 Percentile Background Value (mg/kg)[d,e,f]	Above Detection Limits
1, 1, 1-Trichloroethane*	9.16E-04	2.71E-03	1.60E+05	7.00E+06	1.58E+00	--	No
1, 1, 2-Trichloro-1, 2, 2-trifluoroethane	1.16E-03	3.43E-03	--	--	--	--	No
1, 1, 2-Trichloroethane*	1.65E-03	4.88E-03	1.75E+01	2.30E+03	4.27E-03	--	No
1, 1-Dichloroethene*	4.21E-03	1.25E-02	4.00E+03	1.75E+05	5.01E-02	--	No
1, 2, 4-Trichlorobenzene*	1.93E-03	5.71E-03	3.45E+01	4.53E+03	5.63E-02	--	No
o-Dichlorobenzene*	1.21E-03	3.58E-03	7.20E+03	3.15E+05	7.03E+00	--	No
1, 2-Dichloroethane*	5.35E-04	1.58E-03	1.10E+01	1.44E+03	2.32E-03	--	No
1, 4-Dichlorobenzene	8.92E-04	2.64E-03	1.85E+02	2.43E+04	1.34E-01	--	No
n-Butyl alcohol (1-butanol)	1.02E-01	3.02E-01	8.00E+03	3.50E+05	--	--	No
2, 4, 5-Trichlorophenol*	4.17E-01	1.23E+00	8.00E+03	3.50E+05	2.88E+01	--	No
2, 4, 6-Trichlorophenol	5.83E-01	1.73E+00	8.00E+01	3.50E+03	4.62E-02	--	No
2, 4-Dinitrotoluene*	3.23E-01	9.56E-01	3.23E+00	4.23E+02	1.67E-03	--	No
2, 6-Bis (tert-butyl)-4-methylphenol	7.91E-01	2.34E+00	--	--	--	--	No
2-Butanone(MEK)	3.95E-02	1.17E-01	4.80E+04	2.10E+06	1.97E+01	--	No
2-Chlorophenol*	4.94E-01	1.46E+00	4.00E+02	1.75E+04	4.72E-01	--	No
2-Ethoxyethanol	6.39E-01	1.89E+00	--	--	--	--	No
2-Methylphenol (o-cresol)	3.73E-01	1.10E+00	4.00E+03	1.75E+05	2.33E+00	--	No
o-Nitrophenol	6.27E-01	1.86E+00	--	--	--	--	No

Table 5-9. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (3 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Lognormal 90 Percentile Background Value (mg/kg)[d,e,f]	Above Detection Limits
2-Nitropropane*	5.85E-03	1.73E-02	--	--	--	--	No
p-Chloro-m-cresol (4-Chloro-3-methylphenol)*	5.01E-01	1.48E+00	8.00E+03	3.50E+05	2.21E+01	--	No
4-Methyl-2-pentanone (MIBK)	1.70E-02	5.03E-02	6.40E+03	2.80E+05	2.73E+00	--	No
o-Nitrophenol	6.27E-01	1.86E+00	--	--	--	--	No
Acenaphthene	4.38E-01	1.30E+00	4.80E+03	2.10E+05	4.90E+01	--	No
Acetate	1.93E+02	3.10E+02	--	--	--	--	Yes
2-Propanone (Acetone)	1.29E-01	3.82E-01	7.20E+04	3.15E+06	2.89E+01	--	No
Silver*	1.96E+02	5.18E+02	4.00E+02	1.75E+04	1.36E+01	2.73E+02	Yes
Aluminum	8.04E+04	1.50E+05	8.00E+04	3.50E+06	4.80E+05	2.88E+07	Yes
Polychlorinated Biphenyls*	1.14E-02	3.37E-02	5.00E-01	6.56E+01	--	--	No
Arsenic*	3.18E+01	9.41E+01	6.67E-01	8.75E+01	3.41E-02	2.77E+04	No
Boron	4.24E+00	1.26E+01	1.60E+04	7.00E+05	2.05E+02	5.86E+03	No
Barium*	5.88E+00	1.26E+01	--	--	--	--	Yes
Beryllium*	2.12E+00	6.28E+00	1.60E+02	7.00E+03	6.32E+01	1.00E+04	No
Benzene*	1.47E-03	4.35E-03	1.82E+01	2.39E+03	4.48E-03	--	No
Benzo[a]pyrene*	6.64E-01	1.97E+00	1.37E-01	1.80E+01	2.32E-01	--	No
Bismuth.	2.94E+02	4.37E+02	--	--	--	--	Yes
Di (2-ethylhexyl) phthalate (DEHP)	3.79E+00	5.08E+00	7.14E+01	9.38E+03	1.34E+01	--	Yes

Table 5-9. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (3 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Lognormal 90 Percentile Background Value (mg/kg)[d,e,f]	Above Detection Limits
Bromide	7.14E+01	2.11E+02	--	--	--	--	No
Butylbenzylphthalate*	1.98E+00	2.29E+00	5.26E+02	6.91E+04	1.29E+01	--	Yes
Calcium	3.58E+03	9.53E+03	--	--	--	1.05E+08	Yes
Carbon disulfide*	1.60E-03	4.74E-03	8.00E+03	3.50E+05	5.65E+00	--	No
Carbon tetrachloride*	9.29E-04	2.75E-03	1.43E+01	1.88E+03	5.75E-03	--	No
Cadmium*	3.34E+00	9.89E+00	8.00E+01	3.50E+03	6.90E-01	2.90E+03	No
Cerium	2.00E+02	2.78E+02	--	--	--	--	Yes
Chlorobenzene*	8.60E-04	2.55E-03	1.60E+03	7.00E+04	8.74E-01	--	No
Chloroform*	1.30E-03	3.85E-03	3.23E+01	4.23E+03	7.51E-03	--	No
Chloride	8.56E+01	2.53E+02	--	--	1.00E+03	1.48E+06	No

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-59714, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment*."

[b] 95% Upper Confidence Level Concentration = Mean Concentration + (1.96 × Mean Concentration × Relative Standard Deviation). Mean Concentrations and Relative Standard Deviation provided in Table A-1 in Appendix A of RPP-RPT-58514.

[c] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

[d] DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, Rev. 4, Volume 1.

[e] DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*.

[f] ECF-HANFORD-11-0038, "*Soil Background for Interim Use at the Hanford Site*."

* Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Table 5-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Constituents above Detection in 241-C-111 Tank Residual Wastes. (2 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-111 Residual Wastes to Soil Cleanup Standards				
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits	Above 90 Percentile Background
Acetate	1.93E+02	--	--	--	Yes	--
Silver*	1.96E+02	4.90E-01	1.12E-02	1.44E+01	Yes	Yes
Aluminum	8.04E+04	1.01E+00	2.30E-02	1.67E-01	Yes	No
Barium*	5.88E+00	--	--	--	Yes	--
Bismuth	2.94E+02	--	--	--	Yes	--
Di (2-ethylhexyl) phthalate (DEHP)	3.79E+00	5.31E-02	4.04E-04	2.84E-01	Yes	--
Butylbenzylphthalate*	1.98E+00	3.76E-03	2.87E-05	1.54E-01	Yes	--
Calcium	3.58E+03	--	--	--	Yes	No
Cerium	2.00E+02	--	--	--	Yes	--
Cyanide*	1.69E+01	3.52E-01	8.05E-03	1.74E+01	Yes	--
Chromium, Total*	5.65E+01	4.71E-04	1.08E-05	2.82E-02	Yes	--
Copper	1.92E+01	6.00E-03	1.37E-04	6.76E-02	Yes	No
Fluoride	9.82E+03	2.05E+00	4.68E-02	3.41E+00	Yes	No
Iron	1.04E+04	1.86E-01	4.24E-03	1.84E+00	Yes	No
Hydroxide OH	2.42E+02	--	--	--	Yes	--
Mercury*	2.78E+00	1.16E-01	2.65E-03	1.33E+00	Yes	No
Lanthanum	5.33E+01	--	--	--	Yes	--
Magnesium	1.09E+02	--	--	--	Yes	No
Manganese	5.19E+01	4.63E-03	1.06E-04	1.04E-01	Yes	No
Sodium	1.92E+05	--	--	--	Yes	No
Neodymium	9.27E+01	--	--	--	Yes	--
Ammonia	2.91E+00	--	--	--	Yes	No

Table 5-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Constituents above Detection in 241-C-111 Tank Residual Wastes. (2 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-111 Residual Wastes to Soil Cleanup Standards				
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits	Above 90 Percentile Background
Nickel*	1.37E-01	--	--	--	Yes	--
Nitrite	1.14E+03	4.75E-02	1.09E-03	8.64E+01	Yes	--
Nitrate[b]	2.36E+03	4.15E-03	9.50E-05	1.31E+01	Yes	No
Lead*	2.65E+03	--	2.65E+00	8.83E-01	Yes	No
Phosphate	1.91E+05	--	--	--	Yes	Yes
Silicon	3.52E+03	--	--	--	Yes	--
Samarium	5.68E+01	--	--	--	Yes	--
Sulfate	5.69E+02	--	--	5.69E-01	Yes	No
Strontium	7.97E+01	1.66E-03	3.80E-05	1.18E-02	Yes	--
Thorium	1.00E+00	--	--	--	Yes	--
Titanium	4.17E+01	--	--	--	Yes	No
Tributyl phosphate	1.26E+00	1.13E-02	8.64E-05	2.54E+00	Yes	--
Uranium	7.73E+02	3.22E+00	7.36E-02	2.86E+00	Yes	No
Vanadium	7.21E+00	1.80E-02	4.12E-04	4.51E-03	Yes	No
Yttrium	9.23E+00	--	--	--	Yes	--
Zirconium	4.12E+01	--	--	--	Yes	No

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-59714, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*"

[b] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

* Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium (III), insoluble salts.

-- = Value is not available

Table 5-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Constituents above Detection in 241-C-111 Tank Residual Wastes. (3 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-111 Residual Wastes to Soil Cleanup Standards				
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits	Above 90 Percentile Background
Acetate	3.10E+02	--	--	--	Yes	--
Silver*	5.18E+02	1.29E+00	2.96E-02	3.81E+01	Yes	Yes
Aluminum	1.50E+05	1.88E+00	4.29E-02	3.13E-01	Yes	No
Barium*	1.26E+01	--	--	--	Yes	--
Bismuth	4.37E+02	--	--	--	Yes	--
Di (2-ethylhexyl) phthalate (DEHP)	5.08E+00	7.11E-02	5.41E-04	3.80E-01	Yes	--
Butylbenzylphthalate*	2.29E+00	4.36E-03	3.32E-05	1.78E-01	Yes	--
Calcium	9.53E+03	--	--	--	Yes	No
Cerium	2.78E+02	--	--	--	Yes	--
Cyanide*	3.73E+01	7.76E-01	1.77E-02	3.84E+01	Yes	--
Chromium, Total*	1.02E+02	8.49E-04	1.94E-05	5.09E-02	Yes	--
Copper	3.05E+01	9.52E-03	2.18E-04	1.07E-01	Yes	No
Fluoride	1.11E+04	2.31E+00	5.29E-02	3.85E+00	Yes	No
Iron	1.86E+04	3.33E-01	7.61E-03	3.30E+00	Yes	No
Hydroxide OH	5.29E+02	--	--	--	Yes	--
Mercury*	4.94E+00	2.06E-01	4.70E-03	2.36E+00	Yes	No
Lanthanum	9.39E+01	--	--	--	Yes	--

Table 5-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Constituents above Detection in 241-C-111 Tank Residual Wastes. (3 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-111 Residual Wastes to Soil Cleanup Standards				
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits	Above 90 Percentile Background
Magnesium	2.72E+02	--	--	--	Yes	No
Manganese	1.00E+02	8.93E-03	2.04E-04	2.00E-01	Yes	No
Sodium	2.21E+05	--	--	--	Yes	No
Neodymium	1.60E+02	--	--	--	Yes	--
Ammonia	5.09E+00	--	--	--	Yes	No
Nickel*	2.36E-01	--	--	--	Yes	--
Nitrite	2.80E+03	1.17E-01	2.67E-03	2.12E+02	Yes	--
Nitrate[b]	5.91E+03	1.04E-02	2.38E-04	3.28E+01	Yes	No
Lead*	5.32E+03	--	5.32E+00	1.77E+00	Yes	No
Phosphate	2.33E+05	--	--	--	Yes	Yes
Silicon	5.67E+03	--	--	--	Yes	--
Samarium	8.15E+01	--	--	--	Yes	--
Sulfate	9.94E+02	--	--	9.94E-01	Yes	No
Strontium	1.57E+02	3.26E-03	7.46E-05	2.32E-02	Yes	--
Thorium	2.37E+00	--	--	--	Yes	--
Titanium	1.16E+02	--	--	--	Yes	No
Tributyl phosphate	2.11E+00	1.90E-02	1.45E-04	4.25E+00	Yes	--
Uranium	1.83E+03	7.62E+00	1.74E-01	6.77E+00	Yes	No

Table 5-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Constituents above Detection in 241-C-111 Tank Residual Wastes. (3 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-111 Residual Wastes to Soil Cleanup Standards				
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits	Above 90 Percentile Background
Vanadium	9.61E+00	2.40E-02	5.49E-04	6.01E-03	Yes	No
Yttrium	1.46E+01	--	--	--	Yes	--
Zirconium	7.50E+01	--	--	--	Yes	No

[a] 95% Upper Confidence Level Concentration = Mean Concentration + (1.96 × Mean Concentration × Relative Standard Deviation). Mean Concentrations and Relative Standard Deviation provided in Table A-1, Appendix A of RPP-RPT-59714, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment*."

[b] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

* Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Because of the limitations stated above, comparisons between the concentrations of waste constituents remaining in tank C-111 have not been made against Table 749-2 [under WAC 173-340-7492, "Simplified Terrestrial Ecological Evaluation Procedures," subsection (1) "Purpose"] or Table 749-3 [under WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures," subsection (2) "Problem formulation step," (i) "The chemicals of ecological concern"].

5.6 RISK ASSESSMENT SUMMARY

Cumulative analysis results of the risk assessment performed to examine impacts from post-retrieval inventories for SST C-111 are summarized as follows.

- The impacts estimated for residual waste left in SST C-111, using either the average or the 95% UCL inventory, are orders of magnitude below the various performance objectives identified for the groundwater pathway.
- Total ILCRs estimated for all radionuclides are one to three orders of magnitude below the lower end of the performance objective range 1.0×10^{-6} to 1.0×10^{-4} ILCR.
- Total ILCRs estimated for all detectable nonradionuclides are one to 13 orders of magnitude below the performance objective of 1.0×10^{-5} ILCR.
- Hazard quotient estimated for all detectable analytes are two to four orders of magnitude below the performance objective of 1.0.
- Estimated doses for all detectable radionuclides are between:
    - Four orders of magnitude below the performance objective for the all-pathways dose of 25 mrem/yr
    - Three to four orders of magnitude below the performance objective for drinking water dose of 4 mrem/yr.

Following are conclusions about the impacts from key analytes identified in the residual wastes within SST C-111 for each of the performance metrics evaluated.

- **Total ILCR for Radionuclides:** For both the average and 95% UCL inventory, ^{99}Tc and ^{14}C are the primary contributors to the total ILCR for all radionuclides with the industrial land use and residential land use scenarios. The contribution from the other detectable radionuclides, including ^{129}I and the uranium isotopes, was not detectable in residual waste samples, arrived at the WMA C fenceline within the 10,000-year period of interest below concentrations of 1.0×10^{-3} pCi/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **Total ILCR for Nonradionuclides:** For both the average and 95% UCL inventory, the contribution from nonradioactive analytes detectable in residual waste samples arrived at the WMA C fenceline within the 10,000-year period of interest below concentrations of 1.0×10^{-3} µg/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **Hazard Indices:** For both the average and 95% UCL inventory, fluoride, nitrate, and nitrite are the primary contributors to the hazard indices. The contribution from nonradioactive analytes detectable in residual waste samples arrived at the WMA C fenceline within the 10,000-year period of interest below concentrations of 1.0×10^{-3} mg/L, did not arrive at the WMA C fenceline within the 10,000-year period of interest, or did not have available toxicological information.

- **All-Pathways Dose:** ^{99}Tc with a maximum dose rate of 3.48×10^{-4} mrem/yr, and ^{14}C with a maximum dose of 1.46×10^{-5} mrem/yr, contributed the majority of the radiological dose for the all-pathways farmer scenario (25 mrem/yr). The contribution from all other radionuclides, including ^{129}I and the uranium isotopes, was not detectable in residual waste samples, arrived at the WMA C fenceline below concentrations of 1.0×10^{-3} pCi/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **Drinking Water Dose (Target Organ):** ^{99}Tc with a maximum dose rate of 8.82×10^{-4} mrem/yr, and ^{14}C with a maximum dose of 6.01×10^{-6} mrem/yr, contributed the majority of the radiological dose for beta/photon emitters (4 mrem/yr target organ dose). The contribution to dose from all other radionuclides, including ^{129}I and the uranium isotopes, was not detectable in residual waste samples, arrived at the WMA C fenceline below concentrations of 1.0×10^{-3} pCi/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **Intruder Dose:** Doses calculated from inadvertent intrusion are primarily attributable to doses from ^{90}Sr, ^{137}Cs, ^{239}Pu, and ^{241}Am. The relative contribution and timing of doses from these radionuclides to the total doses estimated during the 1,000-year period of analysis depends on the scenario considered. In general, dose contributions from ^{90}Sr and ^{137}Cs typically account for the majority of the dose during the first 200 to 450 years. Doses from ^{239}Pu and ^{241}Am contribute the majority of the dose realized after 250 to 450 years. For both average and 95% UCL inventories estimated for SST C-111, none of the inadvertent intruder evaluations produce results that exceed the performance objectives for either acute exposure or chronic exposure after ~175 years following closure.

As additional risk management information, concentrations of constituents remaining in waste residuals within tank C-111 are compared against the MTCA cleanup standards. For MTCA Method B and Method C, soil cleanup levels based on human exposure via direct contact or other exposure pathways where contact with the soil is required to complete the pathway, the point of compliance shall be established in the soils throughout the site from the ground surface to 15 ft below the ground surface. Under a closure configuration, waste residuals left in

tank C-111 and other SSTs in WMA C would be expected to be below 15 ft below ground surface.

For MTCA soil cleanup levels protective of groundwater, the assumption is that constituents of interest are found in soils and are immediately available to be leached by infiltrating precipitation. Under a closure configuration, constituents associated with waste residuals left in tank C-111 and other SSTs in WMA C would be contained within a grout-filled tank, a steel tank liner, and an underlying concrete pad below the liner and would not be immediately available for leaching by infiltrating water.

Following are conclusions about the comparison of tank C-111 water residual concentrations against MTCA cleanup levels.

- **MTCA Method B Unrestricted Land Use:** For both the average and 95% UCL inventory, aluminum, fluoride, silver, and uranium are above the cleanup levels. Arsenic is listed as a dangerous constituent per WAC 173-303-9905.

- **MTCA Method C Industrial Land Use:** For both the average and 95% UCL inventory, all constituents are reported at concentrations less than the soil cleanup level.

- **MTCA Soil Concentrations Protective of Groundwater:** For both the average and 95% UCL inventory, fluoride, cadmium, cyanide, fluoride, iron, mercury, nitrate, nitrite, tributyl phosphate, silver, and uranium are greater than the soil cleanup level. For the 95% UCL, mercury and silver are also above the soil cleanup level. Arsenic, cadmium, cyanide, mercury, and silver are listed as dangerous constituents per WAC 173-303-9905.

Table 5-12 provides a comparison of the inventory used in DOE/ORP-2005-01 against the inventory for detected analytes calculated using post-retrieval samples for the average inventory and the 95% UCL inventories. For the purpose of this comparison, Table 5-12 includes inventories calculated from the laboratory's minimum detection limit for an analyte. Inventories calculated from one half of the laboratory's minimum detection limit are included in the risk assessment analysis. The following observations are made from the comparison of the Hanford Tank Waste Operations Simulator (HTWOS) and post-retrieval inventories.

- Comparison of the HTWOS estimated inventories and post-retrieval inventories for analytes important for assessment of groundwater impacts are as follows:

    - Post-retrieval inventories for ^{14}C were not detected in the residual waste.

    - Post-retrieval inventories for ^{99}Tc are approximately 3.2 to 6.3 times more than the HTWOS estimate for ^{99}Tc

    - Post-retrieval inventories for chromium are approximately 0.7 times less to 1.3 times greater than the HTWOS estimate for chromium

- Post-retrieval inventories for nitrate are approximately 0.5 to 1.24 times less than the HTWOS estimates for nitrate
- Post-retrieval inventories for nitrite are approximately 0.5 to 1.1 times less than the HTWOS estimates for nitrite
- Post-retrieval inventories for fluoride are approximately 44.3 to 58.0 times greater than the HTWOS estimate for fluoride.

- Comparison of the HTWOS estimated inventories and post-retrieval inventories for analytes important to assessing inadvertent intruder impacts are as follows.
  - Post-retrieval inventories for ^{90}Sr are approximately 1.6 to 4.0 times more than HTWOS estimates for ^{90}Sr.
  - Post-retrieval inventories for ^{137}Cs are approximately 1.3 to 2.9 times the HTWOS inventory estimates for ^{137}Cs.
  - Post-retrieval inventories for ^{232}Th are approximately 794,000 to 1,920,000 times larger than the HTWOS estimates for ^{232}Th.
  - Post-retrieval inventories for the plutonium isotopes ^{239}Pu, ^{240}Pu and ^{241}Pu were not detected in the residual waste. Post-retrieval inventories for ^{238}Pu are approximately 0.9 times less to 1.7 times greater than those in the HTWOS estimate.
  - Post-retrieval inventories for ^{241}Am are approximately 1.32 to 2.7 times greater than those in the HTWOS estimate.
  - Post-retrieval inventories for the uranium isotopes ^{233}U and ^{232}U were not detected in the residual waste. Post-retrieval inventories for the uranium isotopes ^{235}U, ^{236}U and ^{238}U range from approximately 0.1 to 0.8 times less than those in the HTWOS estimate.

Table 5-12. Comparison of Hanford Tank Waste Operations Simulator Predicted Inventory Used in DOE/ORP-2005-01 with the Average and 95% Upper Confidence Level Post-Retrieval Inventories.

Analyte		Units	DOE/ORP-2005-01[a] (HTWOS Predicted)	Average Post-Retrieval Inventory[b]	95% UCL Inventory[b]	Detected in Residual Wastes	Ratio Average/ HTWOS	Ratio Bounding/ HTWOS
Analytes Important for Groundwater Impacts	^{14}C	Ci	1.31E-03	3.90E-03	1.18E-02	No	N/A	N/A
	^{99}Tc	Ci	1.58E-02	4.97E-02	1.00E-01	Yes	3.15E+00	6.33E+00
	Chromium, Total	Kg	2.19E+00	1.46E+00	2.73E+00	Yes	6.67E-01	1.25E+00
	Fluoride	Kg	5.74E+00	2.54E+02	3.33E+02	Yes	4.43E+01	5.80E+01
	Nitrate	Kg	1.27E+02	6.12E+01	1.57E+02	Yes	4.82E-01	1.24E+00
	Nitrite	Kg	6.58E+01	2.96E+01	7.45E+01	Yes	4.50E-01	1.13E+00
Analytes Important for Inadvertent Intruder	^{90}Sr	Ci	2.80E+04	4.53E+04	1.11E+05	Yes	1.62E+00	3.96E+00
	^{137}Cs	Ci	1.22E+02	1.61E+02	3.55E+02	Yes	1.32E+00	2.91E+00
	^{232}Th	Ci	3.59E-12	2.85E-06	6.91E-06	Yes	7.94E+05	1.92E+06
	^{233}U	Ci	1.52E-06	5.92E-03	1.79E-02	No	N/A	N/A
	^{234}U	Ci	4.66E-02	2.15E-02	6.49E-02	No	N/A	N/A
	^{235}U	Ci	2.04E-03	2.84E-04	6.85E-04	Yes	1.39E-01	3.36E-01
	^{236}U	Ci	7.64E-04	2.30E-04	6.02E-04	Yes	3.01E-01	7.88E-01
	^{238}U	Ci	4.75E-02	6.68E-03	1.62E-02	Yes	1.41E-01	3.41E-01
	^{237}Np	Ci	1.95E-04	1.31E-03	2.85E-03	Yes	6.72E+00	1.46E+01
	^{238}Pu	Ci	9.48E-02	8.73E-02	1.63E-01	Yes	9.21E-01	1.72E+00
	^{239}Pu	Ci	5.16E+00	7.62E-01	2.30E+00	No	N/A	N/A
	^{240}Pu	Ci	1.00E+00	8.29E-02	2.50E-01	No	N/A	N/A
	^{241}Pu	Ci	3.90E+00	7.14E-01	2.16E+00	No	N/A	N/A
	^{241}Am	Ci	5.88E+00	7.79E+00	1.56E+01	Yes	1.32E+00	2.65E+00
	^{242}Cm	Ci	2.79E-03	3.24E-02	4.53E-02	Yes	1.16E+01	1.62E+01
	^{243}Cm	Ci	9.00E-05	6.80E-03	1.36E-02	Yes	7.56E+01	1.51E+02
	^{244}Cm	Ci	2.03E-03	1.30E-01	2.61E-01	Yes	6.40E+01	1.29E+02

[a] Inventories for contaminants having the greatest impact for groundwater or inadvertent intruder pathway.

[b] Includes inventories in sludge calculated from one half of the laboratory's minimum detection limit for an analyte.

Reference: DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*.

HTWOS = Hanford Tank Waste Operations Simulator
N/A = Not applicable
UCL = upper confidence level

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

This section discusses aspects of the tank C-111 waste retrieval operations, provides recommendations for further actions, and addresses opportunities to refine waste retrieval technologies based on lessons learned from the tank C-111 retrieval operation. The format of this section is to provide brief discussions of the major Lessons-Learned topic areas; some of those areas are taken from other tank waste retrieval activities.

There are opportunities to improve future waste retrieval operations by looking at the ways to modify equipment, make operational changes (e.g., operating sequencing and conditions), plan work, and enhance the design and fabrication of equipment. All RDRs have a Lessons Learned section and it must be recognized that previously identified lessons learned have been incorporated in the formulation and operation of subsequent tank waste retrieval operations, and in the tank C-111 retrieval operation, but are not presented here.

6.1 POTENTIAL ENHANCEMENTS

Improvements implemented during the retrieval of tank C-111 are as follows.

The use of ERSS with more radiation-resistant hydraulic hoses allowed the majority of the waste to be retrieved from tank C-111. The ERSS was installed in 2013 in tank C-111 and suffered hydraulic hose failures that were determined to have been largely caused by radiation damage on the hydraulic hoses (RPP-RPT-58658, "*Tank 241-C-111 Mid-Hose Failure Mechanism Report*"). The ERSS underwent significant redesign that incorporated a more radiation-resistant hydraulic hose material and allowed for retrieval activities to be completed in tank C-111. The more radiation-resistant ERSS will play an important role as tanks with larger radionuclide inventories are retrieved.

This improvement made during the C-111 retrieval will be incorporated as applicable in future tank retrievals.

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7. LEAK DETECTION, MONITORING, AND MITIGATION

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

The operational history and decades of waste and liquid level monitoring indicate that tank C-111 had not leaked and was sound before starting retrieval (HNF-EP-0182, "*Waste Tank Summary Report for Month Ending August 31, 2017*," Rev. 351). Additionally, there was no evidence of a leak during retrieval of waste from tank C-111.

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 C-111 waste retrieval were as follows.

a. Drywell moisture and gamma logging showed no evidence of leaks during the tank C-111 waste retrieval.

b. Modified static level monitoring demonstrated no evidence of leakage during retrieval.

c. Material balance calculations showed no evidence of leaks during the tank C-111 waste retrieval.

d. A high-resolution resistivity (HRR) system was deployed with drywells and the tank thermocouple as electrodes to detect changes in baseline soil moisture levels. The HRR system showed no evidence of a leak during retrieval.

e. Transfer line and access pit leak detection showed no evidence of leaks during the tank C-111 waste retrieval.

The Tank Waste Retrieval Work Plan (RPP-37739) has requirements for leak detection during retrieval.

7.1 REQUIREMENTS

Some leak detection and monitoring system requirements are contained in the safety basis controls given in HNF-SD-WM-TSR-006, "*Tank Farms Technical Safety Requirements*," specifically Technical Safety Requirement (TSR) Limiting Condition for Operation Section 3.1.1, *Transfer Leak Detection Systems*. Material balances during transfers are required by the TSR Administrative Control Section 5.11, *Transfer Control*, and RPP-12711, "*Temporary Waste Transfer Line Management Program Plan*." The primary procedures governing notification and reporting of leaks are TFC-OPS-OPER-C-24, "Occurrence Reporting and Processing of Operations Information" and TFC-ESHQ-ENV_FS-C-01, "Environmental

Notification." Table 7-1 presents the tank C-111 leak detection and monitoring functions and requirements from RPP-37739.

Table 7-1. Tank 241-C-111 Leak Detection and Monitoring Functions and Requirements.

Function	Requirement	Basis	Key Elements
Detect leaks during waste removal from tank 241-C-111	The leak detection and monitoring (LDM) system shall be capable of detecting liquid waste releases during all waste removal operations.	*Washington Administrative Code* (WAC) 173-303	Utilize LDM technologies to detect loss of liquid from a tank; see Section 7.2.
Monitor leaks from tank 241-C-111 during waste removal	The waste retrieval system (WRS) 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.	WAC 173-303	Utilize both ex-tank LDM 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-C-111 waste retrieval	The integrated retrieval and LDM 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.	WAC 173-303	Leak mitigation strategy described in Section 7.3.
WRS secondary containment and leak detection	For ex-tank equipment and piping, the WRS shall incorporate secondary containment and leak-detection design features in accordance with 40 CFR 265.193 and DOE O 435.1.	40 CFR 265 WAC 173-303 DOE O 435.1 RPP-13033 HNF-SD-WM-TSR-006	Provide for safe and compliant transfer of waste to the receiver double-shell tank.

CFR = *Code of Federal Regulations* DOE = U.S. Department of Energy

References:
40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart J—Tank Systems, §265.193 Containment and detection of releases.
DOE O 435.1, *Radioactive Waste Management.*
HNF-SD-WM-TSR-006, "*Tank Farms Technical Safety Requirements.*"
RPP-13033, "*Tank Farms Documented Safety Analysis.*"
WAC 173-303, "Dangerous Waste Regulations."

7.2 LEAK DETECTION AND TANK MONITORING

During the sluicing retrieval of tank C-111, HRR was used as the primary leak detection method with drywell moisture logging and Enraf® readings as a backup. Moisture logging is used when the tank is in retrieval status and not in active retrieval. Enraf® readings are used when there is no active retrieval, a liquid pool is available, active ventilation of the head space is minimized, and when access to the tank farms needs to be minimized. None of the leak detection methods used indicated that a leak occurred while tank C-111 was in retrieval status. Figure 7-1 is

timeline for tank C-111 retrieval and shows when each leak detection method was used. Leak detection and monitoring was accomplished by the use of HRR, drywell monitoring, visual inspection, leak detectors, Enraf® gauges in tank AN-101, radiological monitoring, and material balances as shown in Table 7-2 and discussed in Sections 7.2.1 through 7.2.3.

7.2.1 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 and the subsequent resistivity data analyzed for changes with time.

Ideally, drywell-to-tank (WTT) and drywell-to-drywell (WTW) resistivity measurements are available to review and are in agreement. The more reliable WTT measurements that are less susceptible to interference were usually available to make a leak determination. When the waste level in the tank is low, the thermocouple (tank electrode) may not be in contact with the waste; however, the thermocouple tree in tank C-111 remained in contact with the waste and WTT resistivity measurements were the main focus for leak determinations.

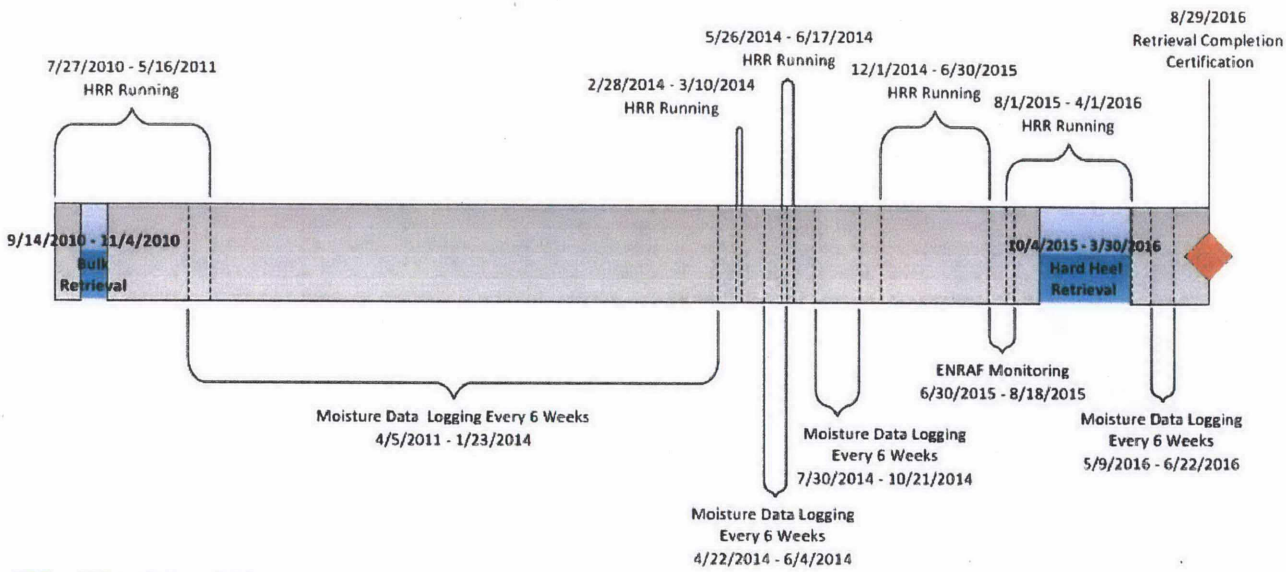
During both the first and second phases of retrieval when sluicing was the main retrieval technology, several anomalous HRR results were evaluated. Table 7-3 identifies the anomalies and provides a description of the anomaly and the resolution during tank C-111 retrieval. None of the anomalous data indicated a leak of the tank.

Additionally, in accordance with RPP-37739, selected drywells surrounding tank C-111 were logged as a backup leak detection method. Gamma logs were obtained prior to retrieval operations and neutron moisture logging was performed prior to retrieval and every six weeks during retrieval (see Figure 7-1). As reported in HGLP-MBL-019, "*241-C-111 Tank Waste Retrieval Project Final Report of Drywell Monitoring Data*," none of the drywells around tank C-111 show evidence of significant changes in either gamma activity or subsurface moisture. Available data from these drywells provide no evidence of any leak or contaminant movement associated with tank retrieval operations.

7.2.2 Single-Shell Tank 241-C-111

In-tank mitigative actions to minimize the risk of a leak were taken before and during tank C-111 retrieval. Mitigative actions of in-tank monitoring of tank C-111 were performed by liquid level monitoring, video inspections and material balance calculations.

Figure 7-1. Tank 241-C-111 Leak Detection Monitoring Timeline.



HRR = high-resolution resistivity

Honeywell Enraf® is a registered trademark of Honeywell International Inc., Corporation Delaware, 101 Columbia Road Morristown, New Jersey.

Table 7-2. Leak Detection and Monitoring Methods for Each Waste Retrieval System Component.

Component	Leak Detection and Monitoring Method
Single-shell tank 241-C-111	Drywells, liquid level indicators, visual inspection, material balance and high-resolution resistivity
Double-shell tank 241-AN-101	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

Table 7-3. High-Resolution Resistivity Anomaly Evaluation During and After Sluicing.

Number	Date	Anomaly Description	Resolution/Comments
2010-11	10/14/10	WTT leak potential numbers were within specification, but higher than normal.	Plots were made and trends reviewed. There was no overall change in the trend lines but an obvious increase in the noise that can cause leak potentials to be high.
2010-11 Rev. 1	10/14/10		Additional data was reviewed and confirmed that there was no change in the trend line, just additional noise.
2010-11 Rev. 2	10/14/10		More data was reviewed and again confirmed that there was no change in the trend line, just additional noise.
2010-11 Rev. 3	10/14/10		It was determined that the noise was from cathodic protection system changes. The response to the cathodic protection system changed after a transformer was damaged.
2011-04	5/16/11	WTT and WTW leak potential numbers for both tanks 241-C-104 and 241-C-111 were higher than normal.	A review of plots showed rapid changes to the resistance readings. Lightning strikes occurred in the area 5/13 and 5/14 followed by rain. The changes occurred for both the tanks being monitored at the same time. The change in readings did not indicate a leak and were caused by the weather.
2015-01	2/8/15	The WTT leak potential values were higher than normal.	The process data constants used to calculate the leak potential values were more restrictive than in the past. The constants were too restrictive resulting in false positive results. Tanks 241-C-102 and 241-C-105 were also being monitored and had similar resistance plots but low leak potential values. Also, there no field activities that would have caused a leak to occur.
2015-02	5/14/15	Leak potential values went high for all tanks being monitored after a large rain event.	A response to rain is expected, this response continued for an unusually long time. One of the high-resolution resistivity junction boxes had a leak and accumulated rain caused anomalous readings.

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

7.2.2.1 Liquid Level Monitoring. The overall waste retrieval operating strategy for tank C-111 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 to implement this strategy. No active retrieval occurred during the following stagnant periods of November 5, 2010 through October 3, 2015. During these stagnant periods, liquid levels in tanks C-111 and AN-101 did not decrease, indicating that no leaks occurred.

7.2.2.2 Enraf® Level Monitoring. For a short time prior to the start of hard heel retrieval, level measurements with an Enraf® were used for leak detection. Liquid was added to the tank to retest the slurry pump prior to retrieval since it had not been operated for some time. A secondary purpose to add the water was to precondition/soften the waste by soaking the hard solids. With a pool of liquid available, no active ventilation, and access restrictions to protect workers from vapors, the Enraf® was used for leak detection. Level measurements were checked daily from June 30, 2015 to August 18, 2015 looking for level fluctuations that might indicate a leak; no level fluctuation indicative of a leak were observed.

7.2.2.3 Visual Inspection. Before initiating waste retrieval operations, a visual assessment and documentation of in-tank conditions in tank C-111 were performed using 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. Observations of the waste surface in tank C-111 indicated that the surface level decrease corresponded with waste retrieval activities.

7.2.2.4 Material Balance. Process control measurements were used periodically to perform a material balance and determine the change in tank C-111 waste inventory. Once determined, the change in waste inventory was compared to the anticipated change (gallons of slurry produced and/or released per gallon of water added, adjusted for changes in the central pool and interstitial liquid volumes).

During retrieval operations, material balances were performed during transfers by Operations for tank leak detection and mitigation for the portion of the system between the portable valve pit and tank AN-101, inclusive. Radiation surveys were required for the portion of the transfer line where volume material balance could not be performed. The frequency of material balance measurements and radiation surveys met the requirements of HNF-IP-1266, "*Tank Farms Operations Administrative Controls*."

7.2.3 Double-Shell Tank 241-AN-101

In-tank monitoring of tank AN-101 was performed by liquid level monitoring, an annulus leak detection system, radiation monitoring, and leak detectors in ancillary equipment. The following is a summary of leak mitigation actions for tank AN-101. More detailed information can be found in HNF-3484, "*Double-Shell Tank Emergency Pumping Guide*" and RPP-5842, *Time Deployment Study for Annulus Pumping*.

7.2.3.1 Liquid Level Monitoring. The waste level in the DST was monitored using an Enraf®, and annulus leak detector probes were used to provide indication of leaks, as described in Section 4.0 of OSD-T-151-00031, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection.*

Daily liquid level measurements were recorded for the receiving DST. The Enraf® gauge was capable of measuring liquid level changes to a precision of 0.25 cm (0.1 in.).

During waste retrieval there was no evidence of a release from tank AN-101 based on results of liquid level monitoring. The tank AN-101 liquid level increase corresponded with the material balance results for tank C-111.

7.2.3.2 Leak Detection. Tank AN-101 was monitored for leaks in the inner shell by a conductivity probe leak detection system installed in the tank annulus during tank construction. Slots cut in the concrete that support the tank at the bottom were designed to drain any leakage to the annulus floor. Enraf® assemblies in the annulus would have activated an audible alarm and an annunciator panel light in the event of liquid leaking to the annulus so that mitigation could have begun. Throughout the tank C-111 waste retrieval campaign, no leaks were detected by any of the leak detectors in tank AN-101.

7.2.3.3 Radiation Monitoring. A continuous air monitor operated to detect airborne radionuclides entrained in the ventilation exhaust stream of the annulus of tank AN-101. 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 AN-101 annulus detected no radiation levels above background during retrieval that could have been attributed to leak-induced airborne radionuclides.

7.2.4 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 WRS.

In accordance with RPP-12711, the hose-in-hose transfer line system underwent radiation monitoring and was equipped with leak detectors as part of the leak detection program.

7.3 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 and minimized 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. Conditions to control leak potential involved the following:

a. In-tank liquid levels during retrieval were lower than liquid levels present before interim stabilization

b. Tank C-111 was retrieved from the center out

c. Liquid was removed between waste retrieval operations

d. Leak assessment protocols were in accordance with procedures

e. Drywell surveys were conducted.

Conditions to control leak minimization included the following.

a. Liquid additions were minimized and liquid pools were removed as practical.

b. Tank C-111 was retrieved from the center out.

c. Equipment handling controls were imposed to minimize the potential for dropping equipment that could have penetrated the tank bottom.

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

7.3.1 Single-Shell Tank 241-C-111

A summary of the tank C-111 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 C-111 was monitored at all times. Key mitigative actions which would have been taken in the event of a leak are described in the RPP-37739, Sections 4.6.1 and 4.6.2.

7.3.2 Double-Shell Tank 241-AN-101

Mitigating actions for a leak from AN-101 primary tank piping into the secondary DST containment system during a waste transfer from tank C-111 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. Leaks at or near the AN-101 tank bottom might have required saltwell jet pumping to remove trapped liquids from between solid layers in the tank. Transfer line leakage would have drained to a common point for collection, detection, and removal.

7.4 CONCLUSION

Based on the available data (presented in Sections 7.2 and 7.3), no evidence of a tank leak occurred during tank C-111 waste retrieval operations. The tank C-111 LDMM program focused on a mitigation strategy to successfully control potential leaks. This strategy included the following.

a. Minimize residual tank waste.

b. Minimize in-tank water use.

c. Minimize standing liquid pools in the tank.

d. Control and monitor additions of water.

e. Visually monitor tank conditions and retrieval operations.

f. Retrieve from the center of the tank out to minimize water accumulation around the tank knuckle.

The goal of the LDMM program for tank C-111 as set forth in RPP-37739 was achieved.

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APPENDIX A

SINGLE-SHELL TANK 241-C-111 INVENTORY PRE- AND POST-SLUICING TECHNOLOGY RETRIEVAL

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APPENDIX A

SINGLE-SHELL TANK 241-C-111 INVENTORY PRE- AND POST-SLUICING TECHNOLOGY RETRIEVAL

Table A-1. Single-Shell Tank 241-C-111 Best-Basis Inventory Pre-Retrieval Inventory and Post-Sluicing Operations. (2 sheets)

Constituent Name	BBI February 2005[a]	BBI June 2015[b]			Constituent Name	BBI February 2005[a]	BBI June 2015[b]	
Analyte	Inventory	Inventory	Unit		Analyte	Inventory	Inventory	Unit
Al	3.13E+04	2.08E+03	Kg		^{99}Tc	2.56E+00	4.97E-02	Ci
Bi	1.77E+03	7.62E+00	Kg		^{106}Ru	3.75E-05	6.10E-16	Ci
Ca	4.39E+03	9.27E+01	Kg		^{113m}Cd	2.55E-01	1.01E-03	Ci
Cl	3.24E+02	2.22E+00	Kg		^{125}Sb	7.71E-02	1.31E-06	Ci
CN	not reported	4.39E-01	Kg		^{126}Sn	1.04E-02	1.60E-04	Ci
Cr	8.88E+01	1.46E+00	Kg		^{129}I	3.24E-02	1.56E-05	Ci
F	9.27E+02	2.54E+02	Kg		^{134}Cs	4.10E-04	3.80E-10	Ci
Fe	1.45E+04	2.69E+02	Kg		^{137}Cs	1.98E+04	1.61E+02	Ci
Hg	4.75E+01	7.19E-02	Kg		^{137m}Ba	1.86E+04	1.52E+02	Ci
K	2.42E+02	1.79E+00	Kg		^{151}Sm	7.67E+02	2.83E+00	Ci
La	1.15E+02	1.38E+00	Kg		^{152}Eu	1.23E-01	5.50E-05	Ci
Mn	8.81E+01	1.34E+00	Kg		^{154}Eu	8.86E+00	2.65E-03	Ci
Na	1.38E+04	4.96E+03	Kg		^{155}Eu	3.87E+00	5.39E-04	Ci
Ni	5.36E+03	1.58E+02	Kg		^{226}Ra	9.73E-06	1.93E-07	Ci
NO_2	1.06E+04	2.96E+01	Kg		^{227}Ac	4.83E-05	4.93E-06	Ci
NO_3	2.05E+04	6.12E+01	Kg		^{228}Ra	4.62E-11	2.85E-06	Ci
Oxalate	2.02E+02	5.41E+00	Kg		^{229}Th	5.94E-09	6.11E-10	Ci
Pb	1.53E+03	6.85E+01	Kg		^{231}Pa	7.71E-05	1.23E-05	Ci
PO_4	1.93E+04	4.94E+03	Kg		^{232}Th	4.78E-11	2.85E-06	Ci
Si	2.44E+03	9.11E+01	Kg		^{232}U	4.44E-05	7.28E-08	Ci
SO_4	1.58E+03	1.47E+01	Kg		^{233}U	4.91E-05	6.79E-09	Ci
Sr	6.21E+01	2.06E+00	Kg		^{234}U	1.51E+00	6.55E-03	Ci
TIC as CO_3	7.36E+03	1.80E+02	Kg		^{235}U	6.59E-02	2.84E-04	Ci
TOC	2.58E+02	1.60E+01	Kg		^{236}U	2.47E-02	2.30E-04	Ci
U_{TOTAL}	4.64E+03	2.00E+01	Kg		^{237}Np	6.31E-03	1.31E-03	Ci

Table A-1. Single-Shell Tank 241-C-111 Best-Basis Inventory Pre-Retrieval Inventory and Post-Sluicing Operations. (2 sheets)

Constituent Name	BBI February 2005[a]	BBI June 2015[b]			Constituent Name	BBI February 2005[a]	BBI June 2015[b]	
Analyte	Inventory	Inventory	Unit		Analyte	Inventory	Inventory	Unit
Zr	5.72E+01	1.07E+00	Kg		^{238}Pu	3.07E+00	8.73E-02	Ci
^{3}H	1.46E+01	6.00E-03	Ci		^{238}U	1.54E+00	6.68E-03	Ci
^{14}C	2.12E-01	3.90E-03	Ci		^{239}Pu	1.67E+02	7.62E-01	Ci
^{59}Ni	3.07E+00	3.80E-04	Ci		^{240}Pu	3.25E+01	8.29E-02	Ci
^{60}Co	1.29E+00	5.34E-04	Ci		^{241}Am	1.90E+02	7.79E+00	Ci
^{63}Ni	2.75E+02	3.55E+00	Ci		^{241}Pu	1.26E+02	8.02E-02	Ci
^{79}Se	2.68E-03	8.73E-05	Ci		^{242}Cm	9.07E-02	3.24E-02	Ci
^{90}Sr	9.07E+05	4.53E+04	Ci		^{242}Pu	1.07E-03	1.15E-06	Ci
^{90}Y	9.07E+05	4.53E+04	Ci		^{243}Am	2.54E-02	7.90E-04	Ci
^{93m}Nb	1.95E-01	4.70E-02	Ci		^{243}Cm	2.93E-03	6.80E-03	Ci
^{93}Zr	2.19E-01	4.99E-02	Ci		^{244}Cm	6.61E-02	1.30E-01	Ci

BBI = Best-Basis Inventory TIC = total inorganic carbon TOC = total organic carbon

[a] RPP-37739, 2013, "*241-C-111 Tank Waste Retrieval Work Plan*," Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

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APPENDIX B

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR TANK 241-C-111 RESIDUAL SOLIDS

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APPENDIX B

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR TANK 241-C-111 RESIDUAL SOLIDS

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-C-111 Residual Solids. (4 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration*	Units	RSD†
1,1,1-Trichloroethane	71-55-6	<	9.16E-04	µg/g	1.00E+00
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	<	1.16E-03	µg/g	1.00E+00
1,1,2-Trichloroethane	79-00-5	<	1.65E-03	µg/g	1.00E+00
1,1-Dichloroethene	75-35-4	<	4.21E-03	µg/g	1.00E+00
1,2,4-Trichlorobenzene	120-82-1	<	1.93E-03	µg/g	1.00E+00
1,2-Dichlorobenzene	95-50-1	<	1.21E-03	µg/g	1.00E+00
1,2-Dichloroethane	107-06-2	<	5.35E-04	µg/g	1.00E+00
1,4-Dichlorobenzene	106-46-7	<	8.92E-04	µg/g	1.00E+00
^{125}Sb	14234-35-6	<	6.04E-01	µCi/g	1.00E+00
^{126}Sn	15832-50-5	<	5.42E-04	µCi/g	1.00E+00
^{129}I	15046-84-1	<	5.62E-05	µCi/g	1.00E+00
^{137}Cs	10045-97-3	—	6.23E+00	µCi/g	5.85E-01
^{137m}Ba	N/A	—	5.88E+00	µCi/g	5.85E-01
^{14}C	14762-75-5	<	1.50E-04	µCi/g	1.00E+00
^{152}Eu	14683-23-9	<	5.07E-01	µCi/g	1.00E+00
^{154}Eu	15585-10-1	<	4.86E-01	µCi/g	1.00E+00
^{155}Eu	14391-16-3	<	8.67E-01	µCi/g	1.00E+00
1-Butanol	71-36-3	<	1.02E-01	µg/g	1.00E+00
2,4,5-Trichlorophenol	95-95-4	<	4.17E-01	µg/g	1.00E+00
2,4,6-Trichlorophenol	88-06-2	<	5.83E-01	µg/g	1.00E+00
2,4-Dinitrotoluene	121-14-2	<	3.23E-01	µg/g	1.00E+00
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	128-37-0	<	7.91E-01	µg/g	1.00E+00
^{228}Th	14274-82-9	<	2.34E-04	µCi/g	1.00E+00
^{230}Th	14269-63-7	<	4.88E-03	µCi/g	1.00E+00
^{231}Pa	14331-85-2	<	1.12E-02	µCi/g	1.00E+00
^{232}Th	N/A	—	1.10E-07	µCi/g	6.97E-01
^{233}U	13968-55-3	<	2.28E-04	µCi/g	1.00E+00
^{234}U	13966-29-5	<	8.28E-04	µCi/g	1.00E+00
^{235}U	15117-96-1	—	1.10E-05	µCi/g	6.92E-01
^{236}U	13982-70-2	—	8.89E-06	µCi/g	7.96E-01
^{237}Np	13994-20-2	—	5.05E-05	µCi/g	5.68E-01
^{238}Pu	13981-16-3	—	3.37E-03	µCi/g	4.11E-01
^{238}U	N/A	—	2.58E-04	µCi/g	6.97E-01
^{239}Pu	15117-48-3	<	2.94E-02	µCi/g	1.00E+00
^{240}Pu	14119-33-6	<	3.20E-03	µCi/g	1.00E+00
^{241}Am	14596-10-2	—	3.01E-01	µCi/g	4.82E-01
^{241}Pu	14119-32-5	<	2.76E-02	µCi/g	1.00E+00
^{242}Cm	15510-73-3	—	1.25E-03	µCi/g	1.40E-01
^{242}Pu	13982-10-0	<	1.21E-03	µCi/g	1.00E+00
^{243}Cm	15757-87-6	—	2.63E-04	µCi/g	4.82E-01
^{244}Cm	13981-15-2	—	5.00E-03	µCi/g	4.82E-01
2-Butanone	78-93-3	<	3.95E-02	µg/g	1.00E+00

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-C-111 Residual Solids. (4 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration*	Units	RSD†
2-Chlorophenol	95-57-8	<	4.94E-01	µg/g	1.00E+00
2-Ethoxyethanol	110-80-5	<	6.39E-01	µg/g	1.00E+00
2-Methylphenol	95-48-7	<	3.73E-01	µg/g	1.00E+00
2-Nitrophenol	88-75-5	<	6.27E-01	µg/g	1.00E+00
2-Nitropropane	79-46-9	<	5.85E-03	µg/g	1.00E+00
^{3}H	15086-10-9	<	2.51E-03	µCi/g	1.00E+00
4-Chloro-3-methylphenol	59-50-7	<	5.01E-01	µg/g	1.00E+00
4-Methyl-2-Pentanone	108-10-1	<	1.70E-02	µg/g	1.00E+00
4-Nitrophenol	100-02-7	<	5.28E-01	µg/g	1.00E+00
^{60}Co	10198-40-0	<	1.91E-01	µCi/g	1.00E+00
^{63}Ni	13981-37-8	—	1.37E-01	µCi/g	3.69E-01
^{79}Se	15758-45-9	<	2.15E-04	µCi/g	1.00E+00
^{90}Sr	10098-97-2	—	1.75E+03	µCi/g	7.14E-01
^{90}Y	10098-91-6	—	1.75E+03	µCi/g	7.14E-01
^{99}Tc	14133-76-7	—	1.92E-03	µCi/g	4.89E-01
Acenaphthene	83-32-9	<	4.38E-01	µg/g	1.00E+00
Acetate	71-50-1	—	1.93E+02	µg/g	3.10E-01
Acetone	67-64-1	<	1.29E-01	µg/g	1.00E+00
Ag	7440-22-4	—	1.96E+02	µg/g	8.38E-01
Al	7429-90-5	—	8.04E+04	µg/g	4.42E-01
Aroclors (Total PCB)	1336-36-3	<	1.14E-02	µg/g	1.00E+00
As	7440-38-2	<	3.18E+01	µg/g	1.00E+00
B	7440-42-8	<	4.24E+00	µg/g	1.00E+00
Ba	7440-39-3	—	1.44E+01	µg/g	4.49E-01
Be	7440-41-7	<	2.12E+00	µg/g	1.00E+00
Benzene	71-43-2	<	1.47E-03	µg/g	1.00E+00
Benzo(a)pyrene	50-32-8	<	6.64E-01	µg/g	1.00E+00
Bi	7440-69-9	—	2.94E+02	µg/g	2.49E-01
Bis(2-ethylhexyl)phthalate	117-81-7	—	3.79E+00	µg/g	1.73E-01
Br	24959-67-9	<	7.14E+01	µg/g	1.00E+00
Butylbenzylphthalate	85-68-7	—	1.98E+00	µg/g	8.05E-02
Ca	7440-70-2	—	3.58E+03	µg/g	8.48E-01
Carbon disulfide	75-15-0	<	1.60E-03	µg/g	1.00E+00
Carbon tetrachloride	56-23-5	<	9.29E-04	µg/g	1.00E+00
Cd	7440-43-9	<	3.34E+00	µg/g	1.00E+00
Ce	7440-45-1	—	2.00E+02	µg/g	1.98E-01
Chlorobenzene	108-90-7	<	8.60E-04	µg/g	1.00E+00
Chloroform	67-66-3	<	1.30E-03	µg/g	1.00E+00
Cl	16887-00-6	<	8.56E+01	µg/g	1.00E+00
CN	57-12-5	—	1.69E+01	µg/g	6.15E-01
Co	7440-48-4	<	2.94E+00	µg/g	1.00E+00
Cr	7440-47-3	—	5.65E+01	µg/g	4.10E-01
Cresol (m & p)	1319-77-3	<	4.71E-01	µg/g	1.00E+00
Cu	7440-50-8	—	1.92E+01	µg/g	2.99E-01
Cyclohexanone	108-94-1	<	6.16E-01	µg/g	1.00E+00
Dibenz[a,h]anthracene	N/A	<	3.16E-01	µg/g	1.00E+00
Diethylphthalate	84-66-2	<	5.84E-01	µg/g	1.00E+00
Di-n-butylphthalate	84-74-2	<	1.90E+00	µg/g	1.00E+00

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-C-111 Residual Solids. (4 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration*	Units	RSD†
Di-n-octylphthalate	117-84-0	<	3.89E-01	µg/g	1.00E+00
Diphenyl amine	122-39-4	<	3.02E-01	µg/g	1.00E+00
Ethyl acetate	141-78-6	<	5.84E-03	µg/g	1.00E+00
Ethyl ether	60-29-7	<	2.55E-03	µg/g	1.00E+00
Ethylbenzene	100-41-4	<	1.07E-03	µg/g	1.00E+00
Eu	7440-53-1	<	2.38E+00	µg/g	1.00E+00
F	16984-48-8	—	9.82E+03	µg/g	6.67E-02
Fe	7439-89-6	—	1.04E+04	µg/g	4.04E-01
Fluoranthene	206-44-0	<	1.72E+00	µg/g	1.00E+00
Formate	12311-97-6	<	2.39E+02	µg/g	1.00E+00
Free OH	N/A	—	2.42E+02	µg/g	6.06E-01
Glycolate	666-14-8	<	7.61E+01	µg/g	1.00E+00
Hexachlorobenzene	118-74-1	<	2.84E-01	µg/g	1.00E+00
Hexachlorobutadiene	87-68-3	<	5.70E-01	µg/g	1.00E+00
Hexachloroethane	67-72-1	<	1.40E-03	µg/g	1.00E+00
Hg	7439-97-6	—	2.78E+00	µg/g	3.96E-01
Isobutanol	78-83-1	<	6.92E+00	µg/g	1.00E+00
K	7440-09-7	<	6.89E+01	µg/g	1.00E+00
La	7439-91-0	—	5.33E+01	µg/g	3.89E-01
Li	7439-93-2	<	2.64E+00	µg/g	1.00E+00
Methylenechloride	75-09-2	<	6.37E-04	µg/g	1.00E+00
Mg	7439-95-4	—	1.09E+02	µg/g	7.62E-01
Mn	7439-96-5	—	5.19E+01	µg/g	4.73E-01
Mo	7439-98-7	<	4.48E+00	µg/g	1.00E+00
Morpholine, 4-nitroso-	59-89-2	<	5.67E-01	µg/g	1.00E+00
Na	7440-23-5	—	1.92E+05	µg/g	7.69E-02
Naphthalene	91-20-3	<	4.80E-01	µg/g	1.00E+00
Nb	7440-03-1	<	1.27E+01	µg/g	1.00E+00
Nd	7440-00-8	—	9.27E+01	µg/g	3.70E-01
NH_3	7664-41-7	—	2.91E+00	µg/g	3.82E-01
Ni	7440-02-0	—	6.11E+03	µg/g	4.57E-01
Nitrobenzene	98-95-3	<	4.89E-01	µg/g	1.00E+00
N-Nitrosodimethylamine	62-75-9	<	5.28E-01	µg/g	1.00E+00
N-Nitroso-di-n-propylamine	621-64-7	<	5.10E-01	µg/g	1.00E+00
NO_2	14797-65-0	—	1.14E+03	µg/g	7.45E-01
NO_3	14797-55-8	—	2.36E+03	µg/g	7.68E-01
Oxalate	338-70-5	<	2.09E+02	µg/g	1.00E+00
Pb	7439-92-1	—	2.65E+03	µg/g	5.14E-01
Pd	7440-05-3	<	2.55E+01	µg/g	1.00E+00
Pentachlorophenol	87-86-5	<	2.88E-01	µg/g	1.00E+00
Phenol	108-95-2	<	5.14E-01	µg/g	1.00E+00
PO_4	14265-44-2	—	1.91E+05	µg/g	1.11E-01
Pr	7440-10-0	<	5.63E+01	µg/g	1.00E+00
Pyrene	129-00-0	<	9.61E-01	µg/g	1.00E+00
Pyridine	110-86-1	<	6.34E-01	µg/g	1.00E+00
Rb	7440-17-7	<	1.21E+02	µg/g	1.00E+00
Rh	7440-16-6	<	2.55E+01	µg/g	1.00E+00
Ru	7440-18-8	<	1.06E+01	µg/g	1.00E+00

Table B-1. Mean Concentrations and Relative Standard Deviations for Selected Constituents in Tank 241-C-111 Residual Solids. (4 sheets)

Constituent Name	CAS Number	< Detection Limit	Mean Concentration*	Units	RSD†
Sb	7440-36-0	<	3.82E+01	µg/g	1.00E+00
Se	7782-49-2	<	6.37E+01	µg/g	1.00E+00
Si	7440-21-3	—	3.52E+03	µg/g	3.11E-01
Sm	7440-19-9	—	5.68E+01	µg/g	2.22E-01
Sn	7440-31-5	<	1.70E+01	µg/g	1.00E+00
SO_4	14808-79-8	—	5.69E+02	µg/g	3.81E-01
Sr	7440-24-6	—	7.97E+01	µg/g	4.93E-01
Ta	7440-25-7	<	1.08E+01	µg/g	1.00E+00
Te	13494-80-9	<	1.91E+01	µg/g	1.00E+00
Tetrachloroethene	127-18-4	<	1.09E-03	µg/g	1.00E+00
Th	7440-29-1	—	1.00E+00	µg/g	6.97E-01
Thiosulfate	14383-50-7	<	1.24E+02	µg/g	1.00E+00
Ti	7440-32-6	—	4.17E+01	µg/g	9.04E-01
Tl	7440-28-0	<	3.18E+01	µg/g	1.00E+00
Toluene	108-88-3	<	7.98E-04	µg/g	1.00E+00
Trans-1,3-Dichloropropene	10061-02-6	<	2.70E-03	µg/g	1.00E+00
Tributyl phosphate	126-73-8	—	1.26E+00	µg/g	3.44E-01
Trichloroethene	79-01-6	<	1.20E-03	µg/g	1.00E+00
Trichlorofluoromethane	75-69-4	<	9.35E-04	µg/g	1.00E+00
U	7440-61-1	—	7.73E+02	µg/g	6.97E-01
V	7440-62-2	—	7.21E+00	µg/g	1.70E-01
Vinyl chloride	75-01-4	<	1.73E-03	µg/g	1.00E+00
W	7440-33-7	<	3.40E+01	µg/g	1.00E+00
Xylene (m & p)	108-28-3M	<	1.67E-03	µg/g	1.00E+00
Xylene (o)	95-47-6	<	9.16E-04	µg/g	1.00E+00
Xylenes (total)	1330-20-7	<	4.04E-04	µg/g	1.00E+00
Y	7440-65-5	—	9.23E+00	µg/g	2.96E-01
Zn	7440-66-6	<	7.64E+01	µg/g	1.00E+00
Zr	7440-67-7	—	4.12E+01	µg/g	4.18E-01

µCi/g = microcurie per gram CAS = Chemical Abstract Services RSD = Relative Standard Deviation
µg/g = micrograms per gram NA = not available

* Radionuclide concentrations are decay corrected to July 1, 2015.
† In accordance with Best-Basis Inventory protocol (RPP-7625, 2015, "*Guidelines for Updating Best-Basis Inventory*," Rev. 12. Washington River Protection Solutions. LLC, Richland, Washington), the relative standard deviation is assumed to be 1.00 if the constituent was not detected.

APPENDIX C

COMPARISON OF SINGLE-SHELL TANK 241-C-111 FINAL INVENTORY TO SINGLE-SHELL TANK 241-C-111 INVENTORY USED IN DOE/ORP-2005-01, INITIAL SINGLE-SHELL TANK SYSTEM PERFORMANCE ASSESSMENT FOR THE HANFORD SITE

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APPENDIX C

COMPARISON OF SINGLE-SHELL TANK 241-C-111 FINAL INVENTORY TO SINGLE-SHELL TANK 241-C-111 INVENTORY USED IN DOE/ORP-2005-01, INITIAL SINGLE-SHELL TANK SYSTEM PERFORMANCE ASSESSMENT FOR THE HANFORD SITE

Table C-1. Comparison of Single-Shell Tank 241-C-111 Final Inventory to Single-Shell Tank 241-C-111 Inventory Used in DOE/ORP-2005-01.

Analyte	Units	DOE/ORP-2005-01, Rev. 0	RPP-RPT-59714, Average Inventory	RPP-RPT-59714, Upper Bounding Inventory
Tritium	Ci	6.36E-01	6.51E-02	1.97E-01
C-14	Ci	9.25E-03	3.90E-03	1.18E-02
I-129	Ci	1.41E-03	1.46E-03	4.41E-03
Tc-99	Ci	1.12E-01	4.97E-02	1.00E-01
Cr	kg	9.68E-01	1.46E+00	2.73E+00
F	kg	4.04E+01	2.54E+02	3.33E+02
NO_2	kg	4.64E+02	2.96E+01	7.45E+01
NO_3	kg	8.96E+02	6.12E+01	1.57E+02
U	kg	0.00E+00	2.00E+01	4.84E+01

References:

DOE/ORP-2005-01, 2006, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*, Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.

RPP-RPT-59714, 2017, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

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APPENDIX D

RISK ASSESSMENT INFORMATION FOR RESIDUAL WASTES REMAINING IN SINGLE-SHELL TANK 241-C-111

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APPENDIX D

RISK ASSESSMENT INFORMATION FOR RESIDUAL WASTES REMAINING IN SINGLE-SHELL TANK 241-C-111

This appendix provides risk assessment information related to post-retrieval inventories estimated to remain in single-shell tank (SST) 241-C-111 (C-111). The potential risk impacts to human health posed by the residual waste in SST C-111 were evaluated using the methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*. The process used for the SST C-111 risk assessment, and this methodology, is described in detail in Chapter 3 of DOE/ORP-2005-01. The SST performance assessment methodology represents the current approach being used to support the assessment of long-term impacts to human health from tank residuals left in individual SSTs in retrieval data reports. Decisions on final closure of tank C-111, all other SSTs, and ancillary facilities and equipment within Waste Management Area C will be supported by a site-specific performance assessment as outlined in Appendix I of the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989).

The risk assessment-related information for post-retrieval inventories estimated to remain in SST C-111 and contained in this appendix are as follows:

- Summary of incremental lifetime cancer risk, radiological dose, and drinking water dose for radionuclide contaminants of potential concern estimated in the average post-retrieval inventory for SST C-111 (see Table D-1)

- Summary of maximum value for incremental lifetime cancer risk and hazard index for nonradionuclide contaminants of potential concern estimated in the average post-retrieval inventory for SST C-111 (see Table D-2)

- Summary of incremental lifetime cancer risk, radiological dose, and drinking water dose for radionuclide contaminants of potential concern estimated in the 95% upper confidence level (UCL) post-retrieval inventory for SST C-111 (see Table D-3)

- Summary of maximum value for incremental lifetime cancer risk and hazard index for nonradionuclide contaminants of potential concern estimated in the 95% UCL post-retrieval inventory for SST C-111 (see Table D-4)

- Tables and plots of doses from a well driller scenario for radioactive contaminants of concern found within the average and 95% UCL inventory estimated for SST C-111 (see Table D-5 and Figure D-1)

- Tables and plots of doses from a rural pasture scenario for radioactive contaminants of concern found within the average and 95% UCL inventories estimated for SST C-111 (see Table D-6 and Figure D-2)

- Tables and plots of doses from a suburban gardener scenario for radioactive contaminants of concern found within the average and 95% UCL inventories estimated for SST C-111 (see Table D-7 and Figure D-3)

- Tables and plots of doses from a commercial farm scenario for radioactive contaminants of concern found within the average and 95% UCL inventories estimated for SST C-111 (see Table D-8 and Figure D-4).

Table D-9 provides a comparison of the average and 95% UCL concentrations for waste residuals within tank C-111 against *Washington Administrative Code* 173-340, "Model Toxics Control Act—Cleanup" cleanup levels for soil direct contact unrestricted land use (Method B), industrial land use (Method C), and soil concentrations protective of groundwater.

Tables D-10 and D-11 provide additional risk management information related to (average and 95% UCL) concentrations of constituents remaining in waste residuals within tank C-111 compared against the *Washington Administrative Code* 173-340 cleanup standards. See Section 5.5 for additional discussion.

Table D-12 provides information on background concentration levels at the Hanford Site that have been developed for selected constituents. This is provided to bring additional perspective in the concentration levels of constituents remaining in residual wastes within tank C-111.

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65 FR 76708, 2000, "National Primary Drinking Water Regulations; Radionuclides; Final Rule," *Federal Register*, Vol. 65, pp. 76708–76753 (December 7).

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WAC 173-303-9905, "Dangerous Waste Constituents List," *Washington Administrative Code*, as amended.

WAC 173-340, "Model Toxics Control Act—Cleanup," *Washington Administrative Code*, as amended.

WAC 173-340-705, "Use of Method B," *Washington Administrative Code*, as amended.

Table D-1. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose per Radionuclide Contaminant of Potential Concern for the Average Inventory for Single-Shell Tank 241-C-111. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose – Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Americium-241	Yes	7.79E+00	0.00E+00	DNA	3.00E+00	4.33E+02	NE	NE	NE	NE
Antimony-125*	No	7.85E+00	0.00E+00	DNA	1.00E+00	2.73E+00	NE	NE	NE	NE
Barium-137m*	Yes	1.52E+02	0.00E+00	DNA	0.00E+00	4.86E-06	NE	NE	NE	NE
Carbon-14	No	1 95E-03	3.00E-03	9.78E+03	0.00E+00	5.73E+03	2.33E-11	1.69E-10	1.46E-05	6.01E-06
Cesium-137 + Daughters	Yes	1.61E+02	0.00E+00	DNA	2.50E+01	3.00E+01	NE	NE	NE	NE
Cobalt-60	No	2.47E+00	0.00E+00	DNA	1.00E-01	5.27E+00	NE	NE	NE	NE
Curium-242	Yes	3.24E-02	0.00E+00	DNA	3.00E+00	4.46E-01	NE	NE	NE	NE
Curium-243	Yes	6.80E-03	0.00E+00	DNA	3.00E+00	2.85E+01	NE	NE	NE	NE
Curium-244	Yes	1.30E-01	0.00E+00	DNA	3.00E+00	1.81E+01	NE	NE	NE	NE
Europium-152	No	6.55E+00	0.00E+00	DNA	1.00E+00	1.33E+01	NE	NE	NE	NE
Europium-154	No	6.30E+00	0.00E+00	DNA	1.00E+00	8.59E+00	NE	NE	NE	NE
Europium-155	No	1.12E+01	0.00E+00	DNA	1.00E+00	4.68E+00	NE	NE	NE	NE
Iodine-129	No	7.30E-04	<1.00E-03	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
Neptunium-237 + D	Yes	1.31E-03	0.00E+00	DNA	2.00E+00	2.14E+06	NE	NE	NE	NE
Nickel-63*	Yes	3.55E+00	0.00E+00	DNA	4.80E+01	1.00E+02	NE	NE	NE	NE
Plutonium-238	Yes	8.73E-02	0.00E+00	DNA	3.00E+00	8.77E+01	NE	NE	NE	NE
Plutonium-239	No	3.81E-01	0.00E+00	DNA	3.00E+00	2.41E+04	NE	NE	NE	NE

Table D-1. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose per Radionuclide Contaminant of Potential Concern for the Average Inventory for Single-Shell Tank 241-C-111. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose – Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Plutonium-240	No	4.15E-02	0.00E+00	DNA	3.00E+00	6.56E+03	NE	NE	NE	NE
Plutonium-241 + D	No	3.57E-01	0.00E+00	DNA	3.00E+00	1.44E+01	NE	NE	NE	NE
Plutonium-242	No	1.58E-02	0.00E+00	DNA	3.00E+00	3.74E+05	NE	NE	NE	NE
Protactinium-231	No	1.45E-01	0.00E+00	DNA	5.50E+02	3.28E+04	NE	NE	NE	NE
Selenium-79*	No	2.78E-03	0.00E+00	DNA	3.10E+00	8.05E+05	NE	NE	NE	NE
Strontium-90 + D	Yes	4.53E+04	0.00E+00	DNA	1.61E+01	2.81E+01	NE	NE	NE	NE
Technetium-99	Yes	4.97E-02	1.98E-01	1.05E+04	0.00E+00	2.11E+05	2.73E-09	6.66E-08	3.48E-04	8.82E-04
Thorium-228 + D	No	3.04E-03	0.00E+00	DNA	3.00E+00	1.91E+00	NE	NE	NE	NE
Thorium-230	No	6.30E-02	0.00E+00	DNA	3.00E+00	7.54E+04	NE	NE	NE	NE
Thorium-232	Yes	2.85E-06	0.00E+00	DNA	3.00E+00	1.41E+10	NE	NE	NE	NE
Tin-126	No	7.00E-03	0.00E+00	DNA	1.00E+00	2.46E+05	NE	NE	NE	NE
Tritium	No	3.26E-02	0.00E+00	DNA	0.00E+00	1.23E+01	NE	NE	NE	NE
Uranium-233	No	2.96E-03	0.00E+00	DNA	6.00E-01	1.59E+05	NE	NE	NE	NE
Uranium-234	No	1.08E-02	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	NE
Uranium-235 + D	Yes	2.84E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	NE
Uranium-236	Yes	2.30E-04	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	NE
Uranium-238 + D	Yes	6.68E-03	0.00E+00	DNA	6.00E-01	4.47E+09	NE	NE	NE	NE

Table D-1. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose per Radionuclide Contaminant of Potential Concern for the Average Inventory for Single-Shell Tank 241-C-111. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose – Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Yttrium-90	Yes	4.53E+04	0.00E+00	DNA	0.00E+00	7.31E-03	NE	NE	NE	NE
Performance Objectives[c]							**1-0E-6 to 1.0E-4[d]**	**1-0E-6 to 1.0E-4[d]**	**25[e]**	**4[f]**

[a] See PNNL-13895, "*Hanford Contaminant Distribution Coefficient Database and Users Guide*," Rev. 1, and Section 4 3 of PNNL-14702, "*Vadose Zone Hydrogeology Data Package for Hanford Assessments*" for the basis for the K_d values listed for the radionuclides.

[b] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*.

[c] Performance objectives apply to the cumulative (i.e., all contaminants) for the entire waste management area.

[d] EPA 540/R/99/006, *Radiation Risk Assessment At CERCLA Sites: Q & A*, Directive 9200.4-31P.

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

[f] 65 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

DNA = Did not arrive at fenceline within the 10,000-year modeling period.
N/A = Radionuclide is not a beta/photon emitter.
NE = Incremental cancer risk for industrial and residential scenarios or radiological dose evaluated for the all-pathways farmer and drinking water only scenarios not evaluated because radiological constituent had no estimated initial inventory or did not arrive in concentrations greater than at the fenceline within the 10,000-year modeling period. In the Decision Management Tool (DMT) that is used to implement the calculational methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* for this Retrieval Data Report, calculated concentrations less than 1.00E-21 pCi/L are considered to be effectively zero. This risk metric may have also not been calculated because the radioactive analyte was predicted to have a concentration less than 0.001 pCi/L, which is well below the ability of standard laboratory analytical methods to detect it.

*Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List."

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern Using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-111. (4 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
1, 1, 2-Trichloroethylene	No	1.56E-05	<1.00E-03	1.20E+04	2.82E-02	NE	NE
1, 4-Dichlorobenzene	No	1.16E-05	<1.00E-03	1.20E+04	1.85E-01	NE	NE
2-Butanone (MEK)	No	5.10E-04	<1.00E-03	1.05E+04	1.35E-03	NE	NE
2-Propanone (Acetone)	No	1.68E-03	<1.00E-03	1.05E+04	1.73E-04	NE	NE
4-Methyl-2-pentanone (MIBK)	No	2.20E-04	<1.00E-03	1.20E+04	4.02E-02	NE	NE
Acetate	Yes	5.01E+00	2.06E-02	1.05E+04	3.00E-04	No CPF	No Rfd
Aluminum	Yes	2.08E+03	0.00E+00	DNA	1.00E+00	NE	NE
Ammonia	Yes	7.54E-02	<1.00E-03	1.05E+04	9.30E-04	NE	NE
Antimony[a]	No	4.95E-01	0.00E+00	DNA	1.00E+00	NE	NE
Arsenic[a]	No	4.13E-01	0.00E+00	DNA	3.90E+01	NE	NE
Barium[a]	Yes	3.72E-01	0.00E+00	DNA	6.00E+01	NE	NE
Benzo[a]pyrene[a]	No	8.60E-03	0.00E+00	DNA	2.86E+02	NE	NE
Beryllium[a]	No	2.75E-02	0.00E+00	DNA	7.00E+01	NE	NE
Bismuth	Yes	7.62E+00	3.13E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Boron	No	5.50E-02	0.00E+00	DNA	3.00E+00	NE	NE
Bromide	No	9.25E-01	3.80E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Butylbenzylphthalate[a]	Yes	5.13E-02	0.00E+00	DNA	4.14E+00	NE	NE
Cadmium[a]	No	4.33E-02	0.00E+00	DNA	1.26E+00	NE	NE
Calcium	Yes	9.27E+01	0.00E+00	DNA	4.00E+00	NE	NE
Cerium	Yes	5.17E+00	2.12E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Chloride	No	1.11E+00	4.56E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Chromium, Total[a]	Yes	1.46E+00	5.99E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Cobalt	No	3.81E-02	<1.00E-03	1.20E+04	1.00E-01	NE	NE
Copper	Yes	4.97E-01	0.00E+00	DNA	3.50E+01	NE	NE
Cyanide[a]	Yes	4.39E-01	0.00E+00	DNA	9.90E+00	NE	NE
Di (2-ethylhexyl) phthalate (DEHP)	Yes	9.82E-02	0.00E+00	DNA	2.62E+01	NE	NE

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern Using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-111. (4 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Dibenz[a, h]anthracene[a]	No	4.09E-03	0.00E+00	DNA	5.72E+02	NE	NE
Diethyl phthalate[a]	No	7.55E-03	<1.00E-03	1.20E+04	2.07E-02	NE	NE
Di-n-butylphthalate[a]	No	2.47E-02	0.00E+00	DNA	1.89E+00	NE	NE
Europium	No	3.08E-02	0.00E+00	DNA	5.00E+01	NE	NE
Fluoride	Yes	2.54E+02	1.04E+00	1.05E+04	0.00E+00	No CPF	1.09E-03
Formate+A2	No	3.10E+00	1.27E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Glycolate C2H3O3	No	9.85E-01	4.04E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Hexachlorobenzene[a]	No	3.68E-03	0.00E+00	DNA	8.46E+00	NE	NE
Hydroxide OH	Yes	6.28E+00	2.58E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Iron	Yes	2.69E+02	0.00E+00	DNA	2.50E+01	NE	NE
Lanthanum	Yes	1.38E+00	5.67E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Lead[a]	Yes	6.85E+01	0.00E+00	DNA	5.20E+00	NE	NE
Lithium	No	3.42E-02	0.00E+00	DNA	3.00E+02	NE	NE
Magnesium	Yes	2.83E+00	0.00E+00	DNA	4.50E+00	NE	NE
Manganese	Yes	1.34E+00	0.00E+00	DNA	1.00E+00	NE	NE
Mercury[a]	Yes	7.19E-02	0.00E+00	DNA	5.20E+00	NE	NE
Molybdenum	No	5.80E-02	0.00E+00	DNA	4.00E+00	NE	NE
m-Xylene	No	2.16E-05	<1.00E-03	1.20E+04	5.88E-02	NE	NE
N, N-Diphenylamine[a]	No	3.91E-03	<1.00E-03	1.20E+04	5.73E-01	NE	NE
Neodymium	Yes	2.40E+00	9.85E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Nickel[a]	Yes	1.58E+02	0.00E+00	DNA	4.80E+01	NE	NE
Niobium	No	1.65E-01	0.00E+00	DNA	1.00E+02	NE	NE
Nitrate	Yes	6.12E+01	2.51E-01	1.05E+04	0.00E+00	No CPF	9.81E-06
Nitrite	Yes	2.96E+01	1.22E-01	1.05E+04	0.00E+00	No CPF	7.60E-05
N-Nitroso-N, N-dimethylamine[a]	No	6.85E-03	<1.00E-03	1.05E+04	3.60E-03	NE	NE
Oxalate	No	2.71E+00	1.11E-02	1.05E+04	0.00E+00	No CPF	No Rfd

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern Using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-111. (4 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
o-Xylene	No	1.19E-05	<1.00E-03	1.20E+04	7.23E-02	NE	NE
Palladium	No	3.30E-01	0.00E+00	DNA	5.00E+01	NE	NE
Pentachlorophenol[a]	No	3.73E-03	<1.00E-03	1.20E+04	1.77E-01	NE	NE
Phenol[a]	No	6.65E-03	<1.00E-03	1.05E+04	8.64E-03	NE	NE
Phosphate	Yes	4.94E+03	2.03E+01	1.05E+04	0.00E+00	No CPF	No Rfd
Polychlorinated Biphenyls[a]	No	1.48E-04	0.00E+00	DNA	9.27E+01	NE	NE
Potassium	No	8.95E-01	3.67E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Praseodymium	No	7.30E-01	3.00E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Rhodium	No	3.30E-01	1.35E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Rubidium	No	1.57E+00	6.43E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Ruthenium	No	1.38E-01	0.00E+00	DNA	1.00E+00	NE	NE
Samarium	Yes	1.47E+00	0.00E+00	DNA	1.00E+00	NE	NE
Selenium[a]	No	8.25E-01	0.00E+00	DNA	5.00E+00	NE	NE
Silicon	Yes	9.11E+01	0.00E+00	DNA	3.00E+01	NE	NE
Silver[a]	Yes	5.07E+00	0.00E+00	DNA	2.70E+00	NE	NE
Sodium	Yes	4.96E+03	2.04E+01	1.05E+04	0.00E+00	No CPF	No Rfd
Strontium	Yes	2.06E+00	0.00E+00	DNA	1.61E+01	NE	NE
Sulfate	Yes	1.47E+01	6.03E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Tantalum	No	1.41E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Tellurium	No	2.48E-01	1.02E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Thallium[a]	No	4.13E-01	0.00E+00	DNA	7.10E+01	NE	NE
Thorium	Yes	2.59E-02	0.00E+00	DNA	1.00E+00	NE	NE
Tin	No	2.20E-01	0.00E+00	DNA	2.50E+02	NE	NE
Titanium	Yes	1.08E+00	0.00E+00	DNA	1.00E+03	NE	NE
Toluene	No	1.04E-05	<1.00E-03	1.20E+04	4.20E-02	NE	NE
Tributyl phosphate	Yes	3.25E-02	<1.00E-03	1.20E+04	5.67E-01	NE	NE
Tungsten	No	4.40E-01	1.81E-03	1.05E+04	0.00E+00	No CPF	No Rfd

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern Using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-111. (4 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Uranium	Yes	2.00E+01	0.00E+00	DNA	6.00E-01	NE	NE
Vanadium	Yes	1.87E-01	0.00E+00	DNA	5.00E+01	NE	NE
Xylenes	No	5.25E-06	<1.00E-03	1.20E+04	5.88E-02	NE	NE
Yttrium	Yes	2.39E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Zinc	No	9.90E-01	0.00E+00	DNA	6.20E+01	NE	NE
Zirconium	Yes	1.07E+00	0.00E+00	DNA	5.00E+02	NE	NE
Performance Objective[d]						**1.0E-06[e]**	**1.0[f]**

[a] Dangerous waste constituent per *Washington Administrative Code* (WAC) 173-303-9905, "Dangerous Waste Constituents List."

[b] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, for the basis for the K_d values listed for chromium and nitrate. The K_d values listed for the organic chemical compounds are determined from the chemicals' organic carbon/water partitioning coefficient and an estimate of 0.03% for the Hanford Site sediments fraction of organic content (PNNL-13895, Rev. 1, page 11, paragraph 3).

[c] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*.

[d] Single Analyte Performance objectives apply to entire waste management area, not just a single component of the waste management area.

[e] WAC 173-340-705, "Use of Method B," subpart (2)(c)(ii).

[f] WAC 173-340-705 (2)(c)(i).

DNA = Did not arrive at fenceline within the 10,000-year modeling period.

NE = Incremental cancer risk or hazard quotient calculated under WAC 173-340, "Model Toxics Control Act – Cleanup," Method B not evaluated because hazardous chemical constituent had no estimated initial inventory or did not arrive in concentrations greater than zero at the fenceline within the 10,000-year modeling period. In the Decision Management Tool (DMT) that is used to implement the calculational methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* for this Retrieval Data Report, calculated concentrations less than 1.00E-21 µg/L are considered to be effectively zero. The risk metric may have also not been calculated because the chemical analyte was predicted to have a concentration less than 0.001 µg/L, which is well below the ability of standard laboratory analytical methods to detect it.

No CPF = No cancer potency factor available.

No Rfd = No reference dose available.

Reference: WAC 173-340, "Model Toxics Control Act—Cleanup."

Table D-3. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose for Single-Shell Tank 241-C-111 per Radionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based Inventory. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose – Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Americium-241	Yes	1.56E+01	0.00E+00	DNA	3.00E+00	4.33E+02	NE	NE	NE	NE
Antimony-125	No	2.37E+01	0.00E+00	DNA	1.00E+00	2.73E+00	NE	NE	NE	NE
Barium-137m	Yes	3.35E+02	0.00E+00	DNA	0.00E+00	4.86E-06	NE	NE	NE	NE
Carbon-14	No	5.90E-03	9.09E-03	9.78E+03	0.00E+00	5.73E+03	7.06E-11	5.10E-10	4.40E-05	1.82E-05
Cesium-137 + Daughters	Yes	3.55E+02	0.00E+00	DNA	2.50E+01	3.00E+01	NE	NE	NE	NE
Cobalt-60	No	7.45E+00	0.00E+00	DNA	1.00E-01	5.27E+00	NE	NE	NE	NE
Curium-242	Yes	4.53E-02	0.00E+00	DNA	3.00E+00	4.46E-01	NE	NE	NE	NE
Curium-243	Yes	1.36E-02	0.00E+00	DNA	3.00E+00	2.85E+01	NE	NE	NE	NE
Curium-244	Yes	2.61E-01	0.00E+00	DNA	3.00E+00	1.81E+01	NE	NE	NE	NE
Europium-152	No	1.98E+01	0.00E+00	DNA	1.00E+00	1.33E+01	NE	NE	NE	NE
Europium-154	No	1.91E+01	0.00E+00	DNA	1.00E+00	8.59E+00	NE	NE	NE	NE
Europium-155	No	3.38E+01	0.00E+00	DNA	1.00E+00	4.68E+00	NE	NE	NE	NE
Iodine-129	No	2.21E-03	<1.00E-03	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
Neptunium-237 + D	Yes	2.85E-03	0.00E+00	DNA	2.00E+00	2.14E+06	NE	NE	NE	NE
Nickel-63	Yes	6.35E+00	0.00E+00	DNA	4.80E+01	1.00E+02	NE	NE	NE	NE
Plutonium-238	Yes	1.63E-01	0.00E+00	DNA	3.00E+00	8.77E+01	NE	NE	NE	NE
Plutonium-239	No	1.15E+00	0.00E+00	DNA	3.00E+00	2.41E+04	NE	NE	NE	NE
Plutonium-240	No	1.25E-01	0.00E+00	DNA	3.00E+00	6.56E+03	NE	NE	NE	NE

Table D-3. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose for Single-Shell Tank 241-C-111 per Radionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based Inventory. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose – Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Plutonium-241 + D	No	1.08E+00	0.00E+00	DNA	3.00E+00	1.44E+01	NE	NE	NE	NE
Plutonium-242	No	4.76E-02	0.00E+00	DNA	3.00E+00	3.74E+05	NE	NE	NE	NE
Neptunium-237 + D	Yes	2.85E-03	0.00E+00	DNA	2.00E+00	2.14E+06	NE	NE	NE	NE
Nickel-63	Yes	6.35E+00	0.00E+00	DNA	4.80E+01	1.00E+02	NE	NE	NE	NE
Plutonium-238	Yes	1.63E-01	0.00E+00	DNA	3.00E+00	8.77E+01	NE	NE	NE	NE
Plutonium-239	No	1.15E+00	0.00E+00	DNA	3.00E+00	2.41E+04	NE	NE	NE	NE
Plutonium-240	No	1.25E-01	0.00E+00	DNA	3.00E+00	6.56E+03	NE	NE	NE	NE
Plutonium-241 + D	No	1.08E+00	0.00E+00	DNA	3.00E+00	1.44E+01	NE	NE	NE	NE
Plutonium-242	No	4.76E-02	0.00E+00	DNA	3.00E+00	3.74E+05	NE	NE	NE	NE
Selenium-79	No	8.40E-03	0.00E+00	DNA	3.10E+00	8.05E+05	NE	NE	NE	NE
Strontium-90 + D	Yes	1.11E+05	0.00E+00	DNA	1.61E+01	2.81E+01	NE	NE	NE	NE
Technetium-99	Yes	1.00E-01	3.99E-01	1.05E+04	0.00E+00	2.11E+05	5.50E-09	1.34E-07	6.99E-04	1.77E-03
Thorium-228 + D	No	9.15E-03	0.00E+00	DNA	3.00E+00	1.91E+00	NE	NE	NE	NE
Thorium-230	No	1.91E-01	0.00E+00	DNA	3.00E+00	7.54E+04	NE	NE	NE	NE
Thorium-232	Yes	6.91E-06	0.00E+00	DNA	3.00E+00	1.41E+10	NE	NE	NE	NE
Tin-126	No	2.12E-02	0.00E+00	DNA	1.00E+00	2.46E+05	NE	NE	NE	NE
Tritium	No	9.85E-02	0.00E+00	DNA	0.00E+00	1.23E+01	NE	NE	NE	NE
Uranium-233	No	8.95E-03	0.00E+00	DNA	6.00E-01	1.59E+05	NE	NE	NE	N/A

Table D-3. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose for Single-Shell Tank 241-C-111 per Radionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based Inventory. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose – Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Uranium-234	No	3.25E-02	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	N/A
Uranium-235 + D	Yes	6.85E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	N/A
Uranium-236	Yes	6.02E-04	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	N/A
Uranium-238 + D	Yes	1.62E-02	0.00E+00	DNA	6.00E-01	4.47E+09	NE	NE	NE	N/A
Yttrium-90	Yes	1.11E+05	0.00E+00	DNA	0.00E+00	7.31E-03	NE	NE	NE	NE
Performance Objectives[c]							**1-0E-6 to 1.0E-4[d]**	**1-0E-6 to 1.0E-4[d]**	**25[e]**	**4[f]**

[a] See PNNL-13895, "*Hanford Contaminant Distribution Coefficient Database and Users Guide*," Rev. 1, and Section 4.3 of PNNL-14702, "*Vadose Zone Hydrogeology Data Package for Hanford Assessments*" for the basis for the K_d values listed for the radionuclides.

[b] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*.

[c] Performance objectives apply to the cumulative (i.e., all contaminants) for the entire waste management area.

[d] EPA 540/R/99/006, *Radiation Risk Assessment At CERCLA Sites: Q & A*, Directive 9200.4-31P.

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

[f] 65 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

DNA = Did not arrive at fenceline within the 10,000-year modeling period.
N/A = Radionuclide is not a beta/photon emitter.
NE = Incremental cancer risk for industrial and residential scenarios or radiological dose evaluated for the all-pathways farmer and drinking water only scenarios not evaluated because radiological constituent had no estimated initial inventory or did not arrive in concentrations greater than at the fenceline within the 10,000-year modeling period. In the Decision Management Tool (DMT) that is used to implement the calculational methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* for this Retrieval Data Report, calculated concentrations less than 1.00E-21 pCi/L are considered to be effectively zero. This risk metric may have also not been calculated because the radioactive analyte was predicted to have a concentration less than 0.001 pCi/L, which is well below the ability of standard laboratory analytical methods to detect it.

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-111 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration-Based Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
1, 1, 2-Trichloroethylene	No	4.71E-05	<1.00E-03	1.20E+04	2.82E-02	NE	NE
1, 4-Dichlorobenzene	No	3.49E-05	<1.00E-03	1.20E+04	1.85E-01	NE	NE
2-Butanone (MEK)	No	1.54E-03	<1.00E-03	1.05E+04	1.35E-03	NE	NE
2-Propanone (Acetone)	No	5.05E-03	<1.00E-03	1.05E+04	1.73E-04	NE	NE
4-Methyl-2-pentanone (MIBK)	No	6.65E-04	<1.00E-03	1.20E+04	4.02E-02	NE	NE
Acetate	Yes	8.43E+00	#N/A	1.05E+04	3.00E-04	#N/A	#N/A
Aluminum	Yes	4.01E+03	0.00E+00	DNA	1.00E+00	NE	NE
Ammonia	Yes	1.37E-01	<1.00E-03	1.05E+04	9.30E-04	NE	NE
Antimony[a]	No	1.50E+00	0.00E+00	DNA	1.00E+00	NE	NE
Arsenic[a]	No	1.25E+00	0.00E+00	DNA	3.90E+01	NE	NE
Barium[a]	Yes	7.22E-01	0.00E+00	DNA	6.00E+01	NE	NE
Benzo[a]pyrene[a]	No	2.60E-02	0.00E+00	DNA	2.86E+02	NE	NE
Beryllium[a]	No	8.30E-02	0.00E+00	DNA	7.00E+01	NE	NE
Bismuth	Yes	1.20E+01	4.93E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Boron	No	1.66E-01	0.00E+00	DNA	3.00E+00	NE	NE
Bromide	No	2.80E+00	1.15E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Butylbenzylphthalate[a]	Yes	6.80E-02	0.00E+00	DNA	4.14E+00	NE	NE
Cadmium[a]	No	1.31E-01	0.00E+00	DNA	1.26E+00	NE	NE
Calcium	Yes	2.52E+02	0.00E+00	DNA	4.00E+00	NE	NE
Cerium	Yes	7.68E+00	3.15E-02	1.05E+04	0.00E+00	No CPF	No Rfd

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-111 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration-Based Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Chloride	No	3.35E+00	1.38E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Chromium, Total[a]	Yes	2.73E+00	1.12E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Cobalt	No	1.15E-01	<1.00E-03	1.20E+04	1.00E-01	NE	NE
Copper	Yes	8.26E-01	0.00E+00	DNA	3.50E+01	NE	NE
Cyanide[a]	Yes	9.93E-01	0.00E+00	DNA	9.90E+00	NE	NE
Di (2-ethylhexyl) phthalate (DEHP)	Yes	1.42E-01	0.00E+00	DNA	2.62E+01	NE	NE
Dibenz[a, h]anthracene[a]	No	1.24E-02	0.00E+00	DNA	5.72E+02	NE	NE
Diethyl phthalate[a]	No	2.28E-02	<1.00E-03	1.20E+04	2.07E-02	NE	NE
Di-n-butylphthalate[a]	No	7.45E-02	0.00E+00	DNA	1.89E+00	NE	NE
Europium	No	9.30E-02	0.00E+00	DNA	5.00E+01	NE	NE
Fluoride	Yes	3.33E+02	1.37E+00	1.05E+04	0.00E+00	No CPF	1.42E-03
Formate+A2	No	9.35E+00	3.84E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Glycolate C2H3O3	No	2.98E+00	1.22E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Hexachlorobenzene[a]	No	1.11E-02	0.00E+00	DNA	8.46E+00	NE	NE
Hydroxide OH	Yes	1.41E+01	5.79E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Iron	Yes	4.99E+02	0.00E+00	DNA	2.50E+01	NE	NE
Lanthanum	Yes	2.52E+00	1.03E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Lead[a]	Yes	1.42E+02	0.00E+00	DNA	5.20E+00	NE	NE
Lithium	No	1.03E-01	0.00E+00	DNA	3.00E+02	NE	NE
Magnesium	Yes	7.22E+00	0.00E+00	DNA	4.50E+00	NE	NE

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-111 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration-Based Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Manganese	Yes	2.66E+00	0.00E+00	DNA	1.00E+00	NE	NE
Mercury[a]	Yes	1.32E-01	0.00E+00	DNA	5.20E+00	NE	NE
Molybdenum	No	1.75E-01	0.00E+00	DNA	4.00E+00	NE	NE
m-Xylene	No	6.50E-05	<1.00E-03	1.20E+04	5.88E-02	NE	NE
N, N-Diphenylamine[a]	No	1.18E-02	<1.00E-03	1.20E+04	5.73E-01	NE	NE
Neodymium	Yes	4.30E+00	1.77E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Nickel[a]	Yes	3.09E+02	0.00E+00	DNA	4.80E+01	NE	NE
Niobium	No	4.99E-01	0.00E+00	DNA	1.00E+02	NE	NE
Nitrate	Yes	1.57E+02	6.45E-01	1.05E+04	0.00E+00	No CPF	2.52E-05
Nitrite	Yes	7.45E+01	3.06E-01	1.05E+04	0.00E+00	No CPF	1.91E-04
N-Nitroso-N, N-dimethylamine[a]	No	2.07E-02	<1.00E-03	1.05E+04	3.60E-03	NE	NE
Oxalate	No	8.15E+00	3.35E-02	1.05E+04	0.00E+00	No CPF	No Rfd
o-Xylene	No	3.58E-05	<1.00E-03	1.20E+04	7.23E-02	NE	NE
Palladium	No	9.95E-01	0.00E+00	DNA	5.00E+01	NE	NE
Pentachlorophenol[a]	No	1.13E-02	<1.00E-03	1.20E+04	1.77E-01	NE	NE
Phenol[a]	No	2.01E-02	<1.00E-03	1.05E+04	8.64E-03	NE	NE
Phosphate	Yes	6.72E+03	2.76E+01	1.05E+04	0.00E+00	No CPF	No Rfd
Polychlorinated Biphenyls[a]	No	4.47E-04	0.00E+00	DNA	9.27E+01	NE	NE
Potassium	No	2.71E+00	1.11E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Praseodymium	No	2.21E+00	9.05E-03	1.05E+04	0.00E+00	No CPF	No Rfd

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-111 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration-Based Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Rhodium	No	9.95E-01	4.08E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Rubidium	No	4.73E+00	1.94E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Ruthenium	No	4.16E-01	0.00E+00	DNA	1.00E+00	NE	NE
Samarium	Yes	2.24E+00	0.00E+00	DNA	1.00E+00	NE	NE
Selenium[a]	No	2.49E+00	0.00E+00	DNA	5.00E+00	NE	NE
Silicon	Yes	1.53E+02	0.00E+00	DNA	3.00E+01	NE	NE
Silver[a]	Yes	1.37E+01	0.00E+00	DNA	2.70E+00	NE	NE
Sodium	Yes	6.56E+03	2.69E+01	1.05E+04	0.00E+00	No CPF	No Rfd
Strontium	Yes	4.17E+00	0.00E+00	DNA	1.61E+01	NE	NE
Sulfate	Yes	2.66E+01	1.09E-01	1.05E+04	0.00E+00	No CPF	No Rfd
Tantalum	No	4.25E-01	1.74E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Tellurium	No	7.45E-01	3.06E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Thallium[a]	No	1.25E+00	0.00E+00	DNA	7.10E+01	NE	NE
Thorium	Yes	6.28E-02	0.00E+00	DNA	1.00E+00	NE	NE
Tin	No	6.65E-01	0.00E+00	DNA	2.50E+02	NE	NE
Titanium	Yes	3.06E+00	0.00E+00	DNA	1.00E+03	NE	NE
Toluene[a]	No	3.13E-05	<1.00E-03	1.20E+04	4.20E-02	NE	NE
Tributyl phosphate	Yes	5.67E-02	<1.00E-03	1.20E+04	5.67E-01	NE	NE
Tungsten	No	1.33E+00	5.46E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Uranium	Yes	4.84E+01	0.00E+00	DNA	6.00E-01	NE	NE

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-111 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration-Based Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Vanadium	Yes	2.70E-01	0.00E+00	DNA	5.00E+01	NE	NE
Xylenes	No	1.59E-05	<1.00E-03	1.20E+04	5.88E-02	NE	NE
Yttrium	Yes	3.96E-01	1.63E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Zinc	No	2.99E+00	0.00E+00	DNA	6.20E+01	NE	NE
Zirconium	Yes	2.02E+00	0.00E+00	DNA	5.00E+02	NE	NE
Performance Objective[d]						**1.0E-06[e]**	**1.0[f]**

[a] Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List."

[b] See PNNL-13895, "*Hanford Contaminant Distribution Coefficient Database and Users Guide*," Rev. 1, for the basis for the K_d values listed for chromium and nitrate. The K_d values listed for the organic chemical compounds are determined from the chemicals' organic carbon/water partitioning coefficient and an estimate of 0.03% for the Hanford Site sediments fraction of organic content (PNNL-13895, Rev. 1, page 11, paragraph 3).

[c] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*.

[d] Single Analyte Performance objectives apply to entire waste management area, not just a single component of the waste management area.

[e] WAC 173-340-705, "Use of Method B," subpart (2)(c)(ii).

[f] WAC 173-340-705 (2)(c)(i).

DNA = Did not arrive at fenceline within the 10,000-year modeling period.

NE = Incremental cancer risk or hazard quotient calculated under WAC 173-340, "Model Toxics Control Act – Cleanup," Method B not evaluated because hazardous chemical constituent had no estimated initial inventory or did not arrive in concentrations greater than zero at the fenceline within the 10,000-year modeling period. In the Decision Management Tool (DMT) that is used to implement the calculational methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* for this Retrieval Data Report, calculated concentrations less than 1.00E-21 µg/L are considered to be effectively zero. The risk metric may have also not been calculated because the chemical analyte was predicted to have a concentration less than 0.001 µg/L, which is well below the ability of standard laboratory analytical methods to detect it.

No CPF = No cancer potency factor available.

No Rfd = No reference dose available.

Reference: WAC 173-340, "Model Toxics Control Act—Cleanup."

Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
A – Average Inventory										
Antimony-125	1.27E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	3.26E-03	3.26E-03	3.25E-03	3.25E-03	3.25E-03	3.25E-03	3.25E-03	3.25E-03	3.25E-03	3.25E-03
Iodine-129	2.18E-06	2.18E-06	2.18E-06	2.18E-06	2.18E-06	2.18E-06	2.18E-06	2.18E-06	2.18E-06	2.18E-06
Cesium-137 + Daughters	1.19E+00	1.18E-01	1.17E-02	1.16E-03	1.15E-04	1.14E-05	1.13E-06	1.12E-07	1.12E-08	1.11E-09
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	3.22E-08	3.18E-08	3.14E-08	3.11E-08	3.07E-08	3.03E-08	3.00E-08	2.96E-08	2.92E-08	2.89E-08
Europium-152	2.57E-03	1.42E-05	7.82E-08	4.32E-10	2.39E-12	1.74E-14	4.35E-15	4.28E-15	4.27E-15	4.27E-15
Europium-154	7.47E-05	2.34E-08	7.34E-12	2.30E-15	7.22E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.04E-09	3.85E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	2.98E-03	4.17E-03	5.31E-03	6.40E-03	7.44E-03	8.44E-03	9.39E-03	1.03E-02	1.12E-02	1.20E-02
Protactinium-231	7.25E-02	7.31E-02	7.30E-02	7.29E-02	7.27E-02	7.26E-02	7.24E-02	7.23E-02	7.21E-02	7.20E-02
Thorium-232	2.04E-06	2.04E-06	2.04E-06	2.04E-06	2.04E-06	2.04E-06	2.04E-06	2.04E-06	2.04E-06	2.04E-06
Uranium-233	1.62E-05	2.24E-05	2.86E-05	3.47E-05	4.07E-05	4.67E-05	5.26E-05	5.84E-05	6.42E-05	6.99E-05
Uranium-234	2.98E-05	3.03E-05	3.11E-05	3.20E-05	3.31E-05	3.43E-05	3.57E-05	3.72E-05	3.89E-05	4.07E-05
Uranium-235 + D	1.13E-05	1.16E-05	1.19E-05	1.22E-05	1.25E-05	1.28E-05	1.31E-05	1.34E-05	1.37E-05	1.40E-05
Uranium-236	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07	5.94E-07
Neptunium-237 + D	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04

Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Plutonium-238	1.71E-03	7.77E-04	3.53E-04	1.60E-04	7.27E-05	3.30E-05	1.50E-05	6.88E-06	3.18E-06	1.51E-06
Uranium-238 + D	5.32E-05	5.32E-05	5.32E-05	5.32E-05	5.32E-05	5.32E-05	5.32E-05	5.32E-05	5.32E-05	5.32E-05
Plutonium-239	2.20E-02	2.19E-02	2.19E-02	2.18E-02	2.18E-02	2.17E-02	2.16E-02	2.16E-02	2.15E-02	2.14E-02
Plutonium-240	2.37E-03	2.35E-03	2.32E-03	2.30E-03	2.27E-03	2.25E-03	2.23E-03	2.20E-03	2.18E-03	2.16E-03
Americium-241	3.99E-01	3.40E-01	2.90E-01	2.47E-01	2.10E-01	1.79E-01	1.53E-01	1.30E-01	1.11E-01	9.46E-02
Plutonium-241 + D	6.27E-04	5.35E-04	4.56E-04	3.88E-04	3.31E-04	2.82E-04	2.40E-04	2.05E-04	1.74E-04	1.49E-04
Curium-242	3.25E-06	1.48E-06	6.69E-07	3.04E-07	1.38E-07	6.26E-08	2.85E-08	1.30E-08	5.99E-09	2.81E-09
Plutonium-242	8.71E-04	8.71E-04	8.71E-04	8.70E-04	8.70E-04	8.70E-04	8.70E-04	8.70E-04	8.70E-04	8.69E-04
Curium-243	2.28E-05	2.43E-06	6.40E-07	4.81E-07	4.66E-07	4.64E-07	4.62E-07	4.61E-07	4.59E-07	4.58E-07
Curium-244	5.65E-05	2.11E-05	2.02E-05	1.99E-05	1.97E-05	1.95E-05	1.93E-05	1.91E-05	1.89E-05	1.87E-05
Tritium	1.41E-11	5.11E-14	1.85E-16	6.70E-19	2.42E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	1.03E-07	2.00E-13	3.89E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	6.75E-06	3.38E-06	1.69E-06	8.45E-07	4.23E-07	2.12E-07	1.06E-07	5.30E-08	2.65E-08	1.33E-08
Selenium-79	1.87E-07	1.87E-07	1.87E-07	1.87E-07	1.87E-07	1.87E-07	1.87E-07	1.87E-07	1.87E-07	1.87E-07
Strontium-90 + D	4.75E+00	4.05E-01	3.45E-02	2.94E-03	2.51E-04	2.14E-05	1.82E-06	1.55E-07	1.32E-08	1.13E-09
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	9.43E-07	9.43E-07	9.43E-07	9.42E-07	9.42E-07	9.42E-07	9.41E-07	9.41E-07	9.41E-07	9.40E-07
Total Dose	**6.45E+00**	**9.72E-01**	**4.45E-01**	**3.60E-01**	**3.20E-01**	**2.89E-01**	**2.63E-01**	**2.41E-01**	**2.23E-01**	**2.07E-01**

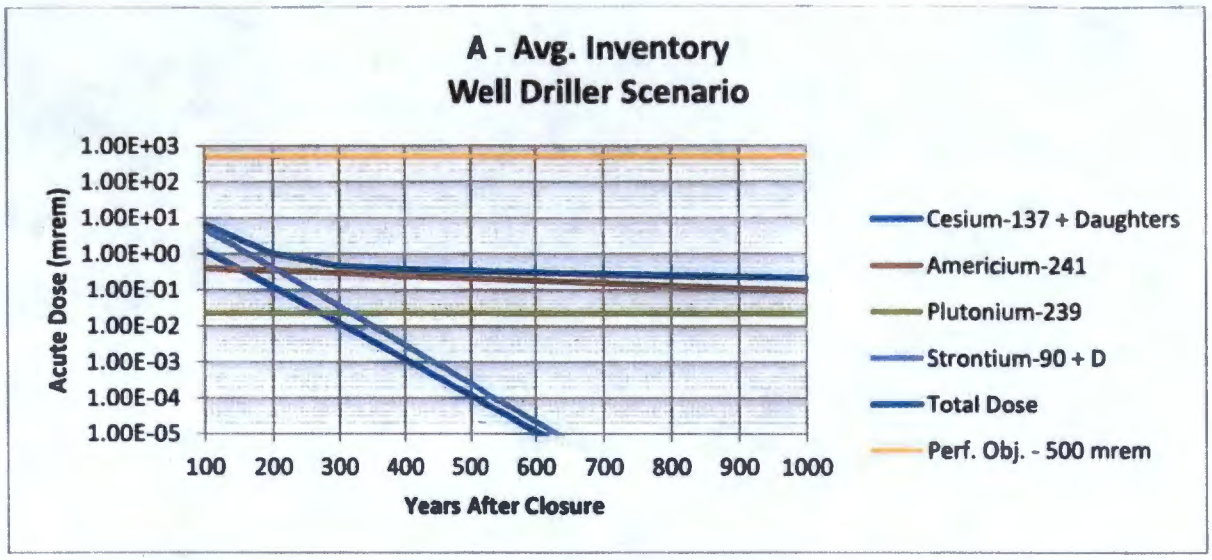
Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

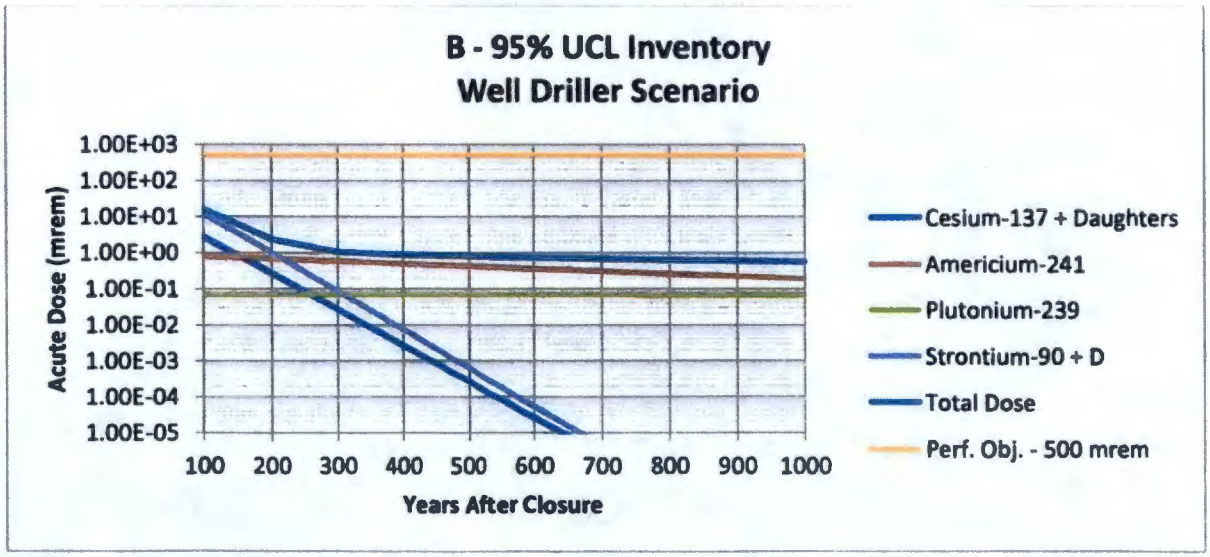
Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
B – 95% Upper Confidence Level Inventory										
Antimony-125	3.85E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	9.84E-03	9.84E-03	9.83E-03	9.83E-03	9.83E-03	9.82E-03	9.82E-03	9.82E-03	9.82E-03	9.81E-03
Iodine-129	6.57E-06	6.57E-06	6.57E-06	6.57E-06	6.57E-06	6.57E-06	6.57E-06	6.57E-06	6.57E-06	6.57E-06
Cesium-137 + Daughters	2.62E+00	2.60E-01	2.58E-02	2.56E-03	2.54E-04	2.52E-05	2.50E-06	2.48E-07	2.46E-08	2.44E-09
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	9.75E-08	9.63E-08	9.51E-08	9.40E-08	9.29E-08	9.17E-08	9.06E-08	8.95E-08	8.85E-08	8.74E-08
Europium-152	7.77E-03	4.29E-05	2.36E-07	1.30E-09	7.21E-12	5.26E-14	1.31E-14	1.29E-14	1.29E-14	1.29E-14
Europium-154	2.26E-04	7.08E-08	2.22E-11	6.96E-15	2.18E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	3.15E-09	1.16E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	9.02E-03	1.26E-02	1.61E-02	1.94E-02	2.25E-02	2.55E-02	2.84E-02	3.12E-02	3.38E-02	3.63E-02
Protactinium-231	2.19E-01	2.21E-01	2.21E-01	2.20E-01	2.20E-01	2.19E-01	2.19E-01	2.18E-01	2.18E-01	2.17E-01
Thorium-232	4.95E-06	4.95E-06	4.95E-06	4.95E-06	4.95E-06	4.95E-06	4.95E-06	4.95E-06	4.95E-06	4.95E-06
Uranium-233	4.90E-05	6.78E-05	8.64E-05	1.05E-04	1.23E-04	1.41E-04	1.59E-04	1.77E-04	1.94E-04	2.11E-04
Uranium-234	8.99E-05	9.16E-05	9.38E-05	9.65E-05	9.98E-05	1.04E-04	1.08E-04	1.12E-04	1.17E-04	1.23E-04
Uranium-235 + D	2.72E-05	2.80E-05	2.87E-05	2.94E-05	3.02E-05	3.09E-05	3.16E-05	3.24E-05	3.31E-05	3.38E-05
Uranium-236	1.55E-06	1.55E-06	1.55E-06	1.55E-06	1.55E-06	1.55E-06	1.55E-06	1.55E-06	1.55E-06	1.55E-06
Neptunium-237 + D	3.48E-04	3.48E-04	3.48E-04	3.48E-04	3.48E-04	3.48E-04	3.48E-04	3.48E-04	3.48E-04	3.48E-04

Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Plutonium-238	3.20E-03	1.45E-03	6.59E-04	2.99E-04	1.36E-04	6.17E-05	2.81E-05	1.28E-05	5.94E-06	2.81E-06
Uranium-238 + D	1.29E-04	1.29E-04	1.29E-04	1.29E-04	1.29E-04	1.29E-04	1.29E-04	1.29E-04	1.29E-04	1.29E-04
Plutonium-239	6.64E-02	6.62E-02	6.61E-02	6.59E-02	6.57E-02	6.55E-02	6.53E-02	6.51E-02	6.49E-02	6.47E-02
Plutonium-240	7.15E-03	7.08E-03	7.00E-03	6.93E-03	6.86E-03	6.78E-03	6.71E-03	6.64E-03	6.57E-03	6.50E-03
Americium-241	8.00E-01	6.81E-01	5.81E-01	4.95E-01	4.21E-01	3.59E-01	3.06E-01	2.61E-01	2.22E-01	1.89E-01
Plutonium-241 + D	1.90E-03	1.62E-03	1.38E-03	1.17E-03	1.00E-03	8.53E-04	7.27E-04	6.19E-04	5.28E-04	4.50E-04
Curium-242	4.55E-06	2.06E-06	9.36E-07	4.25E-07	1.93E-07	8.76E-08	3.99E-08	1.82E-08	8.38E-09	3.92E-09
Plutonium-242	2.63E-03	2.63E-03	2.63E-03	2.63E-03	2.63E-03	2.63E-03	2.63E-03	2.63E-03	2.63E-03	2.62E-03
Curium-243	4.56E-05	4.87E-06	1.28E-06	9.63E-07	9.32E-07	9.27E-07	9.24E-07	9.21E-07	9.19E-07	9.16E-07
Curium-244	1.13E-04	4.24E-05	4.05E-05	4.00E-05	3.96E-05	3.92E-05	3.88E-05	3.84E-05	3.80E-05	3.76E-05
Tritium	4.28E-11	1.55E-13	5.60E-16	2.03E-18	7.33E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	3.10E-07	6.03E-13	1.17E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	1.21E-05	6.04E-06	3.02E-06	1.51E-06	7.56E-07	3.78E-07	1.89E-07	9.47E-08	4.74E-08	2.37E-08
Selenium-79	5.65E-07	5.65E-07	5.65E-07	5.65E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07
Strontium-90 + D	1.16E+01	9.92E-01	8.45E-02	7.20E-03	6.14E-04	5.23E-05	4.46E-06	3.80E-07	3.24E-08	2.76E-09
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	1.90E-06	1.90E-06	1.90E-06	1.90E-06	1.90E-06	1.89E-06	1.89E-06	1.89E-06	1.89E-06	1.89E-06
Total Dose	**1.54E+01**	**2.26E+00**	**1.02E+00**	**8.32E-01**	**7.52E-01**	**6.91E-01**	**6.40E-01**	**5.96E-01**	**5.59E-01**	**5.28E-01**

Figure D-1. Comparison of Well Driller Scenario Doses (mrem) with Performance Objective for Acute Exposure for Key Analytes – A) Average Inventory and B) 95% Upper Confidence Level Inventory in Residual Wastes within Single-Shell Tank 241-C-111.





UCL = upper confidence level

Table D-6. Rural Pasture Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
A – Average Inventory										
Antimony-125	1.33E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	3.69E-04	3.69E-04	3.69E-04	3.69E-04	3.69E-04	3.69E-04	3.69E-04	3.69E-04	3.68E-04	3.68E-04
Iodine-129	2.21E-05	2.21E-05	2.21E-05	2.21E-05	2.21E-05	2.21E-05	2.21E-05	2.21E-05	2.21E-05	2.21E-05
Cesium-137 + Daughters	3.20E-01	3.17E-02	3.15E-03	3.12E-04	3.10E-05	3.07E-06	3.05E-07	3.03E-08	3.00E-09	2.98E-10
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	3.55E-06	3.51E-06	3.47E-06	3.42E-06	3.38E-06	3.34E-06	3.30E-06	3.26E-06	3.22E-06	3.18E-06
Europium-152	2.91E-04	1.60E-06	8.85E-09	4.88E-11	2.71E-13	2.69E-15	1.21E-15	1.21E-15	1.21E-15	1.21E-15
Europium-154	8.44E-06	2.65E-09	8.30E-13	2.60E-16	8.16E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	8.95E-11	3.31E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	7.23E-04	9.77E-04	1.22E-03	1.45E-03	1.68E-03	1.89E-03	2.09E-03	2.29E-03	2.48E-03	2.65E-03
Protactinium-231	1.85E-02	1.87E-02	1.86E-02	1.86E-02	1.86E-02	1.85E-02	1.85E-02	1.84E-02	1.84E-02	1.84E-02
Thorium-232	3.70E-07	3.70E-07	3.70E-07	3.70E-07	3.70E-07	3.70E-07	3.70E-07	3.70E-07	3.70E-07	3.70E-07
Uranium-233	6.59E-06	8.02E-06	9.42E-06	1.08E-05	1.22E-05	1.36E-05	1.49E-05	1.63E-05	1.76E-05	1.89E-05
Uranium-234	1.71E-05	1.72E-05	1.74E-05	1.76E-05	1.79E-05	1.81E-05	1.84E-05	1.88E-05	1.91E-05	1.95E-05
Uranium-235 + D	1.53E-06	1.61E-06	1.69E-06	1.76E-06	1.84E-06	1.92E-06	1.99E-06	2.07E-06	2.15E-06	2.22E-06
Uranium-236	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07
Neptunium-237 + D	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05
Plutonium-238	4.86E-04	2.21E-04	1.00E-04	4.55E-05	2.07E-05	9.40E-06	4.29E-06	1.98E-06	9.27E-07	4.51E-07

Table D-6. Rural Pasture Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Uranium-238 + D	1.37E-05	1.37E-05	1.37E-05	1.37E-05	1.37E-05	1.37E-05	1.37E-05	1.38E-05	1.38E-05	1.38E-05
Plutonium-239	6.27E-03	6.25E-03	6.23E-03	6.21E-03	6.20E-03	6.18E-03	6.16E-03	6.14E-03	6.12E-03	6.11E-03
Plutonium-240	6.75E-04	6.68E-04	6.61E-04	6.54E-04	6.47E-04	6.40E-04	6.34E-04	6.27E-04	6.21E-04	6.14E-04
Americium-241	1.10E-01	9.37E-02	7.98E-02	6.80E-02	5.80E-02	4.94E-02	4.21E-02	3.59E-02	3.06E-02	2.60E-02
Plutonium-241 + D	1.73E-04	1.47E-04	1.26E-04	1.07E-04	9.11E-05	7.76E-05	6.62E-05	5.64E-05	4.80E-05	4.09E-05
Curium-242	9.23E-07	4.19E-07	1.90E-07	8.63E-08	3.92E-08	1.78E-08	8.14E-09	3.74E-09	1.75E-09	8.44E-10
Plutonium-242	2.48E-04	2.48E-04	2.48E-04	2.48E-04	2.48E-04	2.48E-04	2.48E-04	2.48E-04	2.48E-04	2.48E-04
Curium-243	4.92E-06	5.54E-07	1.70E-07	1.35E-07	1.32E-07	1.31E-07	1.31E-07	1.31E-07	1.30E-07	1.30E-07
Curium-244	1.62E-05	6.02E-06	5.74E-06	5.67E-06	5.61E-06	5.56E-06	5.50E-06	5.44E-06	5.38E-06	5.33E-06
Tritium	5.25E-10	1.90E-12	6.87E-15	2.49E-17	9.00E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	1.17E-08	2.28E-14	4.44E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	1.80E-04	8.98E-05	4.49E-05	2.25E-05	1.13E-05	5.63E-06	2.82E-06	1.41E-06	7.05E-07	3.53E-07
Selenium-79	8.92E-07	8.92E-07	8.92E-07	8.92E-07	8.92E-07	8.92E-07	8.92E-07	8.91E-07	8.91E-07	8.91E-07
Strontium-90 + D	2.74E+02	2.34E+01	1.99E+00	1.70E-01	1.45E-02	1.23E-03	1.05E-04	8.96E-06	7.63E-07	6.51E-08
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	1.72E-04	1.72E-04	1.72E-04	1.72E-04	1.72E-04	1.72E-04	1.72E-04	1.72E-04	1.72E-04	1.72E-04
Total Dose	**2.75E+02**	**2.35E+01**	**2.10E+00**	**2.66E-01**	**1.01E-01**	**7.89E-02**	**7.06E-02**	**6.44E-02**	**5.92E-02**	**5.47E-02**
B – 95% Upper Confidence Level Inventory										
Antimony-125	4.03E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	1.12E-03	1.12E-03	1.12E-03	1.11E-03	1.11E-03	1.11E-03	1.11E-03	1.11E-03	1.11E-03	1.11E-03

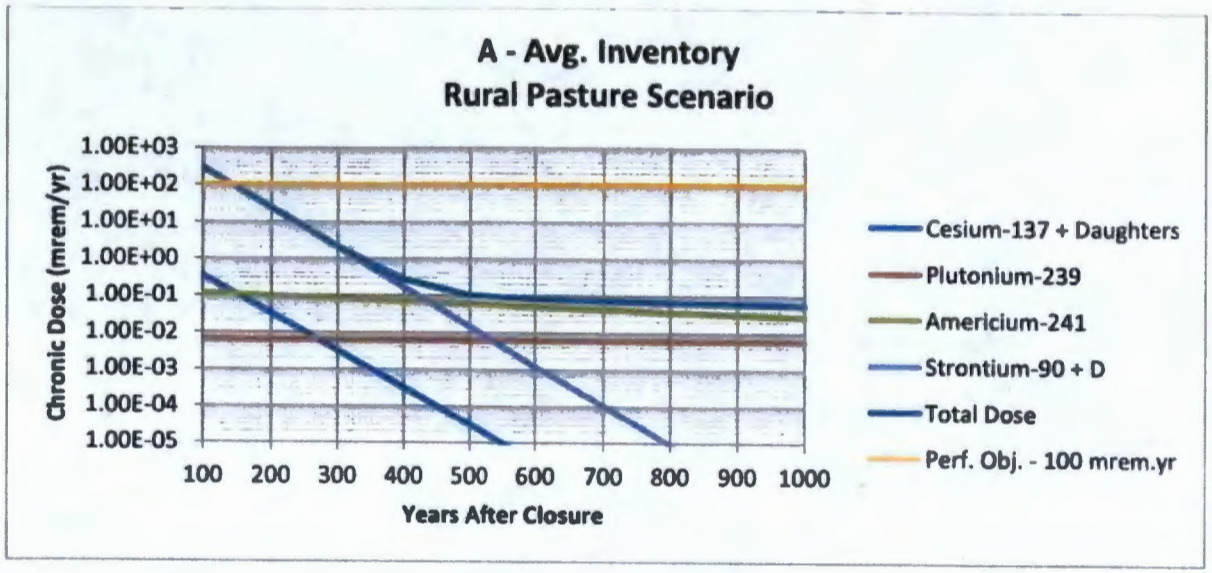
Table D-6. Rural Pasture Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

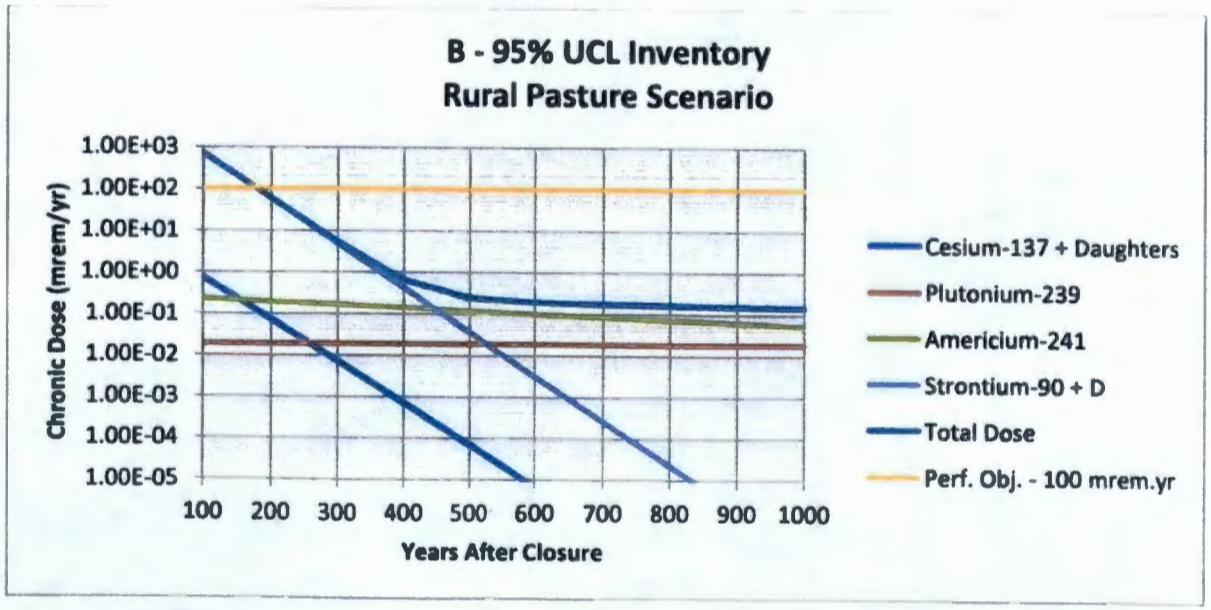
Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Iodine-129	6.68E-05	6.68E-05	6.68E-05	6.68E-05	6.68E-05	6.68E-05	6.68E-05	6.68E-05	6.68E-05	6.68E-05
Cesium-137 + Daughters	7.05E-01	7.00E-02	6.94E-03	6.89E-04	6.83E-05	6.78E-06	6.72E-07	6.67E-08	6.62E-09	6.57E-10
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	1.07E-05	1.06E-05	1.05E-05	1.04E-05	1.02E-05	1.01E-05	9.99E-06	9.87E-06	9.75E-06	9.64E-06
Europium-152	8.79E-04	4.85E-06	2.68E-08	1.48E-10	8.18E-13	8.14E-15	3.67E-15	3.65E-15	3.65E-15	3.65E-15
Europium-154	2.55E-05	8.00E-09	2.51E-12	7.87E-16	2.47E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	2.70E-10	9.98E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	2.19E-03	2.95E-03	3.69E-03	4.40E-03	5.07E-03	5.72E-03	6.33E-03	6.92E-03	7.49E-03	8.03E-03
Protactinium-231	5.59E-02	5.64E-02	5.63E-02	5.62E-02	5.60E-02	5.59E-02	5.58E-02	5.57E-02	5.56E-02	5.54E-02
Thorium-232	8.97E-07	8.97E-07	8.97E-07	8.97E-07	8.97E-07	8.97E-07	8.97E-07	8.97E-07	8.97E-07	8.97E-07
Uranium-233	1.99E-05	2.42E-05	2.85E-05	3.27E-05	3.69E-05	4.10E-05	4.51E-05	4.91E-05	5.31E-05	5.71E-05
Uranium-234	5.17E-05	5.20E-05	5.26E-05	5.32E-05	5.39E-05	5.47E-05	5.57E-05	5.67E-05	5.78E-05	5.90E-05
Uranium-235 + D	3.69E-06	3.88E-06	4.07E-06	4.25E-06	4.44E-06	4.62E-06	4.81E-06	4.99E-06	5.18E-06	5.36E-06
Uranium-236	9.04E-07	9.04E-07	9.04E-07	9.04E-07	9.04E-07	9.04E-07	9.04E-07	9.04E-07	9.04E-07	9.04E-07
Neptunium-237 + D	7.40E-05	7.40E-05	7.40E-05	7.40E-05	7.40E-05	7.40E-05	7.40E-05	7.40E-05	7.40E-05	7.41E-05
Plutonium-238	9.08E-04	4.12E-04	1.87E-04	8.49E-05	3.86E-05	1.75E-05	8.01E-06	3.69E-06	1.73E-06	8.42E-07
Uranium-238 + D	3.33E-05	3.33E-05	3.33E-05	3.33E-05	3.33E-05	3.33E-05	3.33E-05	3.33E-05	3.34E-05	3.34E-05
Plutonium-239	1.89E-02	1.89E-02	1.88E-02	1.88E-02	1.87E-02	1.86E-02	1.86E-02	1.85E-02	1.85E-02	1.84E-02
Plutonium-240	2.04E-03	2.01E-03	1.99E-03	1.97E-03	1.95E-03	1.93E-03	1.91E-03	1.89E-03	1.87E-03	1.85E-03

Table D-6. Rural Pasture Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Americium-241	2.20E-01	1.88E-01	1.60E-01	1.36E-01	1.16E-01	9.89E-02	8.43E-02	7.18E-02	6.12E-02	5.22E-02
Plutonium-241 + D	5.22E-04	4.46E-04	3.80E-04	3.24E-04	2.76E-04	2.35E-04	2.00E-04	1.71E-04	1.45E-04	1.24E-04
Curium-242	1.29E-06	5.85E-07	2.66E-07	1.21E-07	5.48E-08	2.49E-08	1.14E-08	5.23E-09	2.44E-09	1.18E-09
Plutonium-242	7.49E-04	7.48E-04	7.48E-04	7.48E-04	7.48E-04	7.48E-04	7.48E-04	7.48E-04	7.47E-04	7.47E-04
Curium-243	9.85E-06	1.11E-06	3.39E-07	2.71E-07	2.64E-07	2.63E-07	2.62E-07	2.61E-07	2.61E-07	2.60E-07
Curium-244	3.25E-05	1.21E-05	1.15E-05	1.14E-05	1.13E-05	1.12E-05	1.10E-05	1.09E-05	1.08E-05	1.07E-05
Tritium	1.59E-09	5.75E-12	2.08E-14	7.53E-17	2.72E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	3.54E-08	6.89E-14	1.34E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	3.21E-04	1.61E-04	8.04E-05	4.02E-05	2.01E-05	1.01E-05	5.04E-06	2.52E-06	1.26E-06	6.31E-07
Selenium-79	2.70E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06
Strontium-90 + D	6.72E+02	5.73E+01	4.88E+00	4.16E-01	3.55E-02	3.02E-03	2.58E-04	2.19E-05	1.87E-06	1.59E-07
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	3.46E-04	3.46E-04	3.46E-04	3.46E-04	3.46E-04	3.46E-04	3.45E-04	3.45E-04	3.45E-04	3.45E-04
Total Dose	**6.73E+02**	**5.76E+01**	**5.13E+00**	**6.37E-01**	**2.36E-01**	**1.87E-01**	**1.70E-01**	**1.58E-01**	**1.47E-01**	**1.39E-01**

Figure D-2. Comparison of Rural Pasture Scenario Doses with Performance Objective for Chronic Exposure for Key Analytes within A) Average Inventory and B) 95% Upper Confidence Level Inventory Estimated for Residual Wastes in Single-Shell Tank 241-C-111.





UCL = upper confidence level

Table D-7. Suburban Garden Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
A – Average Inventory										
Antimony-125	1.30E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	3.55E-03	3.55E-03	3.55E-03	3.55E-03	3.55E-03	3.55E-03	3.55E-03	3.55E-03	3.55E-03	3.55E-03
Iodine-129	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.10E-04
Cesium-137 + Daughters	3.10E+00	3.08E-01	3.05E-02	3.03E-03	3.00E-04	2.98E-05	2.96E-06	2.93E-07	2.91E-08	2.89E-09
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	6.23E-05	6.15E-05	6.08E-05	6.01E-05	5.93E-05	5.86E-05	5.79E-05	5.72E-05	5.65E-05	5.59E-05
Europium-152	2.79E-03	1.54E-05	8.51E-08	4.69E-10	2.61E-12	3.14E-14	1.72E-14	1.71E-14	1.71E-14	1.71E-14
Europium-154	8.12E-05	2.55E-08	7.99E-12	2.50E-15	7.85E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	8.79E-10	3.25E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	1.24E-02	1.82E-02	2.39E-02	2.93E-02	3.45E-02	3.94E-02	4.41E-02	4.87E-02	5.30E-02	5.71E-02
Protactinium-231	3.92E-01	3.95E-01	3.95E-01	3.94E-01	3.93E-01	3.92E-01	3.91E-01	3.90E-01	3.90E-01	3.89E-01
Thorium-232	4.29E-06	4.29E-06	4.29E-06	4.29E-06	4.29E-06	4.29E-06	4.29E-06	4.29E-06	4.29E-06	4.29E-06
Uranium-233	2.53E-04	2.73E-04	2.93E-04	3.12E-04	3.32E-04	3.51E-04	3.70E-04	3.89E-04	4.07E-04	4.26E-04
Uranium-234	8.11E-04	8.14E-04	8.17E-04	8.21E-04	8.25E-04	8.31E-04	8.37E-04	8.44E-04	8.52E-04	8.60E-04
Uranium-235 + D	3.18E-05	3.34E-05	3.50E-05	3.67E-05	3.83E-05	3.99E-05	4.16E-05	4.32E-05	4.48E-05	4.64E-05
Uranium-236	1.65E-05	1.65E-05	1.65E-05	1.65E-05	1.65E-05	1.65E-05	1.65E-05	1.65E-05	1.65E-05	1.65E-05
Neptunium-237 + D	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03

Table D-7. Suburban Garden Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Plutonium-238	1.08E-02	4.88E-03	2.22E-03	1.01E-03	4.58E-04	2.09E-04	9.62E-05	4.50E-05	2.17E-05	1.12E-05
Uranium-238 + D	5.12E-04	5.13E-04	5.13E-04	5.13E-04	5.13E-04	5.13E-04	5.13E-04	5.13E-04	5.14E-04	5.14E-04
Plutonium-239	1.39E-01	1.39E-01	1.38E-01	1.38E-01	1.37E-01	1.37E-01	1.37E-01	1.36E-01	1.36E-01	1.35E-01
Plutonium-240	1.50E-02	1.48E-02	1.47E-02	1.45E-02	1.44E-02	1.42E-02	1.41E-02	1.39E-02	1.38E-02	1.36E-02
Americium-241	2.41E+00	2.05E+00	1.75E+00	1.49E+00	1.27E+00	1.08E+00	9.23E-01	7.87E-01	6.71E-01	5.72E-01
Plutonium-241 + D	3.78E-03	3.23E-03	2.75E-03	2.34E-03	2.00E-03	1.70E-03	1.45E-03	1.24E-03	1.05E-03	8.99E-04
Curium-242	2.04E-05	9.26E-06	4.21E-06	1.91E-06	8.69E-07	3.97E-07	1.82E-07	8.52E-08	4.10E-08	2.10E-08
Plutonium-242	5.48E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03	5.48E-03
Curium-243	9.42E-05	1.10E-05	3.64E-06	2.99E-06	2.93E-06	2.91E-06	2.90E-06	2.90E-06	2.89E-06	2.88E-06
Curium-244	3.50E-04	1.33E-04	1.27E-04	1.26E-04	1.25E-04	1.23E-04	1.22E-04	1.21E-04	1.19E-04	1.18E-04
Tritium	4.59E-09	1.66E-11	6.00E-14	2.17E-16	7.86E-19	2.85E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	1.17E-07	2.29E-13	4.45E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	1.22E-03	6.09E-04	3.05E-04	1.53E-04	7.63E-05	3.82E-05	1.91E-05	9.56E-06	4.78E-06	2.39E-06
Selenium-79	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05
Strontium-90 + D	3.89E+03	3.32E+02	2.83E+01	2.41E+00	2.05E-01	1.75E-02	1.49E-03	1.27E-04	1.08E-05	9.23E-07
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	1.31E-02	1.31E-02	1.31E-02	1.31E-02	1.31E-02	1.31E-02	1.31E-02	1.31E-02	1.31E-02	1.31E-02
Total Dose	**3.90E+03**	**3.34E+02**	**3.06E+01**	**4.51E+00**	**2.09E+00**	**1.71E+00**	**1.54E+00**	**1.40E+00**	**1.29E+00**	**1.19E+00**

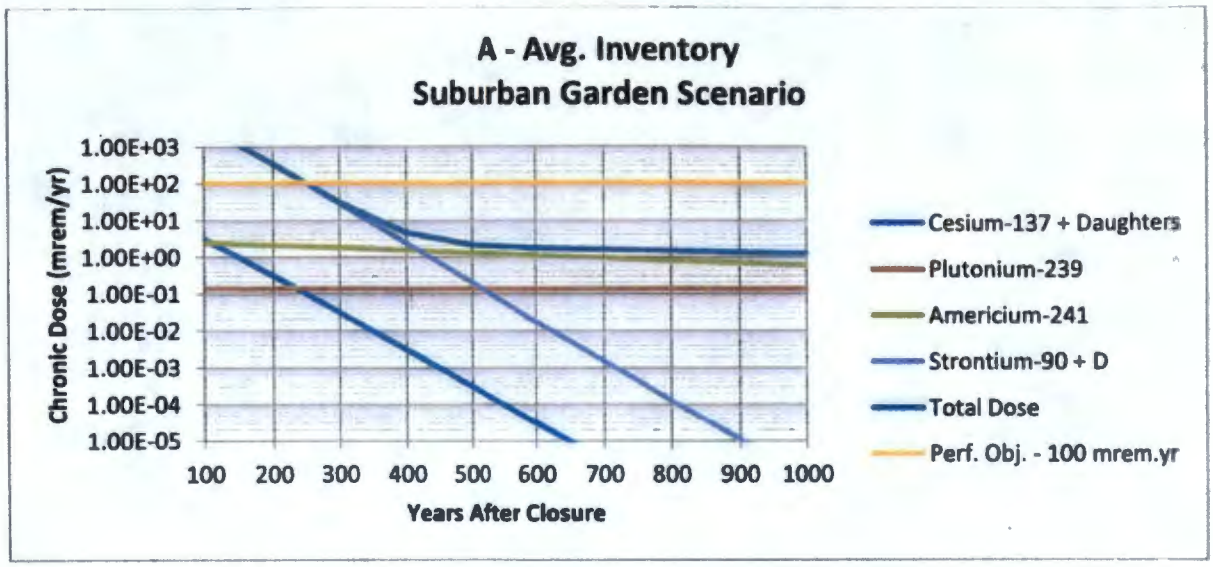
Table D-7. Suburban Garden Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

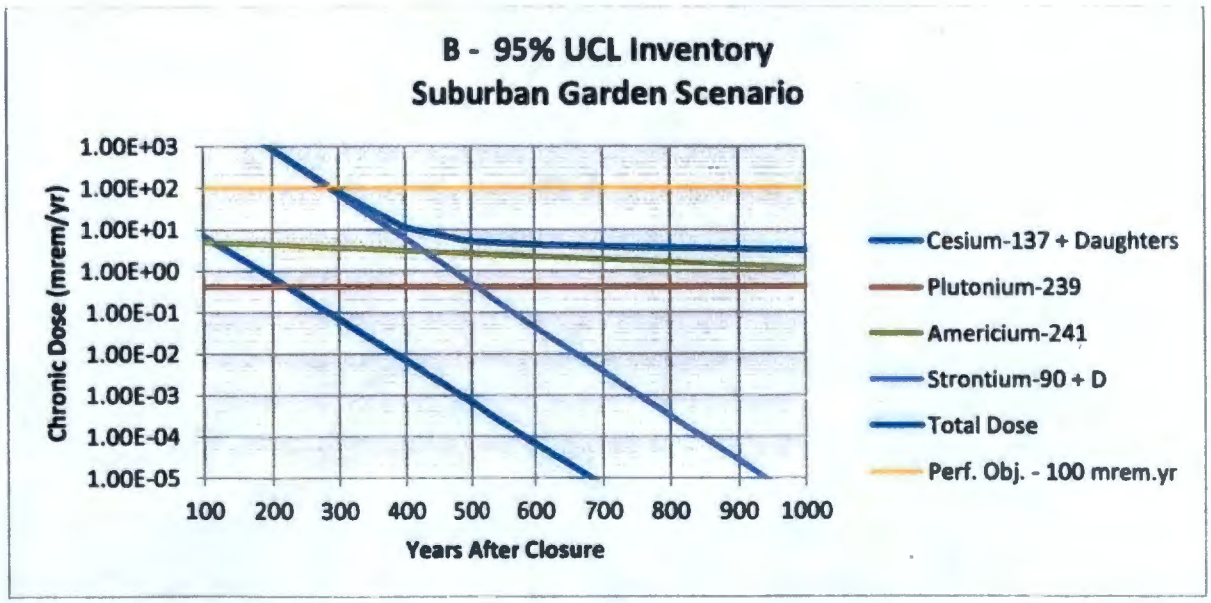
Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
B – 95% Upper Confidence Level Inventory										
Antimony-125	3.92E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02
Iodine-129	3.32E-04	3.32E-04	3.32E-04	3.32E-04	3.32E-04	3.32E-04	3.32E-04	3.32E-04	3.32E-04	3.32E-04
Cesium-137 + Daughters	6.84E+00	6.78E-01	6.73E-02	6.68E-03	6.62E-04	6.57E-05	6.52E-06	6.47E-07	6.41E-08	6.36E-09
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	1.88E-04	1.86E-04	1.84E-04	1.82E-04	1.80E-04	1.77E-04	1.75E-04	1.73E-04	1.71E-04	1.69E-04
Europium-152	8.45E-03	4.66E-05	2.57E-07	1.42E-09	7.88E-12	9.49E-14	5.19E-14	5.17E-14	5.17E-14	5.17E-14
Europium-154	2.46E-04	7.70E-08	2.41E-11	7.57E-15	2.37E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	2.65E-09	9.80E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	3.74E-02	5.51E-02	7.22E-02	8.86E-02	1.04E-01	1.19E-01	1.33E-01	1.47E-01	1.60E-01	1.73E-01
Protactinium-231	1.18E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.18E+00	1.18E+00	1.18E+00	1.18E+00	1.17E+00
Thorium-232	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05
Uranium-233	7.65E-04	8.26E-04	8.85E-04	9.44E-04	1.00E-03	1.06E-03	1.12E-03	1.17E-03	1.23E-03	1.29E-03
Uranium-234	2.45E-03	2.46E-03	2.47E-03	2.48E-03	2.49E-03	2.51E-03	2.53E-03	2.55E-03	2.57E-03	2.60E-03
Uranium-235 + D	7.66E-05	8.06E-05	8.45E-05	8.85E-05	9.24E-05	9.64E-05	1.00E-04	1.04E-04	1.08E-04	1.12E-04
Uranium-236	4.31E-05	4.31E-05	4.31E-05	4.31E-05	4.31E-05	4.31E-05	4.31E-05	4.31E-05	4.31E-05	4.31E-05
Neptunium-237 + D	5.11E-03	5.11E-03	5.11E-03	5.11E-03	5.11E-03	5.11E-03	5.11E-03	5.11E-03	5.11E-03	5.11E-03

Table D-7. Suburban Garden Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Plutonium-238	2.01E-02	9.12E-03	4.14E-03	1.88E-03	8.55E-04	3.90E-04	1.80E-04	8.40E-05	4.06E-05	2.10E-05
Uranium-238 + D	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.25E-03	1.25E-03	1.25E-03
Plutonium-239	4.20E-01	4.18E-01	4.17E-01	4.16E-01	4.15E-01	4.14E-01	4.12E-01	4.11E-01	4.10E-01	4.09E-01
Plutonium-240	4.52E-02	4.47E-02	4.42E-02	4.38E-02	4.33E-02	4.28E-02	4.24E-02	4.20E-02	4.15E-02	4.11E-02
Americium-241	4.82E+00	4.11E+00	3.50E+00	2.99E+00	2.54E+00	2.17E+00	1.85E+00	1.58E+00	1.34E+00	1.15E+00
Plutonium-241 + D	1.14E-02	9.76E-03	8.32E-03	7.09E-03	6.04E-03	5.15E-03	4.39E-03	3.74E-03	3.19E-03	2.72E-03
Curium-242	2.85E-05	1.30E-05	5.88E-06	2.67E-06	1.22E-06	5.55E-07	2.55E-07	1.19E-07	5.74E-08	2.94E-08
Plutonium-242	1.66E-02	1.66E-02	1.66E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02
Curium-243	1.88E-04	2.19E-05	7.28E-06	5.98E-06	5.85E-06	5.83E-06	5.81E-06	5.79E-06	5.77E-06	5.76E-06
Curium-244	7.02E-04	2.68E-04	2.56E-04	2.53E-04	2.50E-04	2.47E-04	2.45E-04	2.42E-04	2.40E-04	2.37E-04
Tritium	1.39E-08	5.02E-11	1.82E-13	6.58E-16	2.38E-18	8.61E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	3.54E-07	6.89E-13	1.34E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	2.18E-03	1.09E-03	5.45E-04	2.73E-04	1.37E-04	6.83E-05	3.42E-05	1.71E-05	8.56E-06	4.28E-06
Selenium-79	4.38E-05	4.38E-05	4.38E-05	4.38E-05	4.38E-05	4.38E-05	4.38E-05	4.38E-05	4.38E-05	4.38E-05
Strontium-90 + D	9.53E+03	8.12E+02	6.92E+01	5.90E+00	5.03E-01	4.29E-02	3.65E-03	3.11E-04	2.65E-05	2.26E-06
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	2.64E-02	2.64E-02	2.64E-02	2.63E-02	2.63E-02	2.63E-02	2.63E-02	2.63E-02	2.63E-02	2.63E-02
Total Dose	**9.54E+03**	**8.19E+02**	**7.46E+01**	**1.07E+01**	**4.87E+00**	**4.04E+00**	**3.69E+00**	**3.43E+00**	**3.20E+00**	**3.01E+00**

Figure D-3. Comparison of Doses from Suburban Gardener Scenario with Performance Objective for Chronic Exposure for Key Analytes within A) Average Inventory and B) 95% Upper Confidence Level Inventory Estimated for Residual Wastes in Single-Shell Tank 241-C-111.





UCL = upper confidence level

Table D-8. Commercial Farm Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
A – Average Inventory										
Antimony-125	5.09E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05
Iodine-129	1.02E-08	1.02E-08	1.02E-08	1.02E-08	1.02E-08	1.02E-08	1.02E-08	1.02E-08	1.02E-08	1.02E-08
Cesium-137 + Daughters	5.12E-03	5.08E-04	5.04E-05	5.00E-06	4.96E-07	4.92E-08	4.88E-09	4.84E-10	4.80E-11	4.76E-12
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	1.72E-10	1.70E-10	1.68E-10	1.66E-10	1.64E-10	1.62E-10	1.60E-10	1.58E-10	1.56E-10	1.54E-10
Europium-152	1.11E-05	6.12E-08	3.38E-10	1.86E-12	1.03E-14	9.89E-17	4.25E-17	4.22E-17	4.22E-17	4.22E-17
Europium-154	3.22E-07	1.01E-10	3.17E-14	9.93E-18	3.11E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	3.41E-12	1.26E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	2.06E-05	2.61E-05	3.13E-05	3.63E-05	4.11E-05	4.57E-05	5.01E-05	5.43E-05	5.83E-05	6.21E-05
Protactinium-231	5.26E-04	5.30E-04	5.29E-04	5.28E-04	5.27E-04	5.26E-04	5.25E-04	5.24E-04	5.23E-04	5.22E-04
Thorium-232	1.10E-08	1.10E-08	1.10E-08	1.10E-08	1.10E-08	1.10E-08	1.10E-08	1.10E-08	1.10E-08	1.10E-08
Uranium-233	1.13E-07	1.61E-07	2.08E-07	2.55E-07	3.01E-07	3.47E-07	3.92E-07	4.37E-07	4.82E-07	5.26E-07
Uranium-234	1.90E-07	1.94E-07	1.98E-07	2.03E-07	2.09E-07	2.16E-07	2.23E-07	2.32E-07	2.40E-07	2.50E-07
Uranium-235 + D	4.61E-08	4.83E-08	5.05E-08	5.27E-08	5.49E-08	5.71E-08	5.92E-08	6.14E-08	6.36E-08	6.58E-08
Uranium-236	3.78E-09	3.78E-09	3.78E-09	3.78E-09	3.78E-09	3.78E-09	3.78E-09	3.78E-09	3.78E-09	3.78E-09
Neptunium-237 + D	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06

Table D-8. Commercial Farm Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Plutonium-238	1.37E-05	6.23E-06	2.82E-06	1.28E-06	5.82E-07	2.64E-07	1.20E-07	5.49E-08	2.53E-08	1.19E-08
Uranium-238 + D	2.52E-07	2.52E-07	2.52E-07	2.52E-07	2.52E-07	2.52E-07	2.52E-07	2.52E-07	2.52E-07	2.52E-07
Plutonium-239	1.77E-04	1.76E-04	1.76E-04	1.75E-04	1.75E-04	1.74E-04	1.74E-04	1.73E-04	1.73E-04	1.72E-04
Plutonium-240	1.90E-05	1.88E-05	1.86E-05	1.84E-05	1.82E-05	1.80E-05	1.79E-05	1.77E-05	1.75E-05	1.73E-05
Americium-241	3.11E-03	2.65E-03	2.26E-03	1.93E-03	1.64E-03	1.40E-03	1.19E-03	1.02E-03	8.65E-04	7.37E-04
Plutonium-241 + D	4.89E-06	4.17E-06	3.55E-06	3.03E-06	2.58E-06	2.20E-06	1.87E-06	1.60E-06	1.36E-06	1.16E-06
Curium-242	2.60E-08	1.18E-08	5.36E-09	2.43E-09	1.10E-09	5.01E-10	2.28E-10	1.04E-10	4.77E-11	2.22E-11
Plutonium-242	7.00E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.98E-06
Curium-243	1.45E-07	1.62E-08	4.83E-09	3.82E-09	3.73E-09	3.71E-09	3.70E-09	3.68E-09	3.67E-09	3.66E-09
Curium-244	4.49E-07	1.69E-07	1.62E-07	1.60E-07	1.58E-07	1.57E-07	1.55E-07	1.53E-07	1.52E-07	1.50E-07
Tritium	1.84E-11	6.65E-14	2.41E-16	8.70E-19	3.15E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	4.46E-10	8.68E-16	1.69E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	3.83E-08	1.92E-08	9.59E-09	4.80E-09	2.40E-09	1.20E-09	6.01E-10	3.01E-10	1.50E-10	7.53E-11
Selenium-79	9.76E-10	9.76E-10	9.76E-10	9.76E-10	9.76E-10	9.76E-10	9.76E-10	9.76E-10	9.76E-10	9.76E-10
Strontium-90 + D	2.26E-02	1.93E-03	1.64E-04	1.40E-05	1.19E-06	1.02E-07	8.67E-09	7.39E-10	6.30E-11	5.37E-12
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	4.27E-09	4.27E-09	4.26E-09	4.26E-09	4.26E-09	4.26E-09	4.26E-09	4.26E-09	4.26E-09	4.25E-09
Total Dose	**3.17E-02**	**5.89E-03**	**3.27E-03**	**2.74E-03**	**2.43E-03**	**2.19E-03**	**1.98E-03**	**1.81E-03**	**1.66E-03**	**1.54E-03**

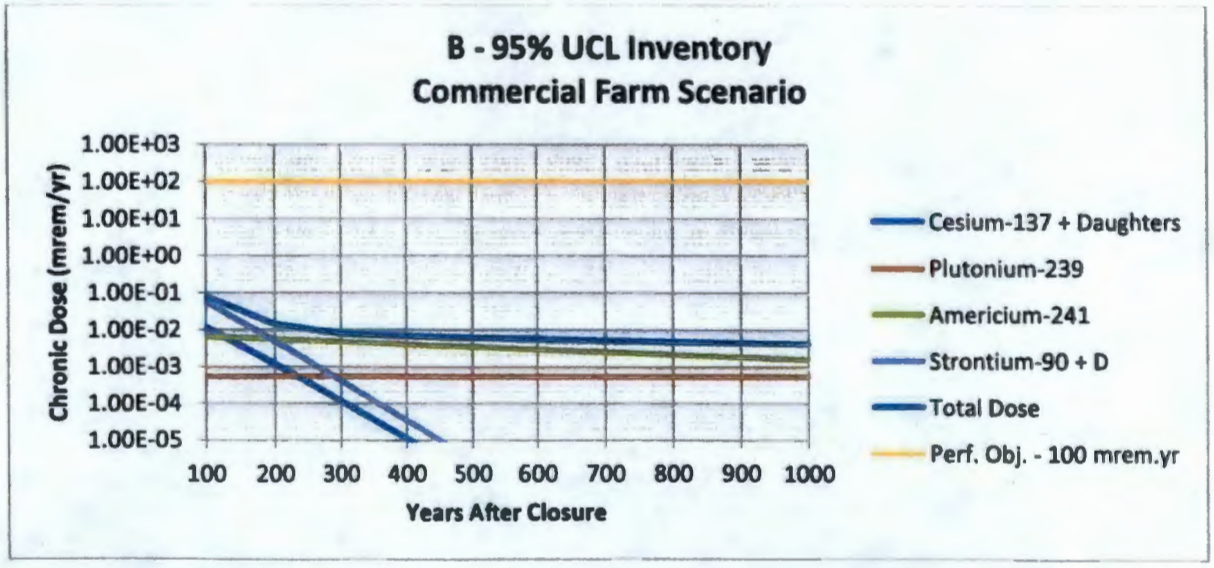
Table D-8. Commercial Farm Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
B – 95% Upper Confidence Level Inventory										
Antimony-125	1.54E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	4.24E-05	4.24E-05	4.24E-05	4.24E-05	4.24E-05	4.23E-05	4.23E-05	4.23E-05	4.23E-05	4.23E-05
Iodine-129	3.08E-08	3.08E-08	3.08E-08	3.08E-08	3.08E-08	3.08E-08	3.08E-08	3.08E-08	3.08E-08	3.08E-08
Cesium-137 + Daughters	1.13E-02	1.12E-03	1.11E-04	1.10E-05	1.09E-06	1.08E-07	1.08E-08	1.07E-09	1.06E-10	1.05E-11
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	5.20E-10	5.14E-10	5.08E-10	5.02E-10	4.96E-10	4.90E-10	4.84E-10	4.78E-10	4.72E-10	4.67E-10
Europium-152	3.35E-05	1.85E-07	1.02E-09	5.63E-12	3.12E-14	2.99E-16	1.28E-16	1.27E-16	1.27E-16	1.27E-16
Europium-154	9.74E-07	3.05E-10	9.57E-14	3.00E-17	9.41E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.03E-11	3.80E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	6.23E-05	7.89E-05	9.47E-05	1.10E-04	1.24E-04	1.38E-04	1.52E-04	1.64E-04	1.76E-04	1.88E-04
Protactinium-231	1.59E-03	1.60E-03	1.60E-03	1.60E-03	1.59E-03	1.59E-03	1.59E-03	1.58E-03	1.58E-03	1.58E-03
Thorium-232	2.67E-08	2.67E-08	2.67E-08	2.67E-08	2.67E-08	2.67E-08	2.67E-08	2.67E-08	2.67E-08	2.67E-08
Uranium-233	3.43E-07	4.87E-07	6.29E-07	7.71E-07	9.11E-07	1.05E-06	1.19E-06	1.32E-06	1.46E-06	1.59E-06
Uranium-234	5.73E-07	5.84E-07	5.98E-07	6.14E-07	6.32E-07	6.52E-07	6.75E-07	6.99E-07	7.26E-07	7.54E-07
Uranium-235 + D	1.11E-07	1.16E-07	1.22E-07	1.27E-07	1.32E-07	1.38E-07	1.43E-07	1.48E-07	1.53E-07	1.59E-07
Uranium-236	9.89E-09	9.89E-09	9.89E-09	9.89E-09	9.89E-09	9.89E-09	9.89E-09	9.89E-09	9.89E-09	9.89E-09
Neptunium-237 + D	2.22E-06	2.22E-06	2.22E-06	2.22E-06	2.22E-06	2.22E-06	2.22E-06	2.22E-06	2.22E-06	2.22E-06

Table D-8. Commercial Farm Doses (mrem/yr) for Single-Shell Tank 241-C-111 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Plutonium-238	2.56E-05	1.16E-05	5.27E-06	2.39E-06	1.09E-06	4.93E-07	2.25E-07	1.03E-07	4.72E-08	2.21E-08
Uranium-238 + D	6.11E-07	6.11E-07	6.11E-07	6.11E-07	6.11E-07	6.11E-07	6.11E-07	6.11E-07	6.11E-07	6.12E-07
Plutonium-239	5.33E-04	5.31E-04	5.30E-04	5.28E-04	5.27E-04	5.25E-04	5.24E-04	5.22E-04	5.21E-04	5.19E-04
Plutonium-240	5.74E-05	5.68E-05	5.62E-05	5.56E-05	5.50E-05	5.44E-05	5.38E-05	5.33E-05	5.27E-05	5.22E-05
Americium-241	6.24E-03	5.31E-03	4.53E-03	3.86E-03	3.29E-03	2.80E-03	2.39E-03	2.03E-03	1.73E-03	1.48E-03
Plutonium-241 + D	1.48E-05	1.26E-05	1.07E-05	9.16E-06	7.80E-06	6.65E-06	5.67E-06	4.83E-06	4.11E-06	3.51E-06
Curium-242	3.64E-08	1.65E-08	7.49E-09	3.40E-09	1.54E-09	7.01E-10	3.19E-10	1.45E-10	6.67E-11	3.11E-11
Plutonium-242	2.11E-05	2.11E-05	2.11E-05	2.11E-05	2.11E-05	2.11E-05	2.11E-05	2.11E-05	2.11E-05	2.11E-05
Curium-243	2.90E-07	3.23E-08	9.66E-09	7.65E-09	7.45E-09	7.41E-09	7.39E-09	7.37E-09	7.35E-09	7.33E-09
Curium-244	9.02E-07	3.40E-07	3.25E-07	3.21E-07	3.18E-07	3.14E-07	3.11E-07	3.08E-07	3.04E-07	3.01E-07
Tritium	5.56E-11	2.01E-13	7.28E-16	2.63E-18	9.53E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	1.35E-09	2.62E-15	5.10E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	6.85E-08	3.43E-08	1.71E-08	8.58E-09	4.29E-09	2.15E-09	1.07E-09	5.38E-10	2.69E-10	1.35E-10
Selenium-79	2.95E-09	2.95E-09	2.95E-09	2.95E-09	2.95E-09	2.95E-09	2.95E-09	2.95E-09	2.95E-09	2.95E-09
Strontium-90 + D	5.54E-02	4.72E-03	4.03E-04	3.43E-05	2.92E-06	2.49E-07	2.12E-08	1.81E-09	1.54E-10	1.32E-11
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	8.59E-09	8.58E-09	8.58E-09	8.58E-09	8.57E-09	8.57E-09	8.57E-09	8.57E-09	8.56E-09	8.56E-09
Total Dose	**7.54E-02**	**1.35E-02**	**7.42E-03**	**6.28E-03**	**5.67E-03**	**5.19E-03**	**4.78E-03**	**4.43E-03**	**4.14E-03**	**3.88E-03**

Figure D-4. Comparison of Doses from Commercial Farm Scenario with Performance Objective for Chronic Exposure for Key Analytes within A) Average Inventory and B) 95% Upper Confidence Level Inventory Estimated for Residual Wastes in Single-Shell Tank 241-C-111.



UCL = upper confidence level

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
1, 1, 1-Trichloroethane*	9.16E-04	2.71E-03	1.60E+05	7.00E+06	1.58E+00	No
1, 1, 2-Trichloro-1, 2, 2-trifluoroethane	1.16E-03	3.43E-03	–	–	–	No
1, 1, 2-Trichloroethane*	1.65E-03	4.88E-03	1.75E+01	2.30E+03	4.27E-03	No
1, 1-Dichloroethene*	4.21E-03	1.25E-02	4.00E+03	1.75E+05	5.01E-02	No
1, 2, 4-Trichlorobenzene*	1.93E-03	5.71E-03	3.45E+01	4.53E+03	5.63E-02	No
o-Dichlorobenzene*	1.21E-03	3.58E-03	7.20E+03	3.15E+05	7.03E+00	No
1, 2-Dichloroethane*	5.35E-04	1.58E-03	1.10E+01	1.44E+03	2.32E-03	No
1, 4-Dichlorobenzene	8.92E-04	2.64E-03	1.85E+02	2.43E+04	1.34E-01	No
n-Butyl alcohol (1-butanol)	1.02E-01	3.02E-01	8.00E+03	3.50E+05	–	No
2, 4, 5-Trichlorophenol*	4.17E-01	1.23E+00	8.00E+03	3.50E+05	2.88E+01	No
2, 4, 6-Trichlorophenol	5.83E-01	1.73E+00	8.00E+01	3.50E+03	4.62E-02	No
2, 4-Dinitrotoluene*	3.23E-01	9.56E-01	3.23E+00	4.23E+02	1.67E-03	No
2, 6-Bis (tert-butyl)-4-methylphenol	7.91E-01	2.34E+00	–	–	–	No
2-Butanone (MEK)	3.95E-02	1.17E-01	4.80E+04	2.10E+06	1.97E+01	No
2-Chlorophenol*	4.94E-01	1.46E+00	4.00E+02	1.75E+04	4.72E-01	No
2-Ethoxyethanol	6.39E-01	1.89E+00	–	–	–	No
2-Methylphenol (o-cresol)	3.73E-01	1.10E+00	4.00E+03	1.75E+05	2.33E+00	No
o-Nitrophenol	6.27E-01	1.86E+00	–	–	–	No
2-Nitropropane*	5.85E-03	1.73E-02	–	–	–	No
p-Chloro-m-cresol (4-Chloro-3-methylphenol)*	5.01E-01	1.48E+00	8.00E+03	3.50E+05	2.21E+01	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
4-Methyl-2-pentanone (MIBK)	1.70E-02	5.03E-02	6.40E+03	2.80E+05	2.73E+00	No
o-Nitrophenol	6.27E-01	1.86E+00	--	--	--	No
Acenaphthene	4.38E-01	1.30E+00	4.80E+03	2.10E+05	4.90E+01	No
Acetate	1.93E+02	3.10E+02	--	--	--	Yes
2-Propanone (Acetone)	1.29E-01	3.82E-01	7.20E+04	3.15E+06	2.89E+01	No
Silver*	1.96E+02	5.18E+02	4.00E+02	1.75E+04	1.36E+01	Yes
Aluminum	8.04E+04	1.50E+05	8.00E+04	3.50E+06	4.80E+05	Yes
Polychlorinated Biphenyls*	1.14E-02	3.37E-02	5.00E-01	6.56E+01	--	No
Arsenic*	3.18E+01	9.41E+01	6.67E-01	8.75E+01	3.41E-02	No
Boron	4.24E+00	1.26E+01	1.60E+04	7.00E+05	2.05E+02	No
Barium*	5.88E+00	1.26E+01	--	--	--	Yes
Beryllium*	2.12E+00	6.28E+00	1.60E+02	7.00E+03	6.32E+01	No
Benzene*	1.47E-03	4.35E-03	1.82E+01	2.39E+03	4.48E-03	No
Benzo[a]pyrene*	6.64E-01	1.97E+00	1.37E-01	1.80E+01	2.32E-01	No
Bismuth	2.94E+02	4.37E+02	--	--	--	Yes
Di (2-ethylhexyl) phthalate (DEHP)	3.79E+00	5.08E+00	7.14E+01	9.38E+03	1.34E+01	Yes
Bromide	7.14E+01	2.11E+02	--	--	--	No
Butylbenzylphthalate*	1.98E+00	2.29E+00	5.26E+02	6.91E+04	1.29E+01	Yes
Calcium	3.58E+03	9.53E+03	--	--	--	Yes
Carbon disulfide*	1.60E-03	4.74E-03	8.00E+03	3.50E+05	5.65E+00	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Carbon tetrachloride*	9.29E-04	2.75E-03	1.43E+01	1.88E+03	5.75E-03	No
Cadmium*	3.34E+00	9.89E+00	8.00E+01	3.50E+03	6.90E-01	No
Cerium	2.00E+02	2.78E+02	--	--	--	Yes
Chlorobenzene*	8.60E-04	2.55E-03	1.60E+03	7.00E+04	8.74E-01	No
Chloroform*	1.30E-03	3.85E-03	3.23E+01	4.23E+03	7.51E-03	No
Chloride	8.56E+01	2.53E+02	--	--	1.00E+03	No
Cyanide*	1.69E+01	3.73E+01	4.80E+01	2.10E+03	9.70E-01	Yes
Cobalt	2.94E+00	8.70E+00	2.40E+01	1.05E+03	4.34E+00	No
Chromium, Total*	5.65E+01	1.02E+02	1.20E+05	5.25E+06	2.00E+03	Yes
Cresylic acid (cresol, mixed isomers)*	4.71E-01	1.39E+00	--	--	--	No
Copper	1.92E+01	3.05E+01	3.20E+03	1.40E+05	2.84E+02	Yes
Cyclohexanone	6.16E-01	1.82E+00	4.00E+05	1.75E+07	--	No
Dibenz[a, h]anthracene*	3.16E-01	9.35E-01	1.37E+00	1.80E+02	4.29E+00	No
Diethyl phthalate*	5.84E-01	1.73E+00	6.40E+04	2.80E+06	7.22E+01	No
Di-n-butylphthalate*	1.90E+00	5.62E+00	8.00E+03	3.50E+05	5.66E+01	No
Di-n-octylphthalate*	3.89E-01	1.15E+00	9.60E+02	4.20E+04	3.19E+05	No
N, N-Diphenylamine*	3.02E-01	8.94E-01	--	--	--	No
Ethyl Acetate	5.84E-03	1.73E-02	7.20E+04	3.15E+06	2.97E+01	No
Diethyl ether	2.55E-03	7.55E-03	1.60E+04	7.00E+05	6.85E+00	No
Ethylbenzene	1.07E-03	3.17E-03	9.09E+01	1.19E+04	3.44E-02	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Europium	2.38E+00	7.04E+00	–	–	–	No
Fluoride	9.82E+03	1.11E+04	4.80E+03	2.10E+05	2.88E+03	Yes
Iron	1.04E+04	1.86E+04	5.60E+04	2.45E+06	5.64E+03	Yes
Fluoranthene*	1.72E+00	5.09E+00	3.20E+03	1.40E+05	6.31E+02	No
Formate+A2	2.39E+02	7.07E+02	–	–	–	No
Hydroxide OH	2.42E+02	5.29E+02	–	–	–	Yes
Glycolate C2H3O3	7.61E+01	2.25E+02	–	–	–	No
Hexachlorobenzene*	2.84E-01	8.41E-01	6.25E-01	8.20E+01	8.77E-02	No
Hexachlorobutadiene*	5.70E-01	1.69E+00	1.28E+01	1.68E+03	6.05E-01	No
Hexachloroethane*	1.40E-03	4.14E-03	2.50E+01	2.45E+03	4.36E-02	No
Mercury*	2.78E+00	4.94E+00	2.40E+01	1.05E+03	2.09E+00	Yes
Isobutanol	6.92E+00	2.05E+01	2.40E+04	1.05E+06	–	No
Potassium	6.89E+01	2.04E+02	–	–	–	No
Lanthanum	5.33E+01	9.39E+01	–	–	–	Yes
Lithium	2.64E+00	7.81E+00	1.60E+02	7.00E+03	1.92E+02	No
Dichloromethane (methylene chloride)*	6.37E-04	1.89E-03	4.80E+02	2.10E+04	2.18E-02	No
Magnesium	1.09E+02	2.72E+02	–	–	–	Yes
Manganese	5.19E+01	1.00E+02	1.12E+04	4.90E+05	5.01E+02	Yes
Molybdenum	4.48E+00	1.33E+01	4.00E+02	1.75E+04	3.23E+01	No
n-Nitrosomorpholine*	5.67E-01	1.68E+00	1.49E-01	1.96E+01	–	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Sodium	1.92E+05	2.21E+05	–	–	–	Yes
Naphthalene*	4.80E-01	1.42E+00	1.60E+03	7.00E+04	4.45E+00	No
Niobium	1.27E+01	3.76E+01	–	–	–	No
Neodymium	9.27E+01	1.60E+02	–	–	–	Yes
Ammonia	2.91E+00	5.09E+00	–	–	–	Yes
Nickel*	1.37E-01	2.36E-01	–	–	–	Yes
Nitrobenzene*	4.89E-01	1.45E+00	1.60E+02	7.00E+03	1.02E-01	No
N-Nitroso-N, N-dimethylamine*	5.28E-01	1.56E+00	1.96E-02	2.57E+00	–	No
N-nitroso-di-n-propylamine	5.10E-01	1.51E+00	1.43E-01	1.88E+01	5.60E-05	No
Nitrite[c]	1.14E+03	2.80E+03	2.40E+04	1.05E+06	1.32E+01	Yes
Nitrate[d]	2.36E+03	5.91E+03	5.68E+05	2.49E+07	1.80E+02	Yes
Oxalate	2.09E+02	6.19E+02	–	–	–	No
Lead*	2.65E+03	5.32E+03	–	1.00E+03	3.00E+03	Yes
Palladium	2.55E+01	7.55E+01	–	–	–	No
Pentachlorophenol*	2.88E-01	8.52E-01	2.50E+00	3.28E+02	3.47E-03	No
Phenol*	5.14E-01	1.52E+00	2.40E+04	1.05E+06	1.10E+01	No
Phosphate	1.91E+05	2.33E+05	–	–	–	Yes
Praseodymium	5.63E+01	1.67E+02	–	–	–	No
Pyrene	9.61E-01	2.84E+00	2.40E+03	1.05E+05	3.27E+02	No
Pyridine*	6.34E-01	1.88E+00	8.00E+01	3.50E+03	–	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Rubidium	1.21E+02	3.58E+02	--	--	--	No
Rhodium	2.55E+01	7.55E+01	--	--	--	No
Ruthenium	1.06E+01	3.14E+01	--	--	--	No
Antimony*	6.04E-01	1.79E+00	--	--	--	No
Selenium*	2.15E-04	6.36E-04	--	--	--	No
Silicon	3.52E+03	5.67E+03	--	--	--	Yes
Samarium	5.68E+01	8.15E+01	--	--	--	Yes
Tin	1.70E+01	5.03E+01	4.80E+04	2.10E+06	4.80E+04	No
Sulfate	5.69E+02	9.94E+02	--	--	1.00E+03	Yes
Strontium	7.97E+01	1.57E+02	4.80E+04	2.10E+06	6.76E+03	Yes
Tantalum	1.08E+01	3.20E+01	--	--	--	No
Tellurium	1.91E+01	5.65E+01	--	--	--	No
Tetrachloroethylene*	1.09E-03	3.23E-03	4.76E+02	2.10E+04	5.30E-02	No
Thorium	1.00E+00	2.37E+00	--	--	--	Yes
Titanium	4.17E+01	1.16E+02	--	--	--	Yes
Thallium*	3.18E+01	9.41E+01	--	--	2.28E-01	No
Toluene*	7.98E-04	2.36E-03	6.40E+03	2.80E+05	4.65E+00	No
1,3-Dichloropropene (cis & trans)*	#N/A	7.99E-03	--	--	--	No
Tributyl phosphate	1.26E+00	2.11E+00	1.11E+02	1.46E+04	4.96E-01	Yes
1, 1, 2-Trichloroethylene	1.20E-03	3.55E-03	2.17E+01	1.75E+03	6.29E-03	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-111, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Trichlorofluoromethane*	9.35E-04	2.77E-03	2.40E+04	1.05E+06	2.82E+01	No
Uranium	7.73E+02	1.83E+03	2.40E+02	1.05E+04	2.70E+02	Yes
Vanadium	7.21E+00	9.61E+00	4.00E+02	1.75E+04	1.60E+03	Yes
Chloroethene(vinyl chloride)*	1.73E-03	5.12E-03	1.39E+00	1.82E+02	3.83E-04	No
Tungsten	3.40E+01	1.01E+02	--	--	--	No
m-Xylene	1.67E-03	4.94E-03	1.60E+04	7.00E+05	1.35E+01	No
o-Xylene	9.16E-04	2.71E-03	1.60E+04	7.00E+05	1.47E+01	No
Xylenes	4.04E-04	1.20E-03	1.60E+04	7.00E+05	1.46E+01	No
Yttrium	9.23E+00	1.46E+01	--	--	--	Yes
Zinc	7.64E+01	2.26E+02	2.40E+04	1.05E+06	5.97E+03	No
Zirconium	4.12E+01	7.50E+01	--	--	--	Yes

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-59714, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment*."

[b] 95% Upper Confidence Level Concentration = Mean Concentration + (1.96 × Mean Concentration × Relative Standard Deviation). Mean Concentrations and Relative Standard Deviation provided in Table A-1 in Appendix A of RPP-RPT-59714.

[c] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

[d] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

* Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-111 Tank Residual Wastes. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
1, 1, 1-Trichloroethane*	9.16E-04	5.73E-09	1.31E-10	5.78E-04	No
1, 1, 2-Trichloro-1, 2, 2-trifluoroethane	1.16E-03	--	--	--	No
1, 1, 2-Trichloroethane*	1.65E-03	9.41E-05	7.17E-07	3.86E-01	No
1, 1-Dichloroethene*	4.21E-03	1.05E-06	2.41E-08	8.41E-02	No
1, 2, 4-Trichlorobenzene*	1.93E-03	5.60E-05	4.26E-07	3.43E-02	No
o-Dichlorobenzene*	1.21E-03	1.68E-07	3.84E-09	1.72E-04	No
1, 2-Dichloroethane*	5.35E-04	4.87E-05	3.71E-07	2.30E-01	No
1, 4-Dichlorobenzene	8.92E-04	4.82E-06	3.67E-08	6.68E-03	No
n-Butyl alcohol (1-butanol)	1.02E-01	1.28E-05	2.91E-07	--	No
2, 4, 5-Trichlorophenol*	4.17E-01	5.21E-05	1.19E-06	1.45E-02	No
2, 4, 6-Trichlorophenol	5.83E-01	7.29E-03	1.67E-04	1.26E+01	No
2, 4-Dinitrotoluene*	3.23E-01	1.00E-01	7.63E-04	1.94E+02	No
2, 6-Bis (tert-butyl)-4-methylphenol	7.91E-01	--	--	--	No
2-Butanone (MEK)	3.95E-02	8.23E-07	1.88E-08	2.01E-03	No
2-Chlorophenol*	4.94E-01	1.24E-03	2.82E-05	1.05E+00	No
2-Ethoxyethanol	6.39E-01	--	--	--	No
2-Methylphenol (o-cresol)	3.73E-01	9.33E-05	2.13E-06	1.60E-01	No
o-Nitrophenol	6.27E-01	--	--	--	No
2-Nitropropane*	5.85E-03	--	--	--	No
p-Chloro-m-cresol (4-Chloro-3-methylphenol)*	5.01E-01	6.26E-05	1.43E-06	2.26E-02	No

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-111 Tank Residual Wastes. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
4-Methyl-2-pentanone (MIBK)	1.70E-02	2.66E-06	6.07E-08	6.23E-03	No
o-Nitrophenol	6.27E-01	–	–	–	No
Acenaphthene	4.38E-01	9.13E-05	2.09E-06	8.95E-03	No
Acetate	1.93E+02	–	–	–	Yes
2-Propanone (Acetone)	1.29E-01	1.79E-06	4.10E-08	4.46E-03	No
Silver*	1.96E+02	4.90E-01	1.12E-02	1.44E+01	Yes
Aluminum	8.04E+04	1.01E+00	2.30E-02	1.67E-01	Yes
Polychlorinated Biphenyls*	1.14E-02	2.28E-02	1.74E-04	–	No
Arsenic*	3.18E+01	4.77E+01	3.63E-01	9.33E+02	No
Boron	4.24E+00	2.65E-04	6.06E-06	2.07E-02	No
Barium*	5.88E+00	–	–	–	Yes
Beryllium*	2.12E+00	1.33E-02	3.03E-04	3.35E-02	No
Benzene*	1.47E-03	8.09E-05	6.16E-07	3.28E-01	No
Benzo[a]pyrene*	6.64E-01	4.85E+00	3.69E-02	2.86E+00	No
Bismuth	2.94E+02	–	–	–	Yes
Di (2-ethylhexyl) phthalate (DEHP)	3.79E+00	5.31E-02	4.04E-04	2.84E-01	Yes
Bromide	7.14E+01	–	–	–	No
Butylbenzylphthalate*	1.98E+00	3.76E-03	2.87E-05	1.54E-01	Yes
Calcium	3.58E+03	–	–	–	Yes
Carbon disulfide*	1.60E-03	2.00E-07	4.57E-09	2.83E-04	No

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-111 Tank Residual Wastes. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Carbon tetrachloride*	9.29E-04	6.50E-05	4.95E-07	1.61E-01	No
Cadmium*	3.34E+00	4.18E-02	9.54E-04	4.84E+00	No
Cerium	2.00E+02	--	--	--	Yes
Chlorobenzene*	8.60E-04	5.38E-07	1.23E-08	9.84E-04	No
Chloroform*	1.30E-03	4.03E-05	3.07E-07	1.73E-01	No
Chloride	8.56E+01	--	--	8.56E-02	No
Cyanide*	1.69E+01	3.52E-01	8.05E-03	1.74E+01	Yes
Cobalt	2.94E+00	1.23E-01	2.80E-03	6.78E-01	No
Chromium, Total*	5.65E+01	4.71E-04	1.08E-05	2.82E-02	Yes
Cresylic acid (cresol, mixed isomers)*	4.71E-01	--	--	--	No
Copper	1.92E+01	6.00E-03	1.37E-04	6.76E-02	Yes
Cyclohexanone	6.16E-01	1.54E-06	3.52E-08	--	No
Dibenz[a, h]anthracene*	3.16E-01	2.31E-01	1.76E-03	7.37E-02	No
Diethyl phthalate *	5.84E-01	9.13E-06	2.09E-07	8.09E-03	No
Di-n-butylphthalate*	1.90E+00	2.38E-04	5.43E-06	3.35E-02	No
Di-n-octylphthalate*	3.89E-01	4.05E-04	9.26E-06	1.22E-06	No
N, N-Diphenylamine*	3.02E-01	--	--	--	No
Ethyl Acetate	5.84E-03	8.11E-08	1.85E-09	1.97E-04	No
Diethyl ether	2.55E-03	1.59E-07	3.64E-09	3.72E-04	No
Ethylbenzene	1.07E-03	1.18E-05	8.97E-08	3.11E-02	No

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-111 Tank Residual Wastes. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Europium	2.38E+00	–	–	–	No
Fluoride	9.82E+03	2.05E+00	4.68E-02	3.41E+00	Yes
Iron	1.04E+04	1.86E-01	4.24E-03	1.84E+00	Yes
Fluoranthene*	1.72E+00	5.38E-04	1.23E-05	2.73E-03	No
Formate+A2	2.39E+02	–	–	–	No
Hydroxide OH	2.42E+02	–	–	–	Yes
Glycolate C2H3O3	7.61E+01	–	–	–	No
Hexachlorobenzene*	2.84E-01	4.54E-01	3.46E-03	3.24E+00	No
Hexachlorobutadiene*	5.70E-01	4.45E-02	3.39E-04	9.42E-01	No
Hexachloroethane*	1.40E-03	5.60E-05	5.71E-07	3.21E-02	No
Mercury*	2.78E+00	1.16E-01	2.65E-03	1.33E+00	Yes
Isobutanol	6.92E+00	2.88E-04	6.59E-06	–	No
Potassium	6.89E+01	–	–	–	No
Lanthanum	5.33E+01	–	–	–	Yes
Lithium	2.64E+00	1.65E-02	3.77E-04	1.37E-02	No
Dichloromethane (methylene chloride)*	6.37E-04	1.33E-06	3.03E-08	2.92E-02	No
Magnesium	1.09E+02	–	–	–	Yes
Manganese	5.19E+01	4.63E-03	1.06E-04	1.04E-01	Yes
Molybdenum	4.48E+00	1.12E-02	2.56E-04	1.39E-01	No
n-Nitrosomorpholine*	5.67E-01	3.80E+00	2.89E-02	–	No

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-111 Tank Residual Wastes. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Sodium	1.92E+05	--	--	--	Yes
Naphthalene*	4.80E-01	3.00E-04	6.86E-06	1.08E-01	No
Niobium	1.27E+01	--	--	--	No
Neodymium	9.27E+01	--	--	--	Yes
Ammonia	2.91E+00	--	--	--	Yes
Nickel*	1.37E-01	--	--	--	Yes
Nitrobenzene*	4.89E-01	3.06E-03	6.99E-05	4.79E+00	No
N-Nitroso-N, N-dimethylamine*	5.28E-01	2.69E+01	2.05E-01	--	No
N-nitroso-di-n-propylamine	5.10E-01	3.57E+00	2.72E-02	9.11E+03	No
Nitrite[b]	1.14E+03	4.75E-02	1.09E-03	8.64E+01	Yes
Nitrate[c]	2.36E+03	4.15E-03	9.50E-05	1.31E+01	Yes
Oxalate	2.09E+02	--	--	--	No
Lead*	2.65E+03	--	2.65E+00	8.83E-01	Yes
Palladium	2.55E+01	--	--	--	No
Pentachlorophenol*	2.88E-01	1.15E-01	8.78E-04	8.31E+01	No
Phenol*	5.14E-01	2.14E-05	4.90E-07	4.68E-02	No
Phosphate	1.91E+05	--	--	--	Yes
Praseodymium	5.63E+01	--	--	--	No
Pyrene	9.61E-01	4.00E-04	9.15E-06	2.94E-03	No
Pyridine*	6.34E-01	7.93E-03	1.81E-04	--	No

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-111 Tank Residual Wastes. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Rubidium	1.21E+02	--	--	--	No
Rhodium	2.55E+01	--	--	--	No
Ruthenium	1.06E+01	--	--	--	No
Antimony*	6.04E-01	--	--	--	No
Selenium*	2.15E-04	--	--	--	No
Silicon	3.52E+03	--	--	--	Yes
Samarium	5.68E+01	--	--	--	Yes
Tin	1.70E+01	3.54E-04	8.10E-06	3.54E-04	No
Sulfate	5.69E+02	--	--	5.69E-01	Yes
Strontium	7.97E+01	1.66E-03	3.80E-05	1.18E-02	Yes
Tantalum	1.08E+01	--	--	--	No
Tellurium	1.91E+01	--	--	--	No
Tetrachloroethylene*	1.09E-03	2.29E-06	5.19E-08	2.06E-02	No
Thorium	1.00E+00	--	--	--	Yes
Titanium	4.17E+01	--	--	--	Yes
Thallium*	3.18E+01	--	--	1.40E+02	No
Toluene*	7.98E-04	1.25E-07	2.85E-09	1.71E-04	No
1,3-Dichloropropene (cis & trans)*	#N/A	--	--	--	No
Tributyl phosphate	1.26E+00	1.13E-02	8.64E-05	2.54E+00	Yes
1, 1, 2-Trichloroethylene	1.20E-03	5.52E-05	6.86E-07	1.91E-01	No

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-111 Tank Residual Wastes. (7 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Trichlorofluoromethane*	9.35E-04	3.90E-08	8.90E-10	3.32E-05	No
Uranium	7.73E+02	3.22E+00	7.36E-02	2.86E+00	Yes
Vanadium	7.21E+00	1.80E-02	4.12E-04	4.51E-03	Yes
Chloroethene(vinyl chloride)*	1.73E-03	1.25E-03	9.49E-06	4.52E+00	No
Tungsten	3.40E+01	--	--	--	No
m-Xylene	1.67E-03	1.04E-07	2.39E-09	1.24E-04	No
o-Xylene	9.16E-04	5.73E-08	1.31E-09	6.23E-05	No
Xylenes	4.04E-04	2.53E-08	5.77E-10	2.76E-05	No
Yttrium	9.23E+00	--	--	--	Yes
Zinc	7.64E+01	3.18E-03	7.28E-05	1.28E-02	No
Zirconium	4.12E+01	--	--	--	Yes

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-59714, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment*."

[b] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

[c] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

* Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Table D-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Hazardous Constituents above Detection in 241-C-111 Tank Residual Wastes. (3 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Acetate	3.10E+02	--	--	--	Yes
Silver*	5.18E+02	1.29E+00	2.96E-02	3.81E+01	Yes
Aluminum	1.50E+05	1.88E+00	4.29E-02	3.13E-01	Yes
Barium*	1.26E+01	--	--	--	Yes
Bismuth	4.37E+02	--	--	--	Yes
Di (2-ethylhexyl) phthalate (DEHP)	5.08E+00	7.11E-02	5.41E-04	3.80E-01	Yes
Butylbenzylphthalate*	2.29E+00	4.36E-03	3.32E-05	1.78E-01	Yes
Calcium	9.53E+03	--	--	--	Yes
Cerium	2.78E+02	--	--	--	Yes
Cyanide*	3.73E+01	7.76E-01	1.77E-02	3.84E+01	Yes
Chromium, Total*	1.02E+02	8.49E-04	1.94E-05	5.09E-02	Yes
Copper	3.05E+01	9.52E-03	2.18E-04	1.07E-01	Yes
Fluoride	1.11E+04	2.31E+00	5.29E-02	3.85E+00	Yes
Iron	1.86E+04	3.33E-01	7.61E-03	3.30E+00	Yes
Hydroxide OH	5.29E+02	--	--	--	Yes
Mercury*	4.94E+00	2.06E-01	4.70E-03	2.36E+00	Yes
Lanthanum	9.39E+01	--	--	--	Yes
Magnesium	2.72E+02	--	--	--	Yes

Table D-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Hazardous Constituents above Detection in 241-C-111 Tank Residual Wastes. (3 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Manganese	1.00E+02	8.93E-03	2.04E-04	2.00E-01	Yes
Sodium	2.21E+05	--	--	--	Yes
Neodymium	1.60E+02	--	--	--	Yes
Ammonia	5.09E+00	--	--	--	Yes
Nickel*	2.36E-01	--	--	--	Yes
Nitrite[b]	2.80E+03	1.17E-01	2.67E-03	2.12E+02	Yes
Nitrate[c]	5.91E+03	1.04E-02	2.38E-04	3.28E+01	Yes
Lead*	5.32E+03	--	5.32E+00	1.77E+00	Yes
Phosphate	2.33E+05	--	--	--	Yes
Silicon	5.67E+03	--	--	--	Yes
Samarium	8.15E+01	--	--	--	Yes
Sulfate	9.94E+02	--	--	9.94E-01	Yes
Strontium	1.57E+02	3.26E-03	7.46E-05	2.32E-02	Yes
Thorium	2.37E+00	--	--	--	Yes
Titanium	1.16E+02	--	--	--	Yes
Tributyl phosphate	2.11E+00	1.90E-02	1.45E-04	4.25E+00	Yes
Uranium	1.83E+03	7.62E+00	1.74E-01	6.77E+00	Yes

Table D-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Hazardous Constituents above Detection in 241-C-111 Tank Residual Wastes. (3 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-111 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Vanadium	9.61E+00	2.40E-02	5.49E-04	6.01E-03	Yes
Yttrium	1.46E+01	--	--	--	Yes
Zirconium	7.50E+01	--	--	--	Yes

[a] 95% Upper Confidence Level Concentration = Mean Concentration + (1.96 × Mean Concentration × Relative Standard Deviation). Mean Concentrations and Relative Standard Deviation provided in Table A-1, Appendix A of RPP-RPT-59714, "*Tank 241-C-111 Residual Waste Inventory Estimates for Component Closure Risk Assessment*."

[b] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

[c] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

* Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Table D-12. Background Data for Selected Constituents for the Hanford Site. (3 sheets)

Analyte Name	Analyte Symbol	Analyte Class	Units	Lognormal 90th Percentile Background Value	Maximum Background Value	Source of Background Value
Cesium-137	Cs-137	RAD	pCi/g	1.1	1.6	DOE/RL-96-12, Rev. 0
Cobalt-60	Co-60	RAD	pCi/g	0.0084	0.039	DOE/RL-96-12, Rev. 0
Europium-154	Eu-154	RAD	pCi/g	0.033	0.079	DOE/RL-96-12, Rev. 0
Europium-155	Eu-155	RAD	pCi/g	0.054	0.1	DOE/RL-96-12, Rev. 0
Gross Beta	—	RAD	pCi/g	23	25	DOE/RL-96-12, Rev. 0
Plutonium-238	Pu-238	RAD	pCi/g	0.0038	0.019	DOE/RL-96-12, Rev. 0
Plutonium-239/240	Pu-239-240	RAD	pCi/g	0.025	0.033	DOE/RL-96-12, Rev. 0
Potassium-40	K-40	RAD	pCi/g	17	20	DOE/RL-96-12, Rev. 0
Radium-226	Ra-226	RAD	pCi/g	0.82	1.2	DOE/RL-96-12, Rev. 0
Strontium-90	Sr-90	RAD	pCi/g	0.18	0.37	DOE/RL-96-12, Rev. 0
Thorium-232	Th-232	RAD	pCi/g	1.3	1.6	DOE/RL-96-12, Rev. 0
Total beta radiostrontium	—	RAD	pCi/g	0.18	0.37	DOE/RL-96-12, Rev. 0
Uranium-233/234	U-233/234	RAD	pCi/g	1.1	1.5	DOE/RL-96-12, Rev. 0
Uranium-234	U-234	RAD	pCi/g	1.1	1.5	DOE/RL-96-12, Rev. 0
Uranium-235	U-235	RAD	pCi/g	0.11	0.39	DOE/RL-96-12, Rev. 0
Aluminum	Al	Metal	µg/kg	1.18E+07	28,800,000	DOE/RL-92-24, Vol. 1, Rev. 4
Antimony*	Sb	Metal	µg/kg	130	385	ECF-HANFORD-11-0038
Arsenic*	As	Metal	µg/kg	6,470	27,700	DOE/RL-92-24, Vol. 1, Rev. 4
Barium*	Ba	Metal	µg/kg	132,000	480,000	DOE/RL-92-24, Vol. 1, Rev. 4
Beryllium*	Be	Metal	µg/kg	1,510	10,000	DOE/RL-92-24, Vol. 1, Rev. 4
Boron	B	Metal	µg/kg	3,890	5,860	ECF-HANFORD-11-0038

Table D-12. Background Data for Selected Constituents for the Hanford Site. (3 sheets)

Analyte Name	Analyte Symbol	Analyte Class	Units	Lognormal 90th Percentile Background Value	Maximum Background Value	Source of Background Value
Cadmium*	Cd	Metal	µg/kg	563	2,900	ECF-HANFORD-11-0038
Calcium	Ca	Metal	µg/kg	1.72E+07	105,000,000	DOE/RL-92-24, Vol. 1, Rev. 4
Chromium	Cr	Metal	µg/kg	18,500	320,000	DOE/RL-92-24, Vol. 1, Rev. 4
Cobalt	Co	Metal	µg/kg	15,700	110,000	DOE/RL-92-24, Vol. 1, Rev. 4
Copper	Cu	Metal	µg/kg	22,000	61,000	DOE/RL-92-24, Vol. 1, Rev. 4
Iron	Fe	Metal	µg/kg	3.26E+07	68,100,000	DOE/RL-92-24, Vol. 1, Rev. 4
Lead*	Pb	Metal	µg/kg	10,200	74,100	DOE/RL-92-24, Vol. 1, Rev. 4
Lithium	Li	Metal	µg/kg	13,300	19,200	ECF-HANFORD-11-0038
Magnesium	Mg	Metal	µg/kg	7.06E+06	32,300,000	DOE/RL-92-24, Vol. 1, Rev. 4
Manganese	Mn	Metal	µg/kg	512,000	1,110,000	DOE/RL-92-24, Vol. 1, Rev. 4
Mercury*	Hg	Metal	µg/kg	13	29	ECF-HANFORD-11-0038
Molybdenum	Mo	Metal	µg/kg	470	3,170	ECF-HANFORD-11-0038
Nickel*	Ni	Metal	µg/kg	19,100	200,000	ECF-HANFORD-11-0038
Potassium	K	Metal	µg/kg	2.15E+06	7,900,000	ECF-HANFORD-11-0038
Selenium*	Se	Metal	µg/kg	780	840	Ecology Publication #94-115
Silver*	Ag	Metal	µg/kg	167	273	ECF-HANFORD-11-0038
Sodium	Na	Metal	µg/kg	690,000	6,060,000	DOE/RL-92-24, V.1, Rev.4
Thallium*	Tl	Metal	µg/kg	185	523	ECF-HANFORD-11-0038
Uranium	U	Metal	µg/kg	3,210	4,042	Isotopic Activity Conversion based on DOE/RL-96-12 values
Vanadium	V	Metal	µg/kg	85,100	140,000	DOE/RL-92-24, Vol. 1, Rev. 4

Table D-12. Background Data for Selected Constituents for the Hanford Site. (3 sheets)

Analyte Name	Analyte Symbol	Analyte Class	Units	Lognormal 90th Percentile Background Value	Maximum Background Value	Source of Background Value
Zinc	Zn	Metal	µg/kg	67,800	366,000	DOE/RL-92-24, Vol. 1, Rev. 4
Ammonia	NH_3	Anion	µg/kg	9,230	26,400	DOE/RL-92-24, Vol. 1, Rev. 4
Chloride	Cl	Anion	µg/kg	100,000	1,480,000	DOE/RL-92-24, Vol. 1, Rev. 4
Fluoride	F^-	Anion	µg/kg	2,810	73,300	DOE/RL-92-24, Vol. 1, Rev. 4
Nitrate	NO_3^-	Anion	µg/kg	52,000	906,000	DOE/RL-92-24, Vol. 1, Rev. 4
Phosphate	PO_4^-	Anion	µg/kg	785	225,000	DOE/RL-92-24, Vol. 1, Rev. 4
Sulfate	SO_4^-	Anion	µg/kg	237,000	12,600,000	DOE/RL-92-24, Vol. 1, Rev. 4

* Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List."

References:
DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analyte*, Rev. 4, Volume 1.
DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*, Rev. 0.
ECF-HANFORD-11-0038, "*Soil Background for Interim Use at the Hanford Site*."
Ecology Publication #94-115, Natural Background Soil Metals Concentrations in Washington State.