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RPP-22520, Rev. 2

241-C-101, 241-C-105, 241-C-110 and 241-C-111 Tanks Waste Retrieval Work Plan

JS Schofield
CH2M Hill Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL-14047

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Abstract: This document establishes the C-101, C-105, C-110 and C-111 Tanks Waste Retrieval Work Plan required by Hanford Federal Facility Agreement and Consent Order.

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RPP-22520
Revision 2

241-C-101, 241-C-105, 241-C-110 AND 241-C-111 TANKS WASTE RETRIEVAL WORK PLAN

J. S. Schofield
CH2M HILL Hanford Group, Inc.

Date Published
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Post Office Box 1500
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Prepared for the U. S. Department of Energy
Office of River Protection

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(2) Title: **241-C-101, 241-C-105, 241-C-110 and 241-C-111 Tanks Waste Retrieval Work Plan**

CHANGE CONTROL RECORD

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0	Initial Release RPP-22520, Rev. 0, per EDT 821208	DG Baide 11/16/04	WT Thompson 11/16/04
1	Revised per ECN 722248 R0, complete revision to incorporate ORP comments and consistency with similar primary documents.	DG Baide 12/16/04	WT Thompson 12/16/04
2 RS	Revised per ECN 723798 R0 to incorporate Ecology comments to date	D.B. Parkman D.B. Parkman 4/12/06	RE Bauer RE Bauer 4/17/06

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Page 1 of 2 ☒ DM ☐ FM ☐ TM

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R 0

1b. Proj. ECN N/A - - R

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17. Description of the Change (Use ECN Continuation pages as needed)
Replace RPP-22520 Rev 1 with RPP-22520 Rev 2 in its entirety.

18. Justification of the Change (Use ECN Continuation pages as needed)
The changes between Rev 1 and Rev 2 are made in response to comments by the Washington State Department of Ecology, to update schedule wording, and to revise incorrect wording related to HRR leak detection.

No USQ evaluation required, this document does not implement any temporary or permanent changes to the facility or procedures. JSS 4/12/06

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21. Revisions Planned (Include a brief description of the contents of each revision)

None planned.

Note: All revisions shall have the approvals of the affected organizations as identified in block 11 "Approval Designator," on page 1 of this ECN.

22. Commercial Grade Item Dedication Numbers (associated with this design change)	23. Engineering Data Transmittal Numbers (associated with this design change, e.g., new drawings, new documents)
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24. Other Non Engineering (not in HDCS) documents that need to be modified due to this change

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Maintenance Procedure	N/A		
Type of Document	**Document Number**	**Type of Document**	**Document Number**

25. Field Change Notice(s) Used?
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If Yes, Record Information on the ECN-2 Form, attach form(s), include a description of the interim resolution on ECN Page 1, block 17, and identify permanent changes.

NOTE: ECNs are required to record and approve all FCNs issued. If the FCNs have not changed the original design media then they are just incorporated into the design media via an ECN. If the FCN did change the original design media then the ECN will include the necessary engineering changes to the original design media.

26. Design Verification Required?
☐ Yes ☒ No
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27. Approvals

Facility/Project Signatures		Date	A/E Signatures		Date
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Quality Assurance	N/A		Project Engineer		
IS&H Engineer	N/A		Quality Assurance		
NS&L Engineer	N/A		Safety		
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Other	J. S. Schofield	John Schofield 4/12/06	Signature or a Control Number that tracks the Approval Signature		
Other					
Other			ADDITIONAL SIGNATURES		
Other					
Other					

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Parkman, DB	S7-67	x			
Luke, JJ	H6-03	x			
Smith, RD	S7-90	x			
Sutey, MJ	S7-90	x			
Doss, SD	S7-03	x			
Faust, TL	T6-03	x			
Saueressig, DJ	S7-75	x			
Krogsrud, S	S7-24	x			
Baide, D	S7-24	x			
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Noyes, DL	H6-60	x			
Quintero, RA	H6-60	x			
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US Environmental Protection Agency					
Bartus, D (H)	HO-57	x			

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LIST OF TERMS

Terms

None required; terms are defined within the document text.

Abbreviations, Acronyms, and Initialisms

1C	bismuth phosphate first-cycle decontamination
AC	Administrative Control
ALARA	as low as reasonably achievable
AMS	articulated mast system
BBI	best-basis inventory
CH2M HILL	CH2M HILL Hanford Group, Inc.
COPC	constituent of potential concern
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
HDW	Hanford Defined Waste
HEPA	high-efficiency particulate air
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HI	hazard index
HQ	hazard quotient
HIHTL	hose-in-hose transfer line
HPGe	high purity germanium
IH	Industrial Hygiene
ITV	in-tank vehicle
ILCR	incremental lifetime cancer risk
LDM	leak detection and monitoring
LDMM	leak detection, mitigation, and monitoring
LETF	Liquid Effluent Treatment Facility
MRS	mobile retrieval system
ORP	Office of River Protection
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyls
PNNL	Pacific Northwest National Laboratory
PUREX	plutonium-uranium extraction
RCRA	*Resource Conservation and Recovery Act of 1976*
RMS	retrieval monitoring system
SGLS	spectral gamma logging system
SST	single-shell tank
UPR	unplanned release
WMA	waste management area
WRS	waste retrieval system

Units

%	percent
Ci/kg	curie per kilogram
Ci	curie
°F	degrees Fahrenheit
ft^3	cubic feet
gal.	gallon
gal/min	gallons per minute
in.	inch
kg	kilogram
kg/m^3	kilograms per cubic meter
kgal	1,000 gallons
m	meter
m^3	cubic meters
mL/g	milliliters per gram
mm/yr	millimeters per year
mrem	millirem
pCi/g	picocurie per gram
vol%	volume percent
wt%	weight percent

1.0 INTRODUCTION

The U.S. Department of Energy (DOE), Office of River Protection (ORP) River Protection Project mission includes storage, retrieval, immobilization, and disposal of radioactive mixed waste presently stored in underground tanks located in the 200 East and 200 West Areas of the DOE Hanford Site. The 241-C-101 (C-101), 241-C-105 (C-105), 241-C-110 (C-110), and 241-C-111 (C-111) single-shell tanks (SSTs), located in the 200 East Area (Figure 1-1), are scheduled for waste retrieval using the mobile retrieval system (MRS) waste retrieval technology. These tanks were identified for waste retrieval with the MRS based on the following:

- Tanks C-101, C-110, and C-111 are classified as 'assumed leakers' in HNF-EP-0182, *Waste Tank Summary Report for Month Ending March 31, 2005*. The MRS provides for waste retrieval in a batch mode where limited volumes of water are introduced into the tank. This technology represents the best available waste retrieval technology for tanks with suspect integrity.

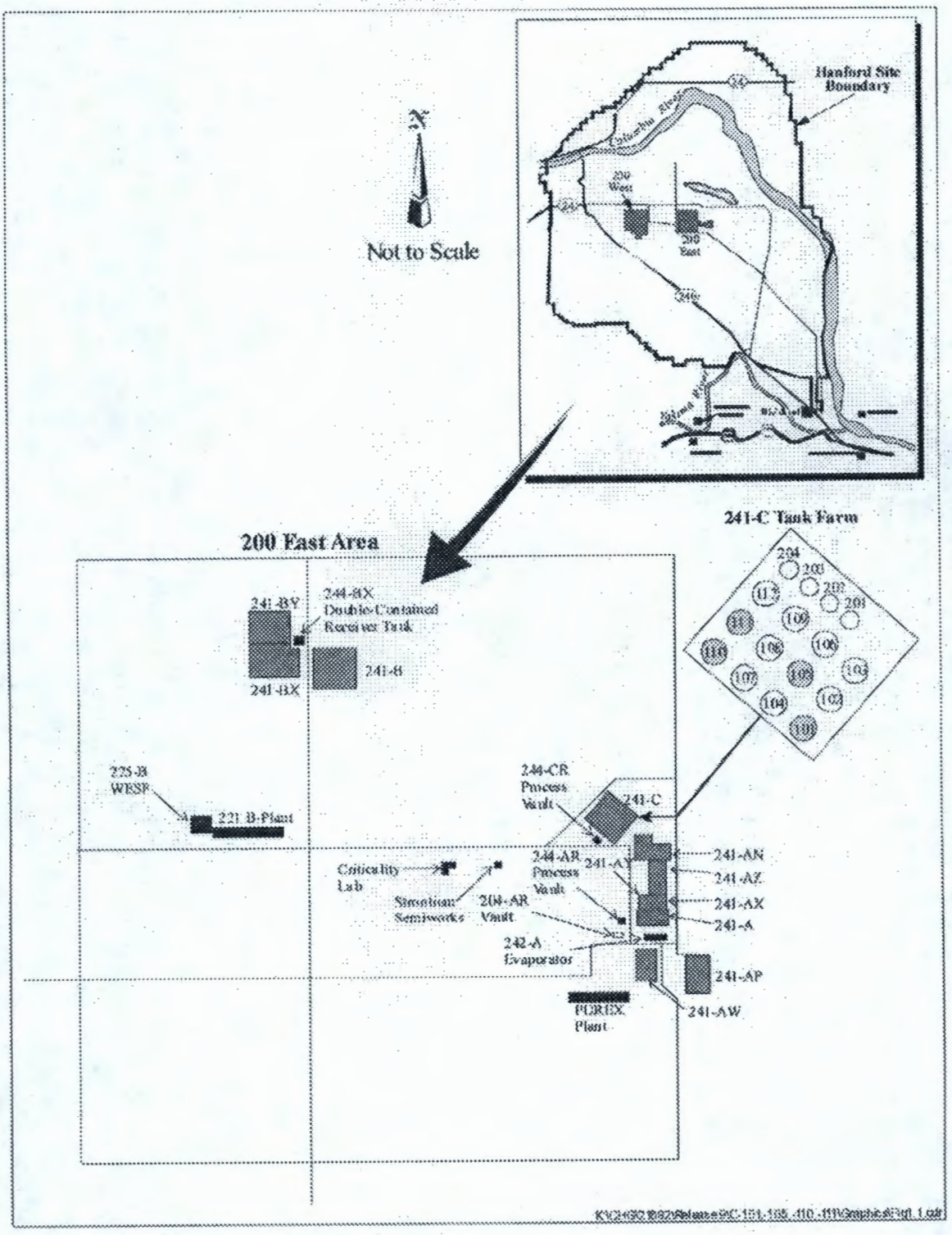
- Tank C-105 is classified as a sound tank; however, vadose zone characterization data collected around tank C-105 indicates that an unplanned release occurred near tank C-105. Because the cause or source of this unplanned release cannot be confirmed, the MRS was selected for retrieving the waste from tank C-105 to minimize the potential for leakage to occur.

This is a primary document developed to meet the requirements identified in Change Request M-45-04-01 of Ecology et al. (1989), *Hanford Federal Facility Agreement and Consent Order* (HFFACO). The relationship of the tank waste retrieval work plans to the overall SST waste retrieval and closure process is described in Appendix I of the HFFACO under Change Request M-45-04-01. The purpose of this document is to provide the Washington State Department of Ecology (Ecology) information on the planned approach for retrieving waste from tanks C-101, C-105, C-110, and C-111 to allow Ecology to approve the waste retrieval action.

Tank waste retrieval work plans have been developed for the other 100-series tanks in the C farm including RPP-21895, *241-C-103 and 241-C-109 Tanks Waste Retrieval Work Plan*; RPP-22393, *241-C-102, 241-C-104, 241-C-107, 241-C-108, and 241-C-112 Tanks Waste Retrieval Work Plan*. A similar document was also prepared for the C-200-series tanks, RPP-16525, *C-200-Series Tanks Retrieval Functions and Requirements*. Neither a functions and requirements document nor a work plan was developed for tank C-106. Regulatory approval to retrieve waste from tank C-106 was established through the HFFACO.

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*) has been incorporated in this document, it is not incorporated for the purpose of regulating the radiation hazards of such components under the authority of this tank waste retrieval work plan or Chapter 70.105 RCW, "Hazardous Waste Management Act."

Figure 1-1. Location Map of C Tank Farm and Surrounding Facilities in the 200 East Area.



2.0 TANKS AND/OR ANCILLARY EQUIPMENT CONDITION AND CONFIGURATION AND WASTE CHARACTERISTICS

2.1 RETRIEVAL START DATES

Dates and associated schedules for retrieval of these tanks will be provided subsequent to renegotiation of milestone M-45-00B.

2.2 TANK HISTORY

This work plan addresses waste retrieval from four 100-series tanks, C-101, C-105, C-110, and C-111, located in the C tank farm in the 200 East Area (Figure 2-2). Summary-level historical data related to the configuration and operating history for these tanks are provided in Table 2-1.

Table 2-1. Summary-Level Tank Data.*

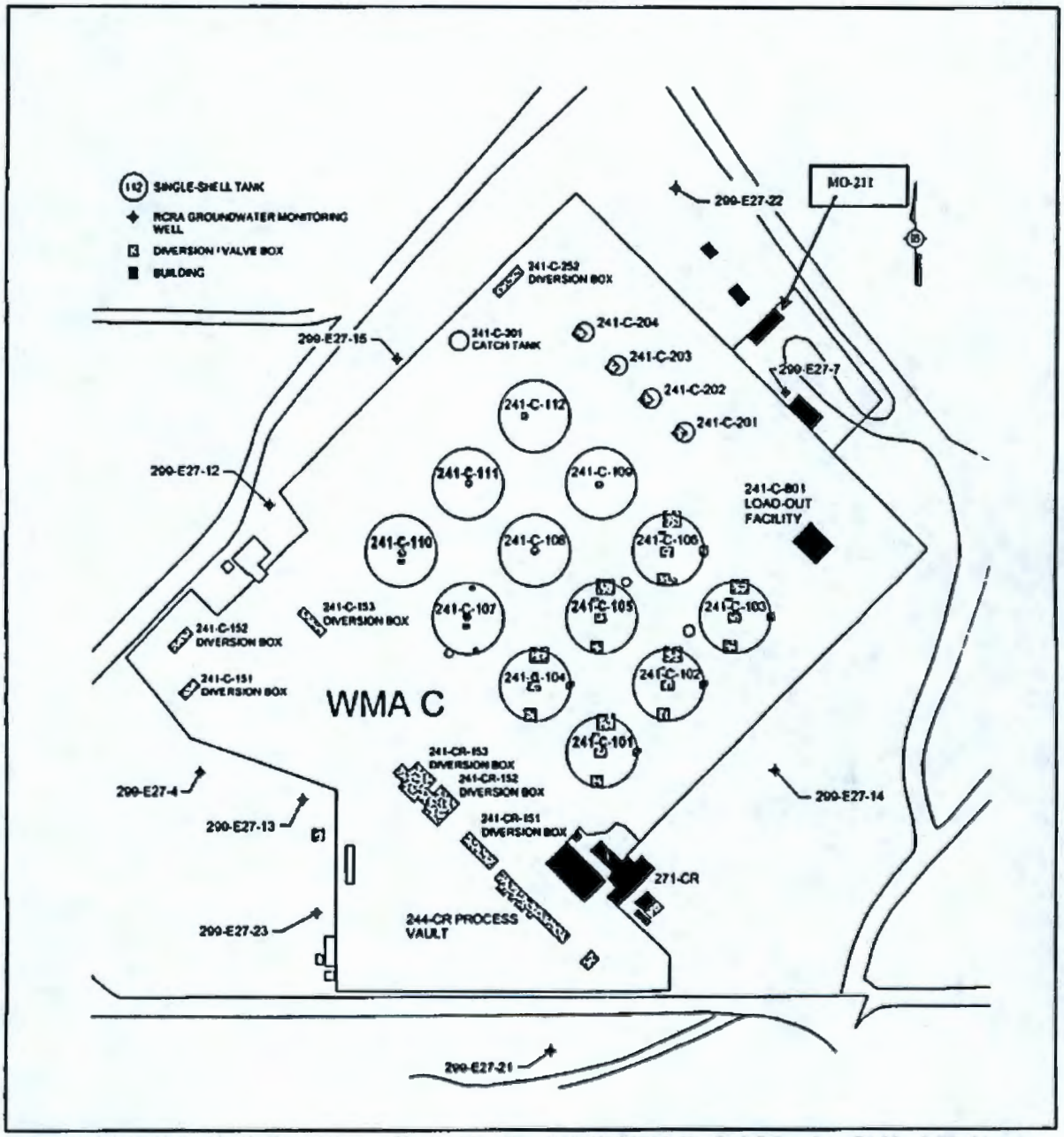
Tank	C-101	C-105	C-110	C-111
Constructed	1943-44	1943-44	1943-44	1943-44
In service	1946	1947	1946	1946
Diameter (ft)	75	75	75	75
Operating depth (in.)	185	185	185	185
Design capacity (gal.)	530,000	530,000	530,000	530,000
Bottom shape	Dish	Dish	Dish	Dish
Ventilation	Passive	Passive	Passive	Passive
Nominal burial depth (ft)	6	6	6	6
Declared inactive	1977	1980	1977	1978
Interim stabilized	11/83	10/95	5/95	3/84

* Best-basis inventory AutoTCR documents (6-10-2005) from TWINS, Web Site - http://twinsweb.pnl.gov/twins.htm.
TWINS = Tank Waste Information Network System.

Figure 2-1. Tanks C-101, C-105, C-110 and C-111 Waste Retrieval Schedule

Schedule will be provided subsequent to renegotiation of milestone M-45-00B.

Figure 2-2. Location of Tanks C-101, C-105, C-110, and C-111.*



* RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

The C farm 100-series tanks are 75 ft in diameter and 32 ft tall. The tanks have a 16-ft operating depth and an operating capacity of 530,000 gal. each. The tanks sit below grade with soil cover to provide shielding from radiation exposure to operating personnel.

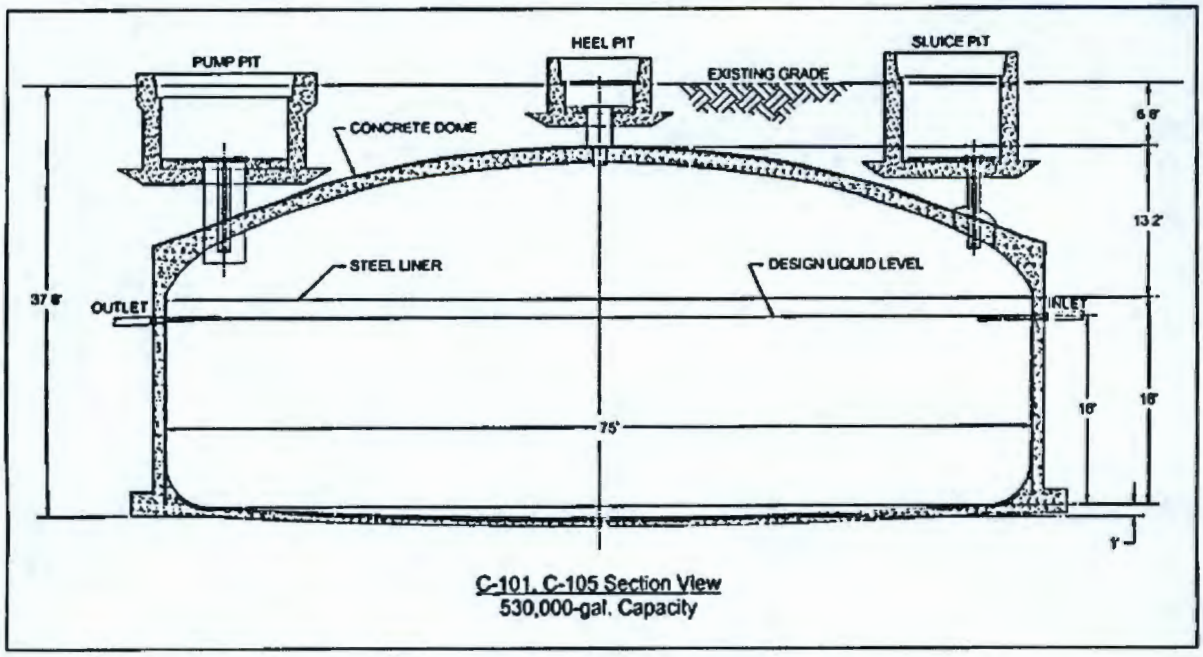
The SSTs were constructed in place with a carbon steel lining on the bottom and sides, and a reinforced concrete shell. The welded liners are independent of the reinforced concrete tanks and were designed to provide leak-tight containment of the liquid radioactive wastes and to protect the reinforced concrete from waste contact. All other loads (e.g., surface live loads, static and dynamic soil loads, dead loads, hydrostatic loads, and hydrodynamic loads) are carried by the reinforced concrete tank structure. The tanks have concave bottoms (center of tanks lower than the perimeter) and a curving intersection of the sides and bottom. Inlet and outlet lines are located near the top of the liners. These lines are also referred to as 'cascade' lines because they allowed transfer of fluids between tanks using gravity flow to support the transfer and storage of waste within a series of three 100-series SSTs.

Tanks C-101 through C-106 were modified after initial tank construction to add pits at the tank farm surface. Tanks C-107 through C-112 were also subsequently modified to add central saltwell pump pits. Because of these modifications, the configuration of tanks C-101 and C-105 is different than tanks C-110 and C-111, as described in the following sections.

2.2.1 Tank C-101 and C-105 Configuration

The existing configurations of tanks C-101 and C-105 are similar as depicted in the cross-section view in Figure 2-3.

Figure 2-3. Tanks C-101 and C-105 Cross-Section View.*



* Adapted from RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

Note: The cascade line configuration in tanks C-101 and C-105 is different. Tank C-101 has only an outlet line and tank C-105 has both an inlet and outlet line.

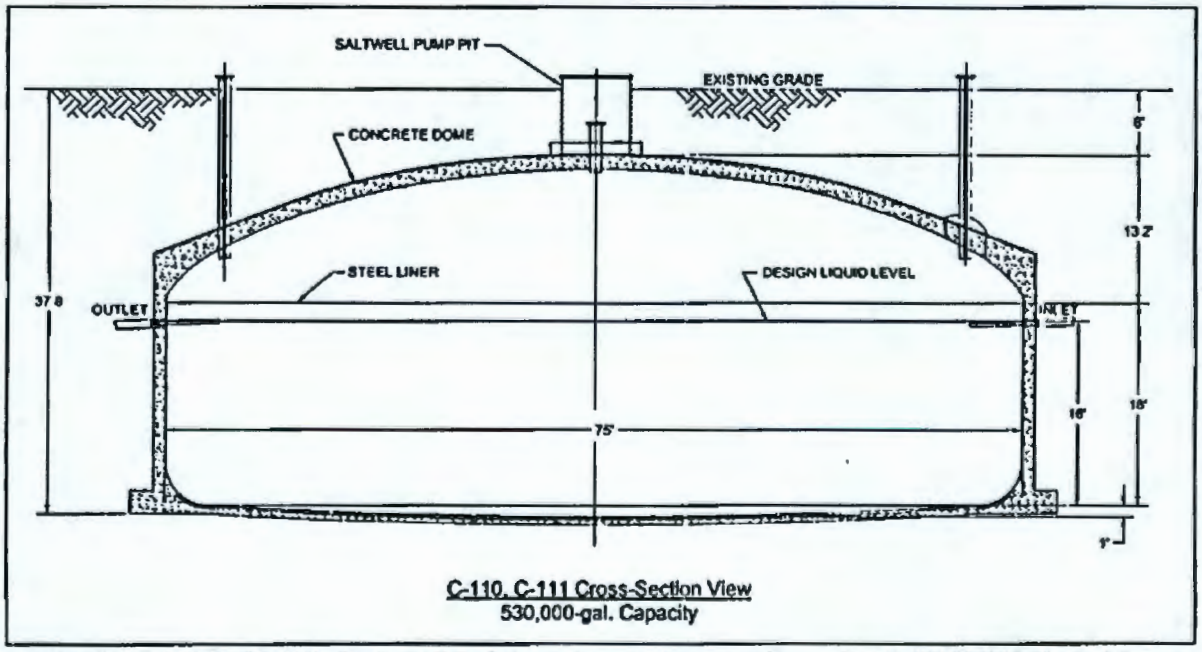
Tanks C-101 and C-105 both have three reinforced concrete process pits that were installed after initial tank construction to facilitate waste retrieval. These pits are constructed of reinforced concrete and extend above grade. The pits provide secondary containment for the primary transfer piping within, and have removable cover blocks or plates that allow entry into, the pits. The pit floors were constructed with drains that direct any liquid back into the tank through a tank riser located in the pit. The condenser hatchway (not shown in Figure 2-3) located above the outside edge of the tank provided an indirect access path into the tank for ventilation.

Each pit used for waste retrieval will have a conductivity probe or thermal leak detector, or another type of leak detector as appropriate.

2.2.2 Tank C-110 and C-111 Configuration

The configuration of tanks C-110 and C-111 is depicted in the cross-section view in Figure 2-4.

Figure 2-4. Tanks C-110 and C-111 Cross-Section View.*



* Adapted from RPP-10435, 2002, *Single-Shell Tank System Integrity Assessment Report*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Note: The cascade line configuration in tanks C-110 and C-111 is different. Tank C-110 has only an outlet line and tank C-111 has both an inlet and outlet line.

Tanks C-110 and C-111 do not have any concrete pits, but do have a caisson that was installed over the center riser after initial tank construction to facilitate waste retrieval. The caissons are constructed of a section of corrugated pipe embedded in a concrete base. The concrete base was sloped to a drain that connected to the tank riser so any leakage within the caisson would drain back into the tank. This caisson extends abovegrade and is closed off on the top with a cover plate.

Drawing H-2-38597, *Salt Well Pump Pit Assembly for Std. 12" Riser*, shows the original installation of the corrugated caisson. The caisson was installed in a groove in the concrete bottom of the pit and sealed with grout. A drain, flush with the bottom of the pit, previously routed drainage to the 12-in. riser. A sump pump is used to pump leakage into the tank.

Each pit or caisson used for retrieval will have a conductivity probe or thermal leak detector, or another type of leak detector as appropriate.

2.3 TANK RISER AND FILL/CASCADE LINE INFORMATION

This section identifies the 'as is' configuration of the risers and fill/cascade lines. Table 2-2 provides the size and current use of tanks C-101 and C-105 risers and fill/cascade lines and any equipment installed in or on the risers; Figure 2-5 provides the tanks C-101 and C-105 riser plan view. Table 2-3 provides the size and current use of tanks C-110 and C-111 risers and fill/cascade lines and any equipment installed in or on the risers;, Figure 2-6 provides the tanks C-110 and C-111 riser plan view. Use of the risers for waste retrieval is described in Section 3.0.

Table 2-2. Tanks C-101 and C-105 Riser and Fill/Cascade Line Descriptions.*

Component Identification Number	Diameter (in.)	Use Description	
		Tank C-101	Tank C-105
R1	4	Abandoned temperature probe, benchmark	Temperature probe (multi-function instrument tree)
R2	12	Temperature probe/manual tape	Ventilation line – air inlet filter
R3	12	Sluicing access riser in weather covered pit (01-C pit)	Spare, weather covered (05-C pit)
R4	4	Drain in weather covered pit (01-C pit)	Recirculating dip leg in weather covered pit (05-C pit)
R5	4	Drain in weather covered pit (01-A pit)	Recirculating dip leg in weather covered pit (05-A pit)
R6	12	Pump in riser in weather covered pit (01-A pit)	Sluicing access riser in weather covered pit (05-A pit)
R7	12	Observation port through pitwall (01-A pit)	Pump
R8	4	Level gauge (ENRAF)[a]/breather filter in offset adapter	Level gauge (ENRAF)
R9	36	Pump in riser in weather covered pit (01-B pit)	Pump in riser in weather covered pit (05-A pit)
R11	12	NA	Exhaust port in condenser hatchway cover
R13	12	Pump in riser in weather covered pit	Future transfer pump
A[b]		NA	Cascade overflow outlet to tank C-106
B[b]		NA	Cascade overflow inlet from tank C-104
N1/C1[b]	3	Spare inlet, plugged	Line V103, sealed in diversion box 241-C151
N2/C2[b]	3	Spare inlet, plugged	Spare inlet, capped
N3/C3[b]	3	Line V102, sealed in diversion box 241-C151	Spare inlet, capped
N4/C4[b]	3	Line V104, sealed in diversion box 241-C151	Spare inlet, capped
N5[b]	3	Cascade outlet overflow to tank C-102	NA

* Reference documents from TWINS, Web Site - http://twinsweb.pnl.gov/twins.htm and H-14-010613, 2003, *Waste Storage Tank (WST) Riser Data*, Sheet 1, Rev. 11 and Sheet 2, Rev. 6, CH2M HILL Hanford Group, Inc., Richland, Washington (with ECNs).

NA = not applicable.

[a] Enraf is the supplier of the identified level gauges; ENRAF is a trademark of Enraf, Inc., Enraf B.V., Delft, The Netherlands.

[b] Cascade and/or fill line, not a riser.

Figure 2-5. Tanks C-101 and C-105 Riser and Fill/Cascade Line Plan View.

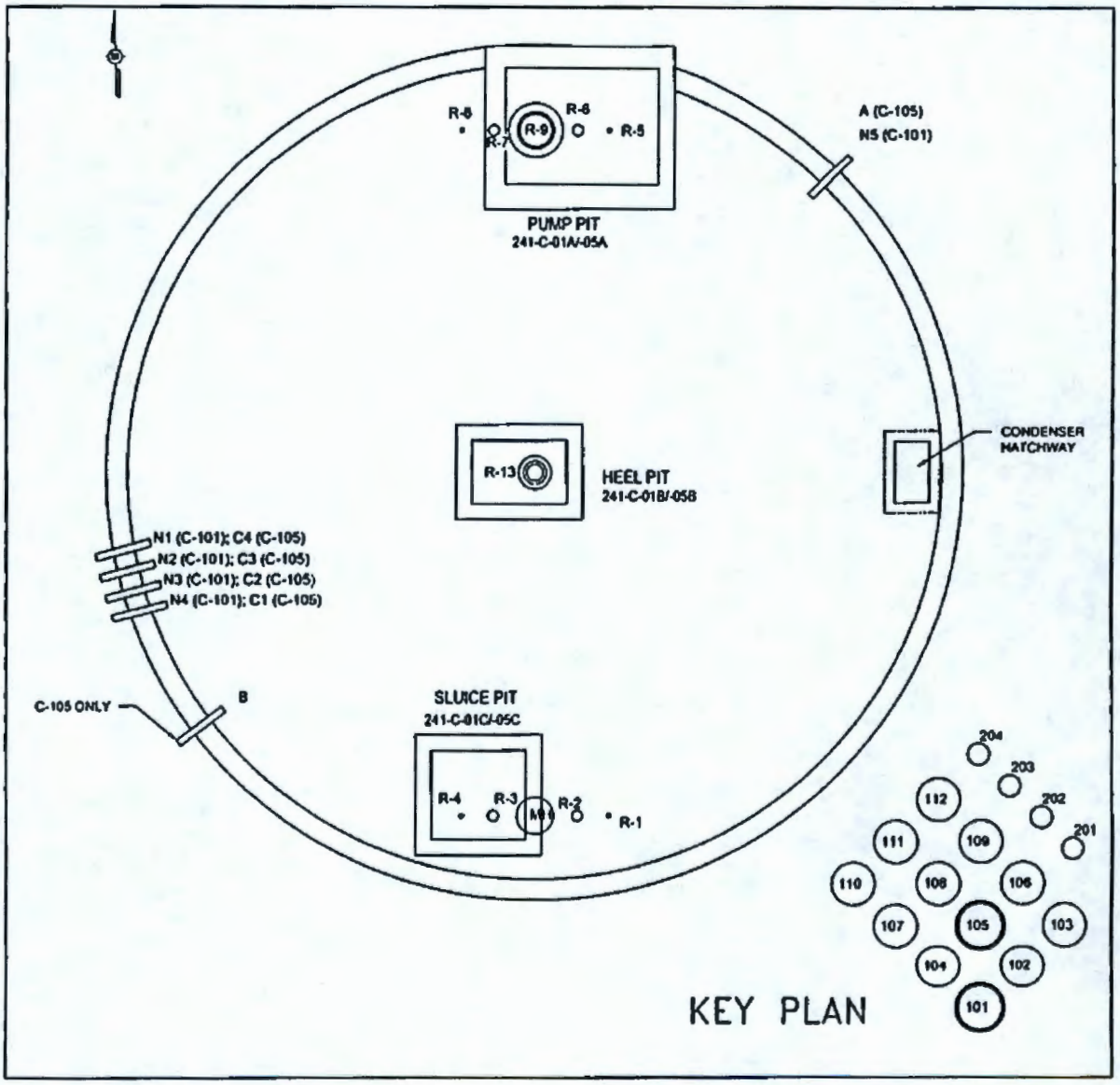


Table 2-3. Tanks C-110 and C-111 Riser and Fill/Cascade Line Descriptions.*

Component Identification Number	Diameter (in.)	Use Descriptions and Comments	
		Tank C-110	Tank C-111
R1	4	Spare, blind flange	Spare, blind flange
R2	12	Spare, blind flange with BM	Spare, blind flange with BM
R3	12	Breather filter	Spare, breather filter with offset adapter
R4	4	Level gauge (ENRAF)[a]	Spare, blind flange
R5	4	Spare, blind flange with BM	Temperature probe
R6	12	Spare	Temperature probe with adapter
R7	12	Observation port	Spare
R8	4	Temperature probe	Level gauge (ENRAF)
R13	12	Saltwell pump in weather covered pit	Saltwell pump in weather covered pit
A[b]	3	Cascade line overflow to tank C-111	NA
C1[b]	3	Fill line, sealed in diversion box 241-C-153	NA
C2[b]	3	Fill line, sealed in diversion box 241-C-153	NA
C3[b]	3	Fill line, sealed in diversion box 241-C-153	NA
C4[b]	3	Spare, capped	NA
N1[b]	3	NA	Cascade overflow outlet line
N2[b]	3	NA	Cascade inlet line from tank C-110
N3[b]	3	NA	Spare, capped
N4[b]	3	NA	Spare, capped
N5[b]	3	NA	Spare, capped
N6[b]	3	NA	Fill line V137, sealed in diversion box 241-C-153

* Best-basis inventory documents from TWINS, Web Site - http://twinsweb.pnl.gov/twins.htm.

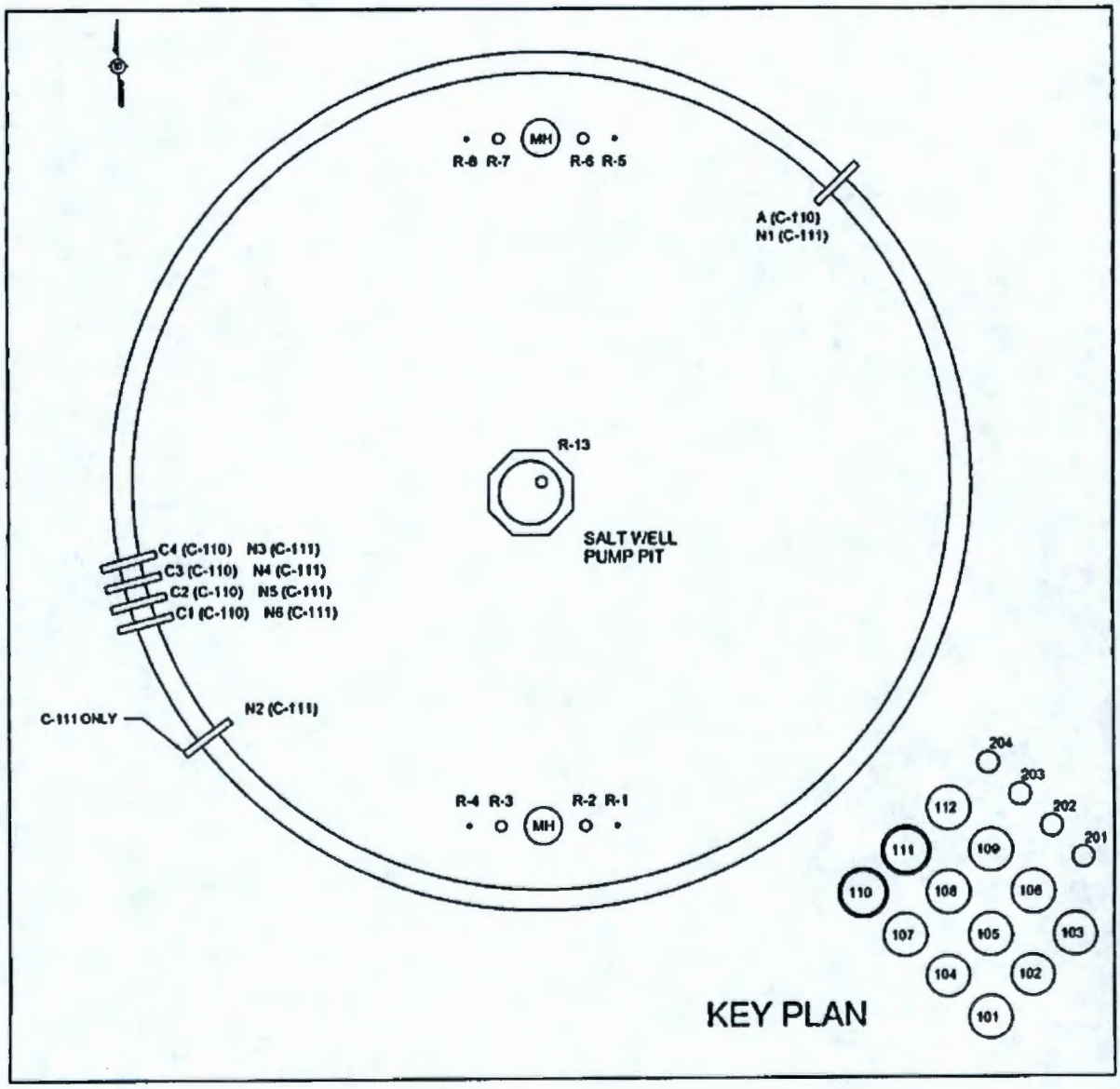
NA = not applicable.

BM = benchmark.

[a] Enraf is the supplier of the identified level gauges; ENRAF is a trademark of Enraf, Inc., Enraf B.V., Delft, The Netherlands.

[b] Cascade and/or fill line, not a riser.

Figure 2-6. Tanks C-110 and C-111 Riser and Fill/Cascade Line Plan View.



2.4 TANK CLASSIFICATION

Tanks C-101, C-110, and C-111 are classified as 'assumed leakers' and tank C-105 is classified as 'sound' in HNF-EP-0182. A description of the 100-series tanks is provided in RPP-13774, *Single-Shell Tank System Closure Plan*, Appendix C, Section C2.0.

2.4.1 Tank C-101

Tank C-101 has been classified as an assumed leaker in HNF-EP-0182 since this monthly document was first issued. This document provides an estimated tank C-101 leak volume of 20,000 gal., and states the volume estimate is based solely on tank level change. The basis for this value is stated to be SD-WM-SAR-006, *Single-Shell Tank Isolation Safety Analysis Report*. SD-WM-SAR-006 provides a table of tank leak volumes which gives the 20,000 gal. estimated leak volume for tank C-101, but no reference for this value was noted in the document. HNF-EP-0182 also states that tank C-101 experienced a level reduction in the late 1960s, was pumped to minimum heel and removed from service in December 1969, and reclassified as a "confirmed leaker" in 1980.

RHO-CD-896, *Review of Classification of Nine Hanford Single-Shell "Questionable Integrity" Tanks*, was released in January 1980 and evaluated the leak status for a number of single shell tanks. The conclusion of this document was that the tank should be classified as a confirmed leaker with an estimated leak volume of 17,000 to 24,000 gal. The basis for this is stated to be a decrease of 4 in. in the tank level between January 1968 and December 1969. It is unstated in RHO-CD-896 how the volume loss estimate was determined (a volume change of 4 in. would be equivalent to a liquid reduction of about 11,000 gal.). RHO-CD-896 discusses elevated readings in some drywells and does not mention evaporation as a potential cause of the level reduction. (An evaluation of the tank volume as provided in the monthly chemical processing waste summary reports from the period show a slow decrease from the time the tank was filled to a maximum of about 574,000 gal. in the second quarter of 1965 to the end of 1969.)

RPP-15317, *241-C Waste Management Area Inventory Data Package*, evaluated past tank leaks and other releases. This document repeats that the tank is classified as a known or suspected leaker in HNF-EP-0182 with a 20,000 gal. estimated leak volume based upon level decreases documented in the 1960s when the tank contained PUREX HLW supernate. The document goes on to conclude however that the level drop was more likely due to evaporation because a 20,000 gal. leak of PUREX HLW supernate would have released 127,000 Ci of Cs^{137} to the soil and that spectral gamma data from drywell monitoring shows no evidence of any leaks of such magnitude occurring.

RPP-14430, *Subsurface Conditions Description of the C and A-AX Waste Management Areas*, provides similar information and includes the spectral gamma drywell scan information for the two drywells (30-01-06 and 30-01-09) which show minor Cs^{137} activity in the 25 to 40 ft. depth below surface near tank C-101.

RPP-13774, *Appendix C: WMA C Closure Action Plan*, performed risk assessments for WMA C and included a number of known UPRs in determining the inventory in the area from past tank leaks using values from RPP-15317 and RPP-14430, but did not include any leakage from tank C-101 in the inventory from past UPRs because evaporation appears to explain the level decrease in the tank and the drywell monitoring data provides little evidence for a leak of a 20,000 gal. magnitude.

RPP-20820, *Waste Retrieval Leak Evaluation Report: Single-Shell Tanks*, provides the most complete evaluation to date for a leak from tank C-101 (and a number of other tanks). This document, using data from past waste summary documents shows that in 1964 it was filled to 546,000 gal., largely with PUREX HLW supernate from tanks A-102 and A-103. In 1965 it was filled to 574,000 gal. with additional liquid from the 244-CR vault. By the end of 1969 the level had reduced to 538,000 gal. with no mention of the reason for the level reduction. The document then includes much of the information from the RHO-CD-896 evaluation in 1980. The document goes on to mention that four drywells were drilled around the tank in 1970, one of which showed slightly above background levels of radiation and two (30-01-06 and 30-01-09) which show elevated Cs^{137} activity in the 25 to 40 ft. depth below surface near tank C-101. Per this document the spare inlet lines to the tank are covered at a waste level of 546,000 gal. in the tank, and mentions that these gasketed caps were not leak tight and could have leaked with a liquid level putting hydraulic pressure on the joint. The spare inlet lines are located between drywells 30-01-06 and 30-01-09, and very close to the latter. The latter drywell showed higher radiation levels than the former. The liquid temperatures in tanks A-102 and A-103 prior to transfer to tank C-101 were in the 94 to 105°C range and with the high level of Cs^{137} would be expected to keep generating heat in tank C-101. The document concludes that evaporation and liquid loss from the drain lines could explain the level drop in tank C-101, but due to the lack of usable drywell data from before 1970 no final conclusions can be drawn.

RPP-20820 includes a plot of the tank C-101 liquid level as Figure 4-20. This plot shows a single peak volume of over 650,000 gal. in 1966, with waste volumes of about 560,000-570,000 gal. before and after. A level of 650,000 gal. would fill the waste up into the concrete dome space and potentially let it run down the outside of the steel liner. This data point is in error. The plot was taken from TWINS, which states the data was obtained from the historical tank contents documents. WHC-SD-WM-ER-313, *Supporting Document for the Historical Tank Content Estimate for C Tank Farm*, gives the source for this data as WHC-MR-0132, *A History of the 200 Area Tank Farms*. In reviewing the data in WHC-MR-132 it can be seen that the value of 656,000 gal. shown for the third quarter of 1966 is in error, summing the individual waste volumes provided next to the 656,000 gal. number gives only 565,000 gal. An evaluation of the quarterly waste summary reports from 1966 confirms that the level in the third quarter of 1966 was 565,000 gal. Although volumes in this range are above the current operating limit for 100 series SSTs, a review of the monthly summary reports for this time period provides evidence that a number of SSTs were maintained at levels above 530,000 gal. A C-100 series tank would need to be filled to a little over 600,000 gal. for the liquid to be above the tank liner.

RPP-23405, *Tank Farm Vadose Zone Contamination: Volume Estimates for Risk Assessments*, reiterates the same information as described above and states that WHC-MR-0132 showed a number of tanks with PUREX HLW supernate had similar level decreases due to evaporation.

The document concludes that based upon waste types present there was adequate heat in tank C-101 for evaporation to account for much of the observed level decrease. Given this information a nominal 1,000 gal. leak was assumed.

In summary, tank C-101 experienced a level decrease of approximately 36,000 gal. between 1965 and 1969. Evaporation due to the high temperature of the waste may explain much of the liquid level decrease, and the fact that the liquid submerged the spare inlet lines (which were not designed to be leak tight) could also explain some of the liquid decrease and the elevated radiation detected in two of the drywells near the spare lines. A 20,000 gal. leak estimate has been published for years for this tank based apparently upon conclusions in RHO-CD-896, but no details are provided for this number. Subsequent evaluations indicated there is little evidence for a 20,000 gal. leak so no leakage from this tank was assumed in RPP-15317 or RPP-14430, and none was assumed in the risk assessment in RPP-13774. Subsequent to RPP-13774 being issued, a nominal 1,000 gal. leak volume has been assigned to tank C-101 in RPP-23405 for risk assessment purposes.

2.4.2 Tank C-110

Tank C-110 is classified as an assumed leaker in HNF-EP-0182. This document provides an estimated tank C-110 leak volume of 2,000 gal., and states the volume estimate is based upon Baumhardt (1989) (correspondence 8901832B R1, *Single-Shell Tank Leak Volumes*, letter from R. J. Baumhardt, WHC to R. E. Gerton, DOE). This reference bases a 2,000 gal. estimated leak volume for tank C-110 on the fact that radiation was detected at an associated drywell with no detectable surface level decrease in the tank, and that is is unreasonable to assume that more than 2,000 gal. would have leaked without a surface level decrease.

RPP-15317, states there is no conclusive evidence of any leak from tank C-110 and suggests that the drywell radioactivity may be material which has percolated down from surface leaks. RPP-14430 provides similar information. No leakage from tank C-110 is assigned in either of these documents nor did RPP-13774 include any inventory for a tank C-110 leak.

RPP-20820 provides a thorough evaluation of the tank C-110 history and concludes that a leak below the 132 inch height (the stable liquid level from 1972 to 1975) was improbable. Per this document, gamma radiation was evident in one drywell, 30-10-09, at about 53 to 56 ft. below grade when the drywell was installed in 1974. The radiation decreased each year and had disappeared entirely by 1979. This is indicative of Ru-Rh^{106} which has a 1-year half-life. This document theorized that the drywell contamination may have originated from a tank overfill in 1952 which covered the non leak-tight spare inlet lines. If this were the leak source however, the Ru-Rh^{106} should have decayed off by the mid-seventies.

RPP-23405 reiterates the information from the documents above and states that the drywell contamination could have come from the tank overfill in 1952 or from a nearby junction box or transfer lines. The document states the leak volume for tank C-110 is unchanged (assuming to mean from that in HNF-EP-0182) at 2,000 gal.

In summary, the only evidence of a leak from tank C-110 is some gamma radiation which appeared on one drywell. This drywell is not located near any other tank. The radiation was detected when the drywell was first scanned in 1975, and disappeared by 1979. No liquid level change occurred in the tank during this time period. No leak volume was assumed in RPP-15317 or RPP-14430, nor in the risk assessment for RPP-13774. A 2,000 gal. leak volume was originally estimated for this tank in 1989 based upon a conservative assumption. This 2,000 gal. volume is assumed in RPP-23405.

2.4.3 Tank C-111

Tank C-111 is classified as an assumed leaker in HNF-EP-0182. This document provides an estimated tank C-111 leak volume of 5,500 gal., states the volume estimate is based upon observed level change only, and references Baumhardt (1989) as the basis. This reference gives a 5,500 gal. estimated leak volume for tank C-111 based upon observed surface level decrease in the tank, but provides no details as to the basis.

RPP-15317 states there are no spectral gamma or well-documented level data suggesting a leak occurred from tank C-111. RPP-14430 provides similar information. Both documents reference SD-WM-TI-356, *Waste Storage Tank Status and Leak Detection Criteria*, as the reference for the tank being classified as questionable integrity in 1968 due to a liquid-level decrease. No leakage from tank C-111 is assigned in either of these documents nor did the risk assessment in RPP-13774 include any inventory for a tank C-111 leak.

RPP-20820 provides a thorough evaluation of the tank C-111 history. No elevated gamma radiation was found in any of the drywells surrounding the tank. During the period from 1964 through 1969 the level dropped 8.5 in. The shape of the level drop curve approximated closely the radiolytic decay curve for Ce-Pr^{144}. A large quantity of Ce-Pr^{144} was added to the tank in 1964 from the Hot Semi-Works. Temperatures of 190°F are also mentioned following the Ce-Pr^{144} addition to the tank. The level decrease had almost stopped by the time the liquid was pumped down to 48 in. in 1969, and there are no indications of any liquid loss after that date. The document concluded that there is no level loss after the waste level was reduced to 48 in., and that the loss before the tank was pumped was probably evaporation, and there is thus no evidence for any leakage from the bottom of the tank.

RPP-23405 reiterates the information from the documents above, and concludes that the level change may have been due to evaporation but that the weak gamma signal available from the tank C-111 waste could also explain the lack of elevated drywell radiation readings. The document states the estimated leak volume for tank C-111 is unchanged (assuming to mean from that in HNF-EP-0182) at 5,500 gal.

In summary, the only evidence of a leak from tank C-111 is the level drop between 1964 and 1969. The rate of level change approximated the decay rate for Ce-Pr^{144}. No level change occurred after the tank liquid level was reduced to 48 in. A 5,500 gal. leak volume was originally estimated for this tank in 1989. No leak volume was assumed in RPP-15317 or RPP-14430, or the risk assessment in RPP-13774. A 5,500 gal. estimated leak volume is assumed in RPP-23405.

2.4.4 Tank C-105

Although tank C-105 is designated as a 'sound' tank in HNF-EP-0182, there is contamination reported in the vadose zone from routine geophysical monitoring between tanks C-105 and C-104. This data indicates that an unplanned release occurred near tank C-105. The cause or source of this unplanned release cannot be confirmed. See Section 7.1.3.3 for UPR information and the leak volume size assumed in RPP-13774 for tank C-105.

Tank C-105 is classified as a sound tank in HNF-EP-0182. There have been no reported unexplained level drops for this tank. Since it is designated as a sound tank there is no estimated leak volume.

RPP-15317 discusses monitoring data associated with tank C-105. Contamination was noted in the soil around drywell 30-05-07 when it was drilled in 1974. Spectral gamma measurement show definite Cs^{137} peak areas between 34 to 44 ft below grade and between 48 and 62 ft. Based upon this data the document states that if C-105 did leak it was prior to 1974 and that the leak appeared to seal afterwards since the tank was used repeatedly until 1978 as an active receipt and feed tank. Because there was no other explanation available for the Cs^{137} presence, a nominal 1,000 gal. leak volume was assigned to the tank.

RPP-14430 provides similar information, and expands upon it. In addition to the same wording about drywell 30-05-07, a small Cs^{137} peak is mentioned in adjacent drywell 30-05-05 between 60 and 65 ft below grade and a very small Cs^{137} peak in adjacent drywell 30-05-08 at 47 ft below grade. The document mentions there was a 36 in. level drop in the tank between 1963 and 1967 when it held PUREX HLW supernate, and that liquid losses due to evaporation are noted in historical records. The document discounts the likelihood of a leak from the cascade line between tanks C-104 and C-105, which has been theorized as a source of the leak. The document assigns a 1,000 gal. estimated leak volume to tank C-105 for risk evaluation purposes.

RPP-13774 assumed a 1,000 gal. leak from tank C-105 for the risk assessment based upon the contamination levels found in drywell 30-05-07.

RPP-20820 provided a thorough evaluation of the tank C-105 history. The tank was filled with thermally hot (94 – 105°C) high PUREX HLW supernate in May of 1963. The Cs^{137} concentration was high enough so that the tank heat generation rate was estimated to exceed 140,000 Btu/hr. From this time until December 1967 when much of the solution was transferred out the tank liquid level decrease was about 36 in., or about 101,000 gal. Records state that the decrease was due to 'steaming', without further elaboration. (Note: WHC-MR-0132 probably is the source for this information as it lists three entries in the 1963 to 1967 time period stating the volume decrease is due to 'steaming' or evaporation.) Drywell 30-04-02 was drilled in 1972, and shortly following a transfer from tank AX-103 to tank C-105 in 1974 using line V-103, an increase in radioactivity at 40 ft below grade showed up. The contamination level rose slowly for a few months until June of 1974. Since then the radiation level has decreased consistent with the decay rate for Cs^{137}. Five other drywells were installed in 1974 to better define this contamination, and when the drywells were first monitored the high radiation levels were noted in drywell 30-05-07. RPP-20820 describes in detail the different occurrence reports and evaluation of the likelihood of the contamination coming from a cascade line or transfer line.

The document also discusses the additional transfers (3.4 million gal. of waste in and out of the tank) in the years after the contamination was noted without any increase or movement of the contamination seen in the drywells. The document concludes that a cascade line leak and/or a V-103 transfer line leak were probable, but that there is insufficient data to say the tank is safe to sluice below a certain depth because there has not been a sufficient time period with a stable surface level over which to demonstrate there was no liquid level decrease.

RPP-23405 reiterates much of the information from the documents above, and states that regardless of the source of the contamination, a contaminant plume clearly exists. Based upon the size of the plume and the expected composition, if it did come from tank C-105 the estimated leak volume was about 1,000 gal.

In summary, the only evidence of a leak from tank C-105 is the level of contamination found in drywell 30-05-07, and residual contamination in adjacent two drywells. There has been no increase in radiation level or change in depth of the indicated radiation since mid 1974. The rate of change in the drywell 30-05-07 radiation levels since then has approximated the decay rate for Cs^{137}. About 3.4 million gal. of waste was transferred in and out of the tank during this period. The 36 in. liquid level change in tank C-105 from 1963 to 1967 was likely due to evaporation from the high level waste in the tank. A leak volume of 1,000 gal. was assumed in RPP-15317, RPP-14430 and used in RPP-13774. RPP-23405 recommends a value of 1,000 gal. be assumed for a leak in the vicinity of tank C-105. RPP-20820 concludes that the contamination in the vicinity of tank C-105 probably did come from a cascade line or transfer line leak, but that level data are not available due to transfers in and out of the tank and periodic water additions to prove conclusively the tank is sound.

2.5 TANK WASTE VOLUME/CHARACTERISTICS

The waste volume and physical properties of the waste currently stored in tanks C-101, C-105, C-110, and C-111 and awaiting retrieval are summarized in Table 2-4.

The tank waste inventory data, including uncertainty, extracted from the best-basis inventory (BBI) (http://twinsweb.pnl.gov/twins.htm) is provided in Appendix E (Tables E-1 through E-4 for tanks C-101, C-105, C-110, and C-111, respectively). There are varying degrees of uncertainty associated with the waste inventory. The inventory uncertainty is a combination of the uncertainty associated with measurements of waste volume and concentration. Inventory uncertainty estimates have been completed for some but not all constituents and for some but not all waste types. The standard deviation is calculated from the variation in the sample analysis results. Details on the methodology used for developing inventory uncertainty values reported in the BBI are provided in RPP-7625, *Best Basis Inventory Process Requirements*. The inventory uncertainty data associated with contaminants that drive long-term risk (e.g., technetium-99) can be used for tanks C-101, C-105, C-110, and C-111 to provide insight to the uncertainty in long-term human health risks presented in Section 7.0. Indicator contaminants identified in Section 7.1.1.1 are noted in Tables E-1 through E-4.

Table 2-4. Waste Volume and Physical Properties Summary.

Waste Property	Unit	Tank C-101	Tank C-105	Tank C-110	Tank C-111
Solids volume [a]	gal.	88,000	132,000	177,000	57,300
Supernate volume [a]	gal.	0	0	1,060	0
Interstitial liquid volume [a]	gal.	4,000	10,000	37,000	4,000
Sludge density [b]	kg/L	1.78	1.55	1.34	1.55
Sludge percent water [b]	%	23.4	28.3	60.3	36.5

[a] HNF-EP-0182, 2005, *Waste Tank Summary Report for Month Ending March 31, 2005*, Rev. 204, CH2M HILL Hanford Group, Inc., Richland, Washington.

[b] Source: Best-basis inventory download from http://twinsweb.pnl.gov/twins.htm dated June 10, 2005.

Although there are uncertainties associated with contaminant inventories in the tanks, the following items show that there is sufficient information on the characteristics that affect waste retrieval, transfer, and storage in the double-shell tanks (DSTs) to proceed with waste retrieval. The information used for waste volumes and constituents is the best available and is deemed sufficient based upon knowledge of those attributes necessary for planning and design purposes to proceed with the retrieval.

- DOE (2003), *Dangerous Waste Permit Application—Single-Shell Tank System* (Part A Permit) list of constituents contains constituents not found in the BBI because of 'protective filing.' The constituents listed in the BBI (25 chemicals and 46 radionuclides) account for approximately 99 wt% of the chemical inventory (not including water and hydroxide) and over 99% of the activity in terms of short- and long-term risk, based on estimates developed using the Hanford Defined Waste (HDW) Model (RPP-19822, *Hanford Defined Waste Model – Revision 5.0).*

- The above meets the requirements in Section 2.1.3 of Appendix I of the HFFACO that requires those contaminants accounting for at least 95% of the impact to groundwater risk be addressed.

- The BBI is the best available data; however, the Part A Permit provides a list of constituents that may or may not be present in the SSTs. To address this uncertainty, a post-retrieval sample will be taken of the residual waste for all constituents identified in the Ecology-approved sampling and analysis plan, pursuant to the requirements of that sampling and analysis plan.

There are currently no plans to perform additional characterization (e.g., sampling and analyses) of the waste in tanks C-101, C-105, C-110, or C-111 to support waste retrieval and transfer. Sampling and analysis activities associated with component closure actions will be performed in accordance with RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*, and RPP-PLAN-23827, *Sampling and Analysis Plan for Single-Shell Tanks Component Closure.*"

Meeting the informational requirements for waste transfers meets the requirements of WAC 173-303-300, "General Waste Analysis." Compliance with the following documents is required before initiating a waste transfer:

1. HNF-SD-WM-EV-053, *Double-Shell Tank Waste Analysis Plan*. SST transfers into the DSTs for any reason must meet the waste acceptance criteria presented in this plan. This plan is written pursuant to WAC 173-303-300(5) and EPA guidance document OSWER 9938.4-03, *Waste Analysis at Facilities That Generate, Treat, Store and Dispose of Hazardous Waste.*

2. Waste Stream Profile Sheet (HNF-SD-WM-EV-053, Appendix A). The sheet addresses the applicable sections of WAC 173-303-300; 40 CFR 761, "Polychlorinated Biphenyls (PCBs). Manufacturing, Processing, Distribution, Commerce, and Use Prohibitions"; 40 CFR 268, "Land Disposal Restrictions"; and WAC 173-303-140 and also requires a waste compatibility assessment pursuant to HNF-SD-WM-DQO-001, *Data Quality Objectives for Tank Farms Waste Compatibility Program*, to meet WAC 173-303-395(1).

2.5.1 Tank C-101 Operating History

The following information is taken from WHC-SD-WM-ER-473, *Tank Characterization Report for Single-Shell Tank 241-C-101.*

Tank C-101 began receiving bismuth phosphate first-cycle decontamination (1C) waste in March 1946. In May 1946, the tank was declared full. During 1946, additions of 1C waste to tank C-101 would continually exceed the capacity of the tank. Therefore, supernate was cascaded to tank C-102. Tank C-101 received uranium recovery waste intermittently from U Plant from 1953 until 1954. During 1953, supernate cascaded to tank C-102 and also to tank C-103. This was the last cascade transfer of supernate to tank C-102 until 1961. It became apparent in 1954 that the overflow outlet of tank C-101 was partially plugged. A small transfer of supernate from tank C-101 to tank B-106 occurred during 1954. Another transfer of supernate also occurred in 1954 to an unspecified destination.

During 1956, tank C-101 received supernate (probably tributyl phosphate waste) from tank C-104. Also, from 1956 until 1957, supernate was sporadically transferred from tank C-101 to tanks C-109 and C-112 for in-tank settling and scavenging of cesium-137 by ferrocyanide. During 1957, tank C-101 received waste of an unspecified type from tank BY-101.

Beginning in 1960 and intermittently until 1962, tank C-101 received PUREX cladding waste from an unspecified source. During 1962, the addition of the PUREX cladding waste exceeded the capacity of tank C-101 and subsequently led to the cascade of supernate to tank C-102. During 1963, tank C-101 received supernate from tank A-102, and supernate was pumped from tank C-101 to tank B-107. The only other transfers for which the destination or the source are known are as follows: in 1964, tank C-101 received waste of an unspecified type from tank A-103; in 1965, tank C-101 received waste of an unspecified type from the CR vault; in 1969, supernate was transferred out of tank C-101 to tank C-105; and in 1974, supernate was transferred out of tank C-101 to tank C-104.

Tank C-101 was removed from service in 1975 and declared inactive in 1977. It was classified as an 'assumed leaker' in 1980 with an approximate leak volume of 20,000 gal. (HNF-EP-0182). Intrusion prevention was completed in December 1982, and the tank was interim stabilized in November 1983 (HNF-EP-0182).

2.5.2 Tank C-105 Operating History

The following information is taken from WHC-SD-WM-ER-489, *Tank Characterization Report for Single-Shell Tank 241-C-105.*

Tank C-105 began receiving 1C waste from the bismuth phosphate process in 1947. The 1C waste remained in the tank until 1953, when a sluicing program for recovery of the uranium was started. Virtually no solids were left after the sluicing operations.

In 1954 the tank was filled to capacity with uranium recovery waste generated during the processing of 1C waste to recover uranium. In 1956, the tank was pumped to a 79,000-gal. heel.

In August 1956, tank C-105 received PUREX cladding waste enroute to the BY tank farm and to other tanks within the C tank farm. The tank remained full and static from mid-1960 until 1963, when it was pumped to a 125,000-gal. heel; there was no record of a sludge measurement. During 1963, the first transfer of PUREX neutralized high-level waste was received from tank A-102. A significant liquid level decrease of 36 in. was recorded during the static period between the time of fill and late 1967. Although evaporation was indicated as the cause of this waste loss, no documentation of other decrease studies or temperature data are available. A 109,000-gal. sludge volume was recorded in 1965 (two years after the PUREX high-level waste transfer).

From 1967 until February 1977, tank C-105 served as a receiver for PUREX supernate wash waste and PUREX sludge supernate from the A and AX tank farms and also from tanks C-103 and C-106. Although administrative controls were applied to prevent/minimize it, some A and AX solids were believed to have been transported to tank C-105. This material was then pumped to the 221-B Building for cesium recovery processing. Tank C-105 was declared inactive in November 1980. Partial interim isolation was completed in August 1983, and the tank was interim stabilized in October 1995 (HNF-EP-0182).

2.5.3 Tank C-110 Operating History

The following information is taken from HNF-SD-WM-ER-367, *Tank Characterization Report for Single-Shell Tank 241-C-110.*

Tank C-110 began receiving 1C waste in May 1946, and by April 1947 was filled with 1C waste. During that time, waste was transferred to tank C-111 through the cascade line. Supernate waste was transferred to tank B-106 in 1952. Also, in 1952, tank C-110 was an active receiver of

tributyl phosphate waste, and it was determined that the overflow line to tank C-111 had become plugged with waste.

In 1952 and 1953, the tank received uranium recovery waste (WHC-MR-0132, *A History of the 200 Area Tank Farms*). In 1956, waste was transferred from tank C-110 to the CR process vault through tank C-109.

The tank received organic wash waste from PUREX in 1956. Waste was sent to tank BY-112 in 1967 and to tank C-102 in 1969.

From 1970 until 1972, evaporator bottoms waste and ion exchange waste were sent to the tank from tanks BY-104, BX-104, and BX-103. During this time, supernate waste was sent to tanks C-108, C-109, C-112, and C-104. Waste was sent to tank C-112 in 1975 and to tank C-103 in 1976. In 1983 waste was transferred to tank AN-103.

Tank C-110 was removed from service in 1976 and declared inactive in 1977. In 1984 it was classified as an 'assumed leaker.' The tank was interim stabilized in May 1995 and intrusion prevention was completed in September 1996 (HNF-EP-0182).

2.5.4 Tank C-111 Operating History

The following information is taken from WHC-SD-WM-ER-475, *Tank Characterization Report for Single-Shell Tank 241-C-111*.

Tank C-111 entered service in 1946 when 1C waste from the bismuth phosphate process began cascading from tank C-110 into tank C-111. In November 1946, the tank was declared full and subsequent waste additions cascaded into tank C-112.

In 1952, supernate was transferred out of tank C-111 to tank BY-106, and the tank began to receive uranium recovery waste. Beginning in 1955, tank C-111 served primarily as the settling tank for ferrocyanide (TFeCN) waste resulting from in-farm scavenging of cesium-137 (WHC-SD-WM-ER-133, *An Assessment of the Inventories of the Ferrocyanide Watchlist Tanks*). During 1956, that ferrocyanide waste was transferred and the tank received PUREX organic wash waste and cladding waste from unspecified sources. Also during this time period (from 1956 to 1957), supernate that had been scavenged of cesium-137 was intermittently transferred from the tank to disposal cribs. Tank C-111 received intermittent transfers of supernate from tank C-105 and other sources from late 1959 until early 1961.

Waste from the Hot (or Strontium) Semi-Works Plant was intermittently transferred to tank C-111 for approximately two years in the early 1960s. Final transfers of supernate out of tank C-111 occurred during the late 1960s and early 1970s. The final waste transfer was completed approximately in 1976 after tank C-111 was suspected of leaking. Tank C-111 was removed from service in 1975 and was declared inactive in 1978. Tank C-111 was interim stabilized in 1984.

2.6 TANK ANCILLARY EQUIPMENT

There is a complex waste transfer system of pipelines (transfer lines), diversion boxes, vaults, valve pits, and other miscellaneous structures that are collectively referred to as ancillary equipment. The routing of liquid waste to and from the tanks was accomplished using this transfer system. The diversion boxes provide the means for routing waste from one transfer line to another via jumper assemblies. The diversion boxes are belowground, reinforced concrete boxes that were designed to contain any waste that leaked from the waste transfer line connections and route it to a collection tank.

One valve pit, 241-C (a corrugated structure with a concrete floor), also served the C tank farm and is located southwest of tank C-103. This pit was installed as part of the saltwell pumping program to allow multiple saltwells to pump to the 244-CR vault receiver tank, 003, through a single transfer line, SN-275.

Table 2-5 provides a summary of the C tank farm ancillary equipment connected to tanks C-101, C-105, C-110, and C-111.

The existing buried waste transfer lines routed to tanks C-101, C-105, C-110, and C-111 have been isolated to prevent the inadvertent transfer of waste or intrusion of water into the tanks following retrieval with the exception of the cascade lines and saltwell transfer lines. With these isolation measures in place, the process lines are in a stable configuration and do not represent pathways for water or additional waste to enter the tanks.

Unplanned releases from the ancillary equipment that are attributed to ancillary equipment leaks include the following:

- **UPR-200-E-16.** In 1959, the transfer line between tanks C-105 and C-108 leaked and contaminated the soil near the tank C-105 pit.
- **UPR-200-E-81.** In 1969, a transfer line leaked at the 241-C-151 diversion box resulting in a surface puddle (approximately 6 ft by 40 ft) a few feet west of 241-C-151 diversion box. Waste was being transferred from the 202-A Building to tank C-102 via the 241-C-151 diversion box at time of leak discovery.
- **UPR-200-E-82.** In 1968, a transfer line leaked near the 241-C-152 diversion box resulting in an approximately 1,000-gal. surface pool of waste. Waste was being transferred from tank C-105 to the 221-B Building via the 241-C-152 diversion box at the time of leak discovery.
- **UPR-200-E-86.** In 1971, transfer line 812 leaked outside the southwest corner of the tank farm fence. Waste was being transferred from the 244-AR vault to the C tank farm at time of leak discovery.

Based on the historical information presented in Sections 2.2 and 2.5, the abandoned process lines used for previous waste transfers will be internally contaminated through contact with the waste. These abandoned lines were constructed with a positive slope to facilitate drainage (a design requirement). Where possible, these lines were either flushed following use or were used

for dilute waste transfers that should have minimized significant solid and/or liquid waste buildup in the lines.

There is no available information on the current condition or on the volume/characteristics of any waste associated with piping and other ancillary equipment. For the purpose of assessing the long-term human health risk for the overall waste management area (WMA), an ancillary equipment source term was defined to include the residual waste in the C farm piping components, 244-CR vault tanks, and the 241-C-301 catch tanks. Unplanned releases (UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86) associated with known transfer line leaks are also included in the long-term human health risk for the overall WMA plan. There are no known leaks from cascade lines associated with the tanks. Additional details on the methodology used to estimate the inventory associated with the ancillary equipment are provided in Section 7.0.

2.6.1 Tank C-101 Ancillary Equipment

Tank C-101 is connected to tank C-102 by a 3-in. diameter cascade line (WHC-SD-WM-ER-473). Tank C-101 has 10 risers of varying diameters and lengths of protrusion into the tank and 5 nozzles. The risers provide access to various in-tank equipment. Table 2-2 identifies the purpose of each riser and nozzle. A cross-section view of tank C-101 is shown in Figure 2-3. Figure 2-7 illustrates the line and riser locations into and around tank C-101 along with their current uses.

Twenty-four pathways enter tank C-101 or its associated pits. The pathways include lines, risers, pit drains, weep holes, and ventilation ducts. Twenty pathways into tank C-101 have already been isolated, as shown in Table 2-6. Current plans for isolation of all remaining pathways are shown in Table 2-7. This work will be accomplished in accordance with the tank closure plan.

2.6.2 Tank C-105 Ancillary Equipment

Tank C-105 is connected to tanks C-104 and C-106 by 3-in. diameter cascade lines (WHC-SD-WM-ER-489). Tank C-105 has 12 risers of varying diameters and lengths of protrusion into the tank. The risers provide access to various in-tank equipment. Table 2-2 identifies the purpose of each riser. A cross-section view of tank C-105 is shown in Figure 2-3. Figure 2-8 illustrates the line and riser locations into and around tank C-105 along with their current uses.

Twenty-eight pathways enter tank C-105 or its associated pits. The pathways include lines, risers, pit drains, weep holes, and ventilation ducts. Twenty-three pathways into tank C-105 have already been isolated, as shown in Table 2-8. Current plans for isolation of all remaining pathways are shown in Table 2-9. This work will be accomplished in accordance with the tank closure plan.

2.6.3 Tank C-110 Ancillary Equipment

Tank C-110 is connected to tank C-111 by a 3-in. diameter cascade line. Tank C-110 has nine risers of varying diameters and lengths of protrusion into the tank. The risers provide access to various in-tank equipment. Table 2-3 identifies the purpose of each riser. A cross-section view of tank C-110 is shown in Figure 2-4. Figure 2-9 illustrates the line and riser locations into and around tank C-110 along with their current uses.

Nine pathways enter tank C-110 or its associated pits. The pathways include lines, a pit drain, and risers. Eight pathways into tank C-110 have already been isolated, as shown in Table 2-10. Current plans for isolation of all remaining pathways are shown in Table 2-11. This work will be accomplished in accordance with the tank closure plan.

Table 2-5. C Tank Farm Components Associated with Tanks C-101, C-105, C-110, and C-111.* (2 Sheets)

Single-Shell Tanks			
Tank 241-	Constructed	Declared Inactive	Constructed Operating Capacity (gal.)
C-101	1943 – 1944	1977	530,000
C-105	1943 – 1944	1980	530,000
C-110	1943 – 1944	1977	530,000
C-111	1943 – 1944	1978	530,000
Diversion Boxes			
Unit 241-	Constructed	Removed from Service	Description
241-C-151	1946	1985	Interconnected 241-C-151 diversion box and C tank farm
241-CR-152	1946	1985	Interconnected 241-C-151 diversion box and C tank farm
241-CR-153	TBD	TBD	Interconnected 241-CR-152 diversion box and C tank farm
Valve Pits			
Facility Number		Description	
241-C		Valve pit	
Tank Pits			
Facility Number		Description	
241-C-01A		Pump pit	
241-C-01B		Heel pit	
241-C-01C		Sluice pit	
241-C-05A		Pump pit	
241-C-05B		Heel pit	
241-C-05C		Sluice pit	
241-C-10		Covered saltwell caisson	
241-C-11		Covered saltwell caisson	
Transfer Lines			
Line Number	Connecting Facilities		
8010	241-C-101-01A-U1	241-CR-152-L11	
8044	241-C-101-01A-U2	241-CR-152-U2	
8031	241-C-101-01A-U3	241-CR-152-L14	
Drain line	241-C-101-01B	Line 8010	
8114	241-C-101-01B-U3	241-C-103	
SN250/8070	241-C-101-01B-U2	241-CR-152	

Table 2-5. C Tank Farm Components Associated with Tanks C-101, C-105, C-110, and C-111.* (2 Sheets)

8047	241-C-101-01C-U2	241-CR-152-U1
8053	241-C-101-01C-U6	241-CR-152-L11
Transfer Lines		
Line Number	**Connecting Facilities**	
8020	241-C-101-01C-U1	241-CR-152-L9
V102	241-C-101-N3	241-C-151-L4
V104	241-C-101-N4	241-C-151-L5
3206	241-C-105-05A-U1	241-CR-153-L12
8238	241-C-105-05A-U2	241-CR-153-U4
8237	241-C-105-05A-U3	241-CR-153-L15
V122/8206	241-C-105-05A-U4	241-CR-152-L8
V115	241-C-105-05A-U8	241-CR-152-L1
8263	241-C-105-05B-U2	241-CR-152
8217	241-C-105-05C-U1	241-CR-153-L7
8241	241-C-105-05C-U2	241-CR-153-U3
8321	241-C-105-05C-U3	241-CR-153-L12
V103	241-C-105-C1	241-C-151-L3
V137	241-C-110-R6	241-C-153-L2
2-in. M-5 saltwell line to tank C-103 capped at pump pit	241-C-110-R13	Rerouted to 241-C valve pit L4
V141	241-C-110-R3	241-C-153-L6
V138	241-C-110-C1	241-C-153-L3
V139	241-C-110-C2	241-C-153-L4
V140	241-C-110-C3	241-C-153-L5
P4	241-C-111-R6	Waste scavenging valve box capped near 241-C valve pit
2-in. M-5 saltwell line to tank C-103 capped at pump pit	241-C-111-R13	241-C-103
V137	241-C-111-N6	241-C-153

* RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

Figure 2-7. Tank C-101 Plan View.

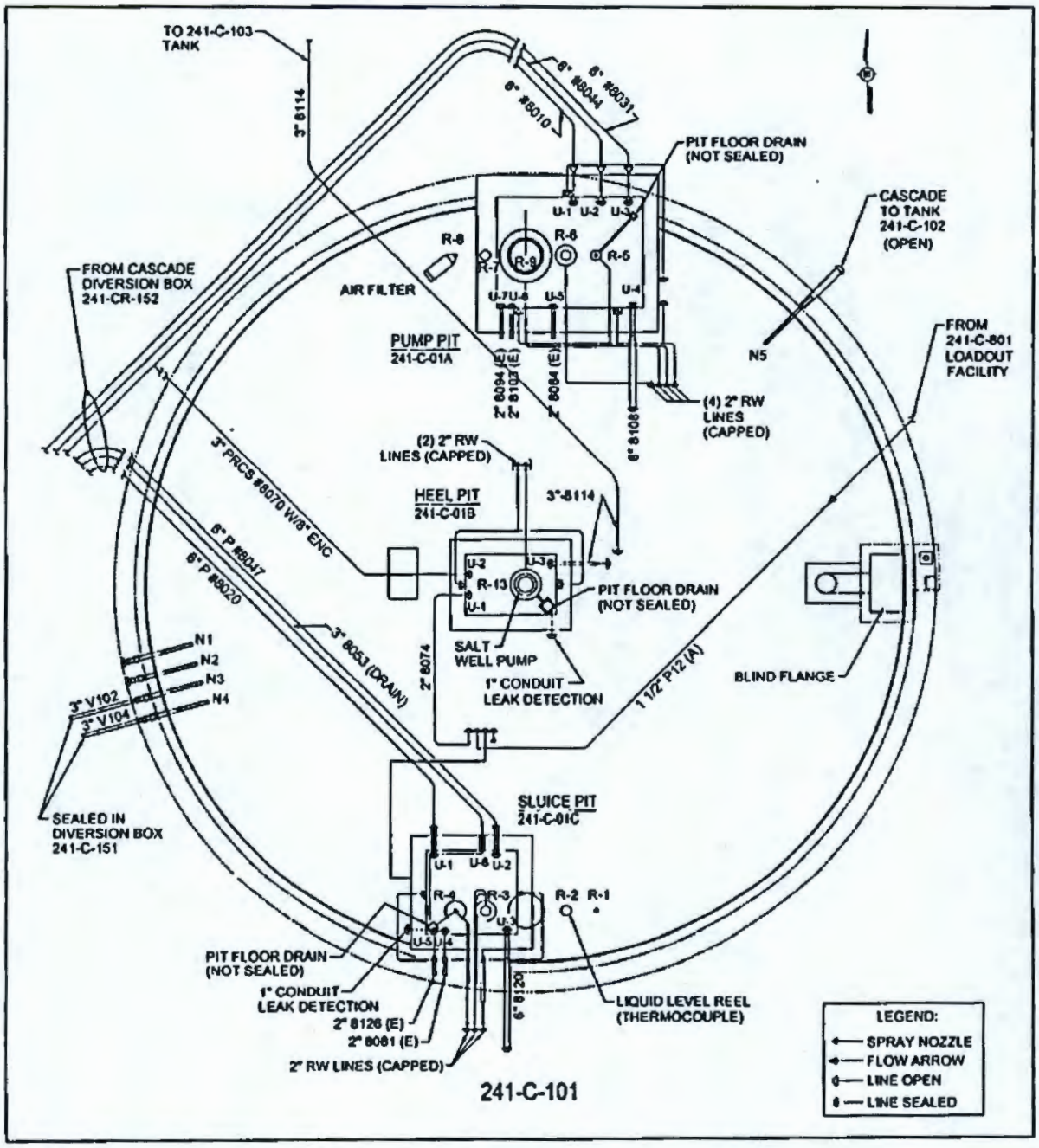


Table 2-6. Tank C-101 Previously Isolated Lines. (2 Sheets)

Intrusion Path	Description	Tank waste transfer line?	Isolation technique and status	Verification*
8010	Transfer line	Yes	Isolation blank in 241-CR-152, L11	H-2-73340 H-14-104175
8044	Transfer line	Yes	Isolation blank in 241-CR-152, U2	H-2-73340 H-14-104175
8031	Transfer line	Yes	Isolation blank in 241-CR-152, L14	H-2-73340 H-14-104175
8108	Spare nozzle	No	Capped outside pit during tank construction, never used	H-2-73340
8084	Electrical conduit	No	Sealed	H-2-73340
8103	Electrical conduit	No	Sealed	H-2-73340
8094	Spare electrical conduit	No	Sealed	H-2-73340
8074	Transfer line	Yes	Line T's into 8010, which has an isolation blank installed	H-2-73340. No line number listed on H-14-104175.
8070	Transfer line	Yes	Isolation blank in 241-CR-152 per H-2-73340. Line not listed on H-14-104175	H-2-73340
8114	Transfer line	Yes	Line cut and capped outside heel pit	H-2-73340. No line number listed on H-14-104175.
8053	Pit drain line	No	Plugged at 241-CR-152, L11	H-2-73340. No line number listed on H-14-104175.
8020	Transfer line	Yes	Isolation blank at 241-CR-152, L9	H-14-104175
8047	Transfer line	Yes	Isolation blank at 241-CR-152, U1	H-14-104175
8120	Spare nozzle	No	Capped during tank construction, never used	H-2-73340
8081	Nozzle 01C U4	No	Sealed	Assy. #3, H-2-73453
8126	Nozzle 01C U5	No	Sealed	Assy. #3, H-2-73453
N1	Spare tank nozzle	No	Capped during tank construction, never used	H-2-73340
N2	Spare tank nozzle	No	Capped during tank construction, never used	H-2-73340
V102	Transfer line through tank wall of tank nozzle N3.	Yes	Isolation blank at 241-C-151, L4	H-14-104175

Table 2-6. Tank C-101 Previously Isolated Lines. (2 Sheets)

Intrusion Path	Description	Tank waste transfer line?	Isolation technique and status	Verification*
V104	Transfer line through tank wall of tank nozzle N3.	Yes	Isolation blank at 241-C-151, LS	H-14-104175

* Verification documents reference information is provided in Section 9.0 of this document.

Note: Raw water, steam, and air lines are cut and capped outside pits.

Table 2-7. Tank C-101 Currently Open Lines.

Line	Description	Tank waste transfer line?	Planned isolation technique
Cascade line to tank C-102	Isolate with tank C-102	Yes	No action until final closure fill in tank C-102 blocks this line
--	01A pit drain	No	To be left open
--	01B pit drain	No	To be left open
--	01C pit drain	No	To be left open

Figure 2-8. Tank C-105 Plan View.

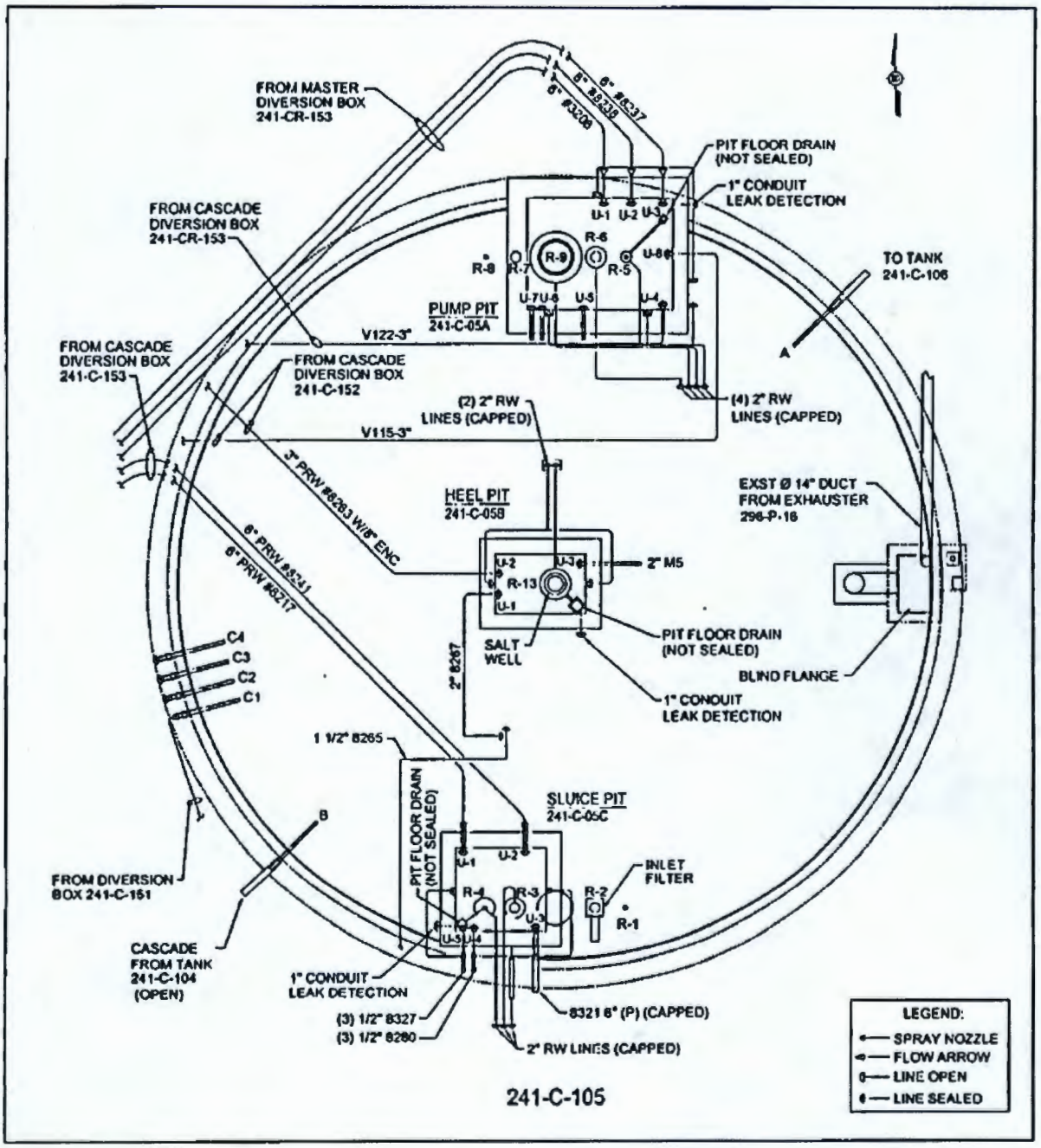


Table 2-8. Tank C-105 Previously Isolated Lines. (2 Sheets)

Intrusion Path	Description	Tank Waste Transfer Line?	Isolation Technique and Status	Verification*
Nozzle C1 (V103)	Waste transfer line into tank	Yes	Isolated in diversion box 241-C-151, L3	H-2-73338
Nozzle C2	Spare nozzle	No	Isolated at tank construction; never used	HW-72743 H-2-73345
Nozzle C3	Spare nozzle	No	Isolated at tank construction; never used	HW-72743 H-2-73345
Nozzle C4	Spare nozzle	No	Isolated at tank construction; never used	HW-72743 H-2-73345
3206 or 8206	Waste transfer line on pump pit nozzle U-1	Yes	Isolated in diversion box 241-CR-153, L12; drawings disagree on line number	H-2-73345 H-2-73339
8238	Waste transfer line on pump pit nozzle U-2	Yes	Isolated in diversion box 241-CR-153, U4	H-2-73345 H-2-73339
8237	Waste transfer line on pump pit nozzle U-3	Yes	Isolated in diversion box 241-CR-153, L15	H-2-73345 H-2-73339
V122	Waste transfer line on pump pit nozzle U-4	Yes	Isolated in diversion box 241-C-152, L8	H-2-73345 H-2-73339
Electrical conduit	Electrical conduit on pump pit nozzle U-5	No	Penetration plugged	H-2-73450
Electrical conduit	Electrical conduit on pump pit nozzle U-6	No	Penetration plugged	H-2-73450
Electrical conduit	Electrical conduit on pump pit nozzle U-7	No	Penetration plugged	H-2-73450
V115	Waste transfer line on pump pit nozzle U-8	Yes	Isolated in diversion box 241-C-152, L1	H-2-73339
Water lines	Four raw water lines to pump pit	No	Lines cut and capped outside pit	H-2-71842
8267	Steam line to heel pit nozzle U-1 from HC gang valve	Yes	Cut and capped at HC gang valve location	H-2-71842 H-2-41847
8263	Waste transfer line on heel pit nozzle U-2. T's into 8206	Yes	Line 8206 Isolated in diversion box 241-CR-153, L12	H-2-73345 H-2-73339
Undesignated line	Unidentified line on heel pit nozzle U-3	Yes	Line cut and capped outside pit	H-2-73345 H-2-73973
Water lines	Two raw water lines to heel pit	No	Lines cut and capped outside pit	H-2-71842 H-2-73345
8217	Waste transfer line on sluice pit nozzle U-1	Yes	Isolated in diversion box 241-CR-153, L7	H-2-73345 H-2-73339
8241	Waste transfer line on sluice pit nozzle U-2	Yes	Isolated in diversion box 241-CR-153, U3	H-2-73345 H-2-73339
Undesignated line	Spare waste transfer line on sluice pit nozzle U-3	No	Spare. Capped outside sluice pit at construction.	H-2-73345 H-2-41194

Table 2-8. Tank C-105 Previously Isolated Lines. (2 Sheets)

Intrusion Path	Description	Tank Waste Transfer Line?	Isolation Technique and Status	Verification*
8280	1.5-in. air line on sluice pit nozzle U-4	No	Nozzle sealed at sluice pit 241-C-05C, U4	H-2-73345 H-2-73453
8327	1.2-in. air line on sluice pit nozzle U-5	No	Nozzle sealed at sluice pit 241-C-05C, U5	H-2-73345 H-2-73453
Water lines	Three raw water lines to sluice pit	No	Lines cut and capped outside sluice pit	H-2-73345 H-2-71842

* Verification documents reference information is provided in Section 9.0 of this document.

Table 2-9. Tank C-105 Currently Open Lines.

Line	Description	Tank Waste Transfer Line?	Planned Isolation Technique
Nozzle B	Cascade line from tank C-104	Yes	No action until tank fill.
Nozzle A	Cascade line to tank C-106	Yes	No action until tank fill.
Pump pit drain	Pit floor drain into tank C-105	No	Drains blocked when pit cover is weather sealed. Separate isolation not required.
Heel pit drain	Pit floor drain into tank C-105	No	Drains blocked when pit cover is weather sealed. Separate isolation not required.
Sluice pit drain	Pit floor drain into tank C-105	No	Drains blocked when pit cover is weather sealed. Separate isolation not required.
Exhaust duct	Exhaust duct from condenser hatchway	No	To be determined.

Figure 2-9. Tank C-110 Plan View.

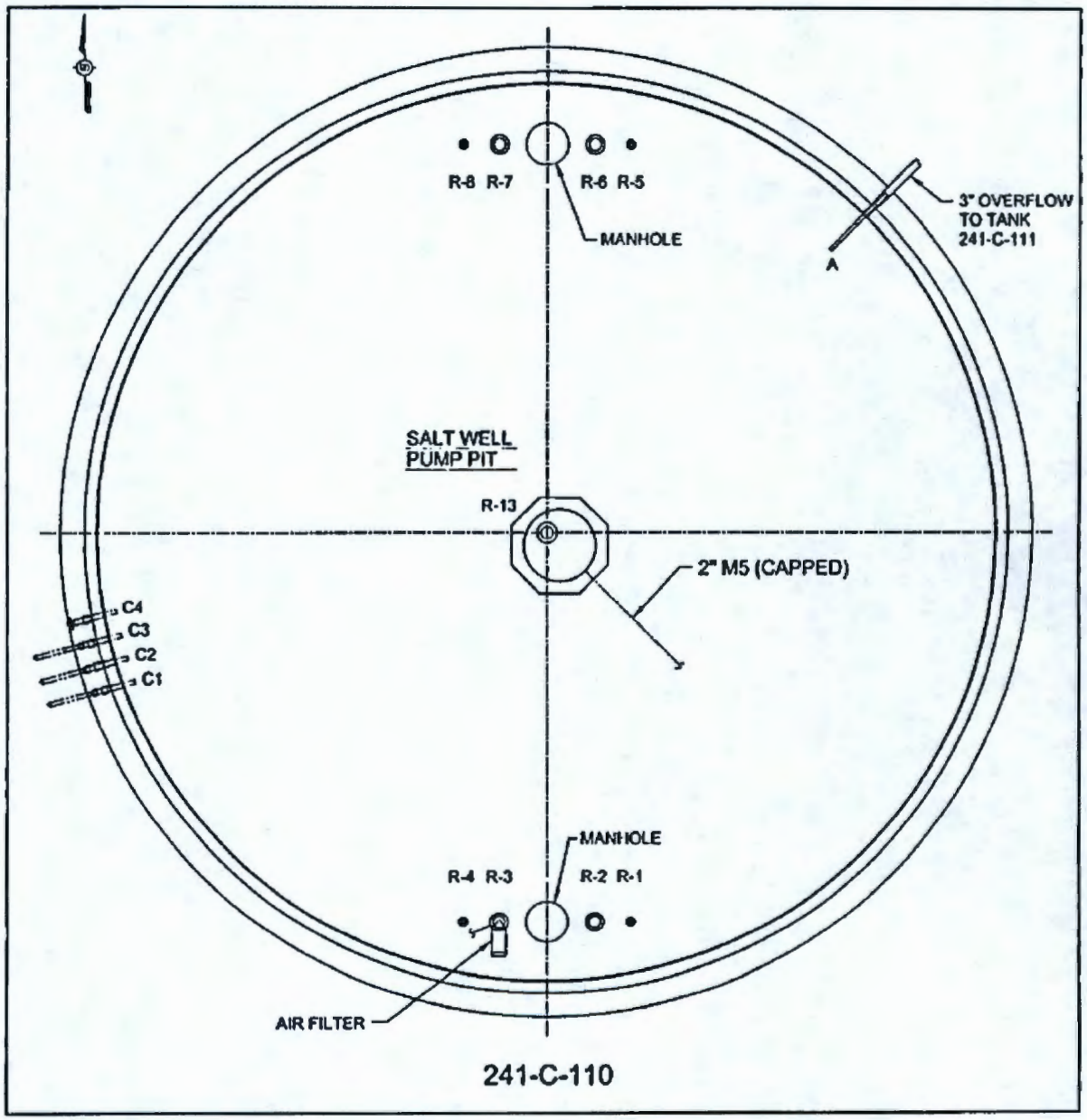


Table 2-10. Tank C-110 Previously Isolated Lines.

Intrusion Path	Description	Tank Waste Transfer Line?	Isolation Technique and Status	Verification*
Nozzle C1 (V138)	Waste transfer line into tank	Yes	Isolated in diversion box 241-C-153, L3	H-2-73338
Nozzle C2 (V139)	Waste transfer line into tank	Yes	Isolated in diversion box 241-C-153, L4	H-2-73338
Nozzle C3 (V140)	Waste transfer line into tank	Yes	Isolated in diversion box 241-C-153, L5	H-2-73338
Nozzle C4	Spare nozzle	No	Isolated at tank construction; never used	H-2-37010 H-2-73341
V137	Waste scavenging line	Yes	Cut and capped near riser	H-2-73350
V141	Pump out line	Yes	Cut and capped 50 ft from tank	H-2-73350
Unknown	Saltwell transfer line	Yes	Cut and capped near riser	H-2-73350
Diptubes	Two 1-in. diptubes in R-2	No	Removed and riser blanked	H-2-73350

* Verification documents reference information is provided in Section 9.0 of this document.

Table 2-11. Tank C-110 Currently Open Lines.

Line	Description	Tank Waste Transfer Line?	Planned Isolation Technique
Nozzle A	Cascade line to tank C-111	Yes	No action until tank fill.

2.6.4 Tank C-111 Ancillary Equipment

Tank C-111 is connected to tank C-110 and tank C-112 by 3-in. diameter cascade lines. Tank C-111 has nine risers of varying diameters and lengths of protrusion into the tank. The risers provide access to various in-tank equipment. Table 2-3 identifies the purpose of each riser. A cross-section view of tank C-111 is shown in Figure 2-4. Figure 2-10 illustrates the line and riser locations into and around tank C-111 along with their current uses.

Seven pathways enter tank C-111 or its associated pits. The pathways include lines a pit drain, and risers. Five pathways into tank C-111 have already been isolated, as shown in Table 2-12. Current plans for isolation of all remaining pathways are shown in Table 2-13. This work will be accomplished in accordance with the tank closure plan.

Table 2-12. Tank C-111 Previously Isolated Lines.

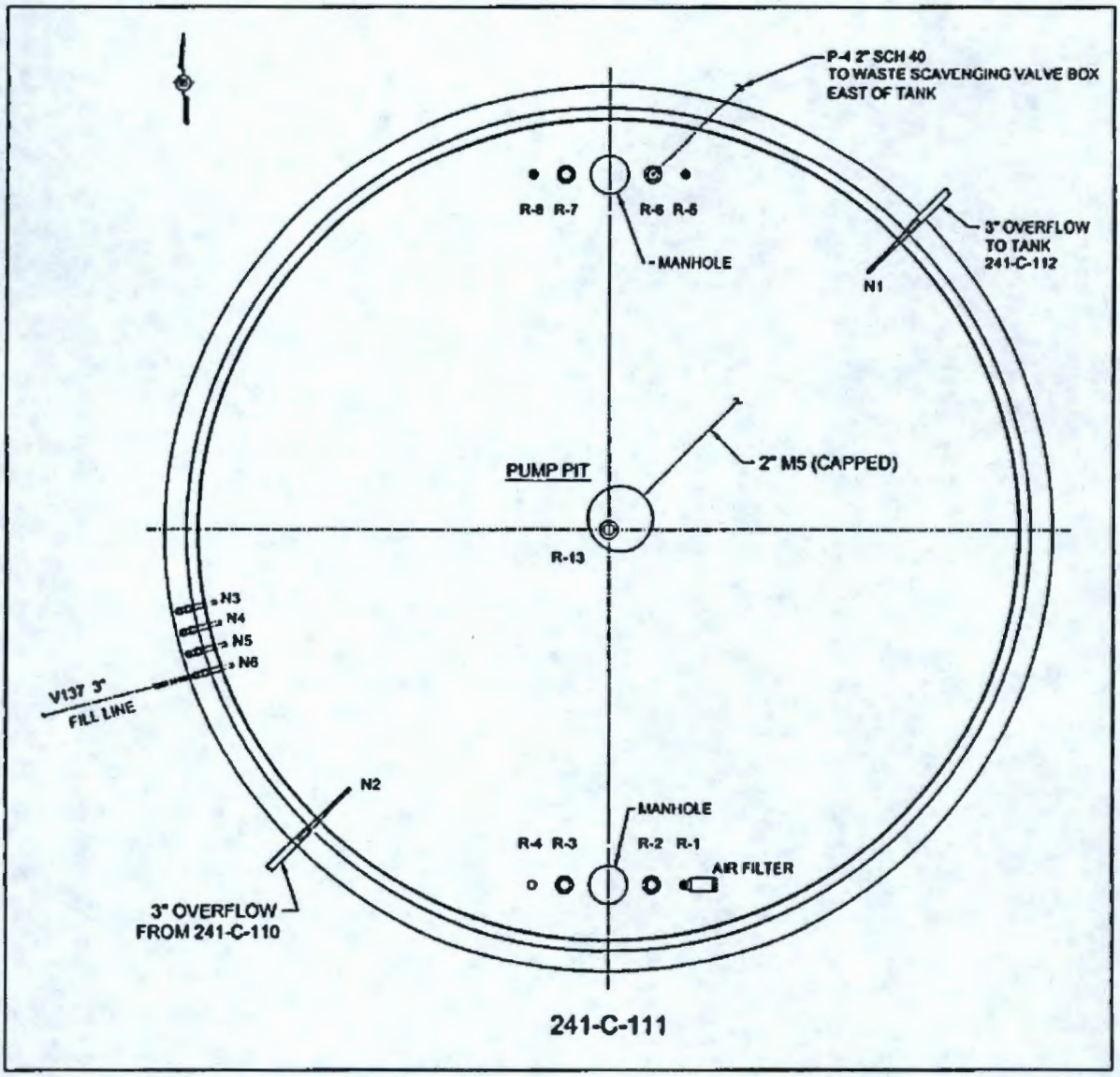
Intrusion Path	Description	Tank Waste Transfer Line?	Isolation Technique and Status	Verification*
Unknown	Waste scavenging line	Yes	Cut and capped near R-6	H-2-73341
Unknown	Salt waste transfer line	Yes	Cut and capped near R-13	H-2-73341
Nozzle N3	Spare nozzle	No	Isolated at tank construction; never used	H-2-73341
Nozzle N4	Spare nozzle	No	Isolated at tank construction; never used	H-2-73341
Nozzle N5	Spare nozzle	No	Isolated at tank construction; never used	H-2-73341

* Verification documents reference information is provided in Section 9.0 of this document.

Table 2-13. Tank C-111 Currently Open Lines.

Line	Description	Tank Waste Transfer Line?	Planned Isolation Technique
Nozzle N1	Cascade line to tank C-112	Yes	No action until tank fill.
Nozzle N2	Cascade line from tank C-110	Yes	No action until tank fill.

Figure 2-10. Tank C-111 Plan View.



3.0 PLANNED WASTE RETRIEVAL TECHNOLOGY

This section provides a description of the planned waste retrieval technology for retrieving the waste from tanks C-101, C-105, C-110, and C-111.

3.1 SYSTEM DESCRIPTION

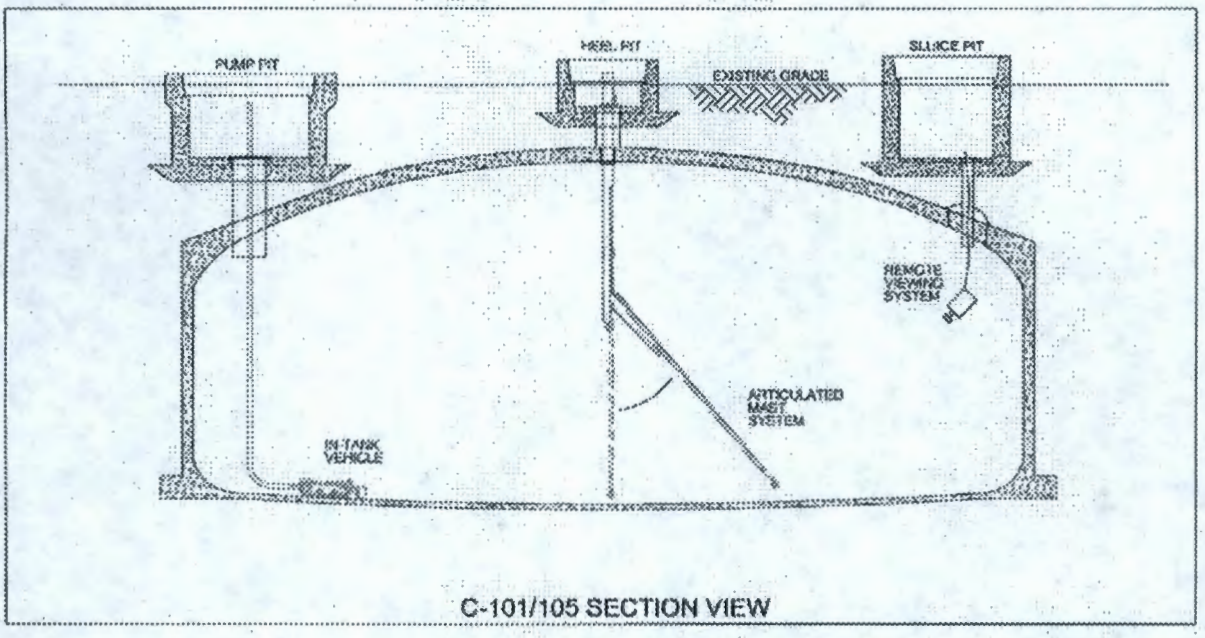
This section provides a description of the WRS and how it will be operated. Continued design development and incorporation of lessons learned may lead to changes in the design and/or operating strategy.

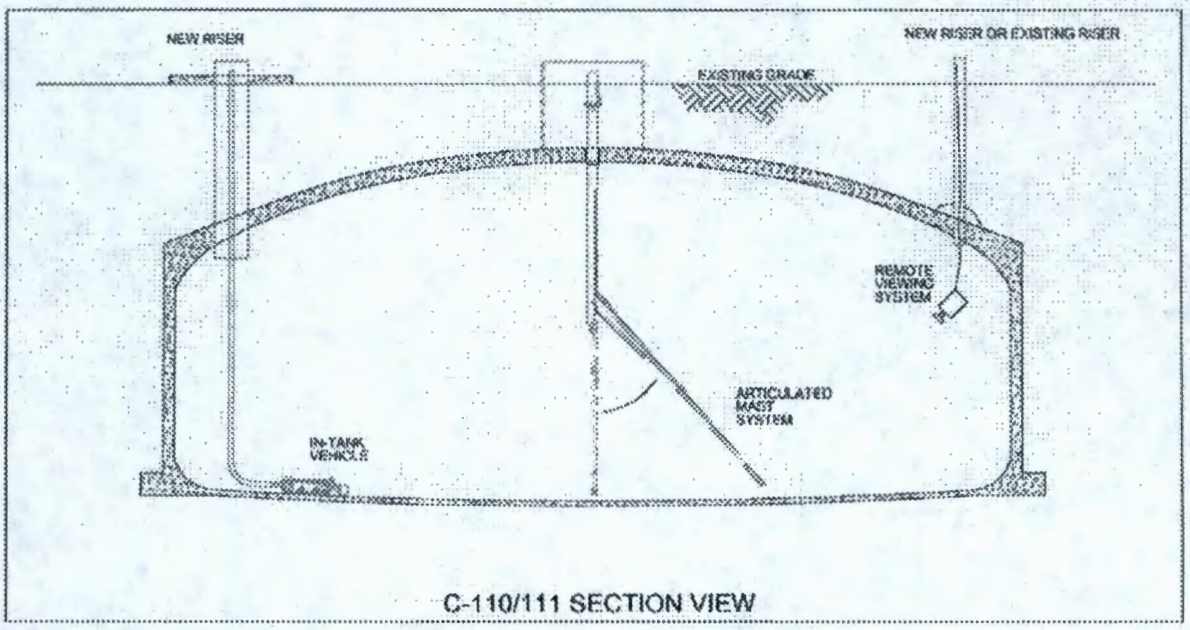
3.1.1 Waste Retrieval System Physical System Description

The MRS is a vacuum-based WRS that will consist of an articulated mast installed near the center of the tank along with an in-tank vehicle (ITV) designed to move waste toward the center of the tank where it can be removed with the mast. A conceptual diagram of the MRS in-tank components is shown in Figure 3-1. The articulating arm on the mast has a vacuum head that can be moved around the central region of the tank with an effective reach of approximately 16 ft. Air or water can be injected at the vacuum head to assist in mobilizing the waste. If needed, a series of five scarifying, high-pressure, low-volume water jets located around the outside of the vacuum head can be used to dislodge waste. Both the central mast and the ITV have the capability to use low-pressure water (approximately 125 lb/in^2) and high-pressure water (approximately 1,500 lb/in^2) to mobilize waste. The waste is deposited in a batch vessel located above grade in the vessel/pump skid where load cells and a level gauge indicate the waste batch volume. The batch vessel has a working volume of approximately 400 gal.

The ITV is an adaptation of a commercially available tracked vehicle. The ITV will have the ability to for push waste, a low-pressure water cannon to wash down tank walls and equipment, and a three-nozzle scarifier system that can be used to dislodge and mobilize waste, if necessary. The ITV may be deployed at any time. The purpose of the ITV is to push or jet waste toward the center of the tank where it can be removed with the vacuum system. Water and hydraulic lines are routed to the ITV through an umbilical line that is controlled using the umbilical management system. The umbilical management system consists of a hydraulically driven spool used to play out and reel in the umbilical line during ITV operation. The umbilical management system is located above grade over a large-diameter (36-in. or greater) riser and includes an enclosure that serves to minimize fugitive emissions by maintaining ventilation flow back into the tank. The umbilical management system also includes an ITV and a decontamination system to wash down the drip pan to collect any liquid from the outside of the hose. The drip pan drains back into the tank.

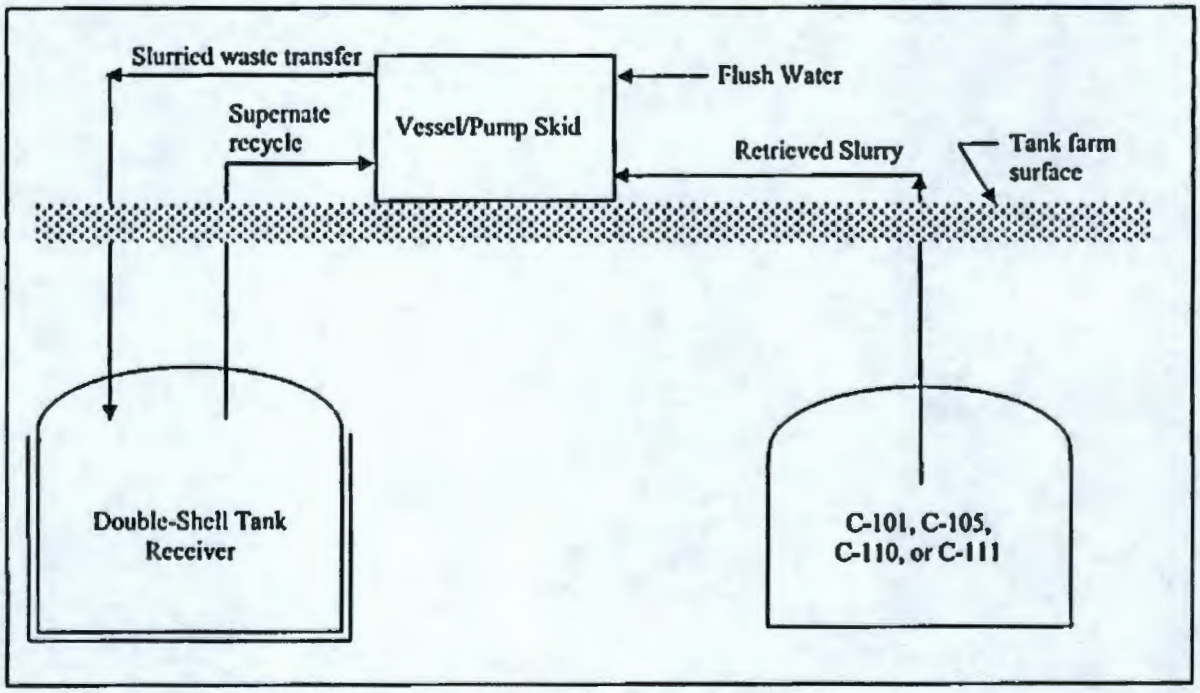
Figure 3-1. Mobile Retrieval System In-Tank Components Conceptual Diagram.





To minimize waste volumes, the current waste retrieval plan includes the use of water, or DST supernate, to facilitate waste transfers from the batch vessel to the DST receiver tank. The MRS is capable of removing waste from the tanks at a solids loading that may be too high to be transferred to the DST receiver tank without dilution. If used, the recycled supernate would only be used for waste transfers and would not be introduced into the SST during waste retrieval other than for off-normal system draining. The current waste retrieval strategy for using DST supernate is shown in Figure 3-2. Additional detail on the planned use of supernate during waste retrieval is discussed in Section 3.2.

Figure 3-2. Waste Transfer Liquid Supply.



Both the vessel/pump skid and the vacuum skid provide secondary containment and leak detection. Both skids provide for leak collection and drainage back to the tank being retrieved.

The vacuum will be produced by tandem vacuum pumps installed upstream of the waste receiving vessel. The tandem vacuum pumps provide a level of redundancy in that normally only one pump would be operated. The system does have the capability to run both of the vacuum pumps simultaneously if needed for waste removal. Offgas from the vacuum system will be returned to the tank being retrieved. Active ventilation of the tank will be provided per the requirements of the NOC.

Miscellaneous process and skid drainage will be routed back to the tank being retrieved during waste retrieval operations. During routine operations, a small volume of contaminated seal water from the vacuum system and line drainage will be generated and routed back to the tank undergoing waste retrieval. Also, under upset or emergency conditions, waste contained in the batch vessel can be drained back to the tank being retrieved as part of recovery actions.

The major components of the MRS include the following:

- Articulated mast system (AMS)
- ITV
- Vessel/pump skid
- Vacuum skid
- Hydraulic power packs
- Monitoring and control system
- Ventilation system
- Compressed air skid
- Water supply skid
- Closed-circuit television camera system
- Control trailer.

The modular design of the system incorporates reliability and maintainability features that allow for continued operation, repair, and/or replacement of components in the event of a component failure. Redundant slurry pumps are contained in the vessel/pump skid and provide the capability to transfer waste out of the batch vessel in the event that one of the pumps fail. Spare parts required to support operations have been evaluated and are being procured to support system operations.

Various monitoring instruments will be used to collect data to support operation of the WRS and perform environmental monitoring. Cameras will be installed in each of the SSTs to provide the capability to visually monitor and aid in control of waste retrieval operations. Instrumentation will also be provided to monitor process control data (e.g., pressures and flowrates). Existing ENRAF[1] level gauges will be retracted during waste retrieval operations but may be used periodically to monitor waste levels. This information will be used to support material balance calculations.

Before initiating waste retrieval, a formal waste compatibility assessment will be performed in accordance with HNF-SD-WM-OCD-015, *Tank Farm Waste Transfer Compatibility Program*. HNF-SD-WM-OCD-015 provides a formal process for determining waste compatibility through the preparation of documented waste compatibility assessments for waste transfers. The primary purpose of the program is to ensure that sufficient controls are in place to prevent the formation of incompatible mixtures during waste transfer operations. Waste compatibility assessments are prepared before all waste transfers into the DST system to ensure that the waste transfer will comply with specific administrative control, safety, regulatory, programmatic, and operational decision rules related to waste chemistry and waste properties. Waste compatibility assessments require the preparation of calculations to determine source tank and/or receiver tank compositions and to assess those compositions against specified decision rules that are provided in HNF-SD-WM-OCD-015.

Formal issuance of the compatibility assessment will not be completed until just before waste retrieval operations begin to ensure that current conditions are captured in the assessment.

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[1] ENRAF is a trademark of Enraf, Inc., Enraf B.V., Delft, The Netherlands.

During waste retrieval operations, the tank(s) being retrieved will be actively ventilated. The ventilation system will consist of skid-mounted high-efficiency particulate air (HEPA) filtered portable exhausters. The ventilation system(s) are designed to pass air through the tank, thereby reducing condensation and fog within the tank. The ventilation systems required by Washington State Department of Health (WDOH) include a heater, prefilter, demister, two HEPA filters and test sections, exhaust fan, and stack. Project plans may include the design and installation of ventilation systems(s) to support waste retrieval operations for the C farm tanks as shown in Figure 3-3. Details of the ventilation systems are provided in AIR 05-407, *Categorical Tank Farm Facility Waste Retrieval and Closure: Phase II Waste Retrieval Operations* and DE05NWP-002, *Notice of Construction (NOC) Application for Operations of Waste Retrieval Systems in the Single-Shell Tank (SST) Farms*. ORP and CH2M HILL Hanford Group, Inc. (CH2M HILL), pursuant to federal requirements for protection of their workers, will develop and implement a personal exposure sampling and monitoring plan for SST waste retrievals. This plan will be developed and implemented by the Industrial Hygiene (IH) department(s) per the CH2M HILL Environmental Health Program with consideration of input from Ecology. Subsequent to issuance of the IH sampling and monitoring plan, changes to that portion of the plan pertaining to sampling exhauster emissions at the stack will be provided to Ecology for Ecology's information in as timely a manner as possible.

Condensate drainage from the exhauster(s) will be routed back to an SST undergoing waste retrieval. Any change to this drainage routing will covered by a Change Notice Form to this TWRWP. The rate of condensate coming from the exhausters and demisters which originated in a tank undergoing MRS retrieval is dependent upon a variety of items which include, but are not limited to, the ambient air temperature, the tank vapor space temperature, the air flow from the tank, the percent relative humidity in the tank exit air, whether retrieval conditions are being performed or not, the temperature of the air stream returned to the SST from the air separator blowers, the amount of insulation on the vent duct, and the operational status of the vent duct heat trace. It is roughly estimated that the condensate formation rate from one of these four tanks will be about 0 to 5 gal/day/tank when it is exhausted and not undergoing MRS retrieval, and about 0 to 25 gal/day/tank when it is undergoing MRS retrieval. The rates will likely be in the lower end of both of these ranges most of the time. These numbers are very rough estimates only.

See Section 4.1.3 on level monitoring for SST used as catch tank for exhauster condensate drainage. If retrieval of this SST is completed prior to completion of retrieval of tanks C-101, C-105, C-110 and C-111, Ecology will be informed via a Change Notice of any subsequent routing change for disposition of the condensate.

New equipment will be installed in the tanks to support waste retrieval. Existing equipment will be removed if, and as required, to make room for the new equipment. It is currently planned that the articulated mast will be installed in the center riser located in the center pit; however, the AMS could be deployed in other risers if available.

The configuration of tanks C-110 and C-111 is different in that there are no concrete pits and only a single central corrugated metal saltwell pump pit. The WRS for tanks C-110 and C-111 will require design and construction of new aboveground pits to support installation of the MRS. Additionally, new tank risers may need to be designed and installed on tanks C-110 and C-111 to

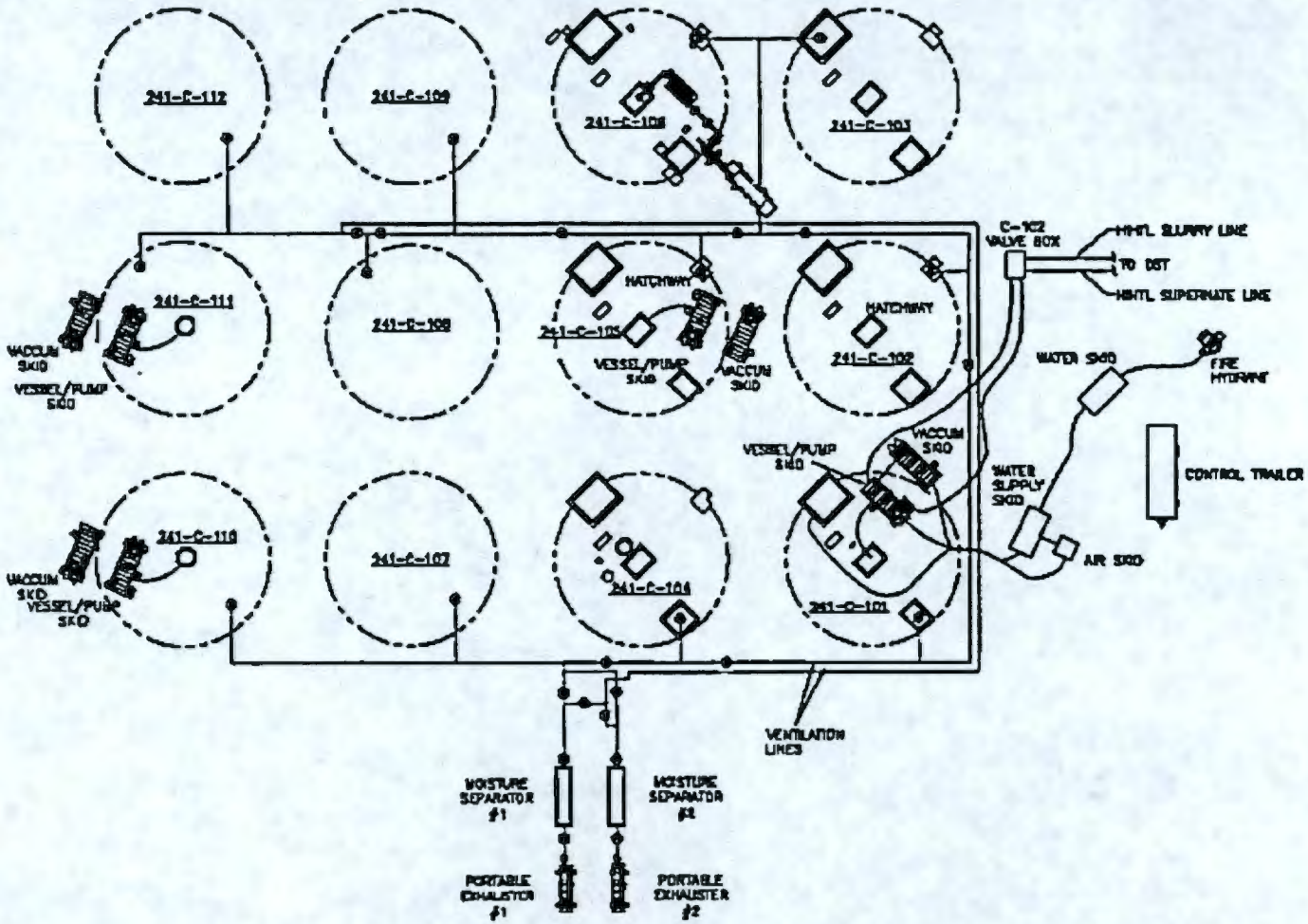
allow the ITV to be installed. All pits will be inspected and will drain to the SST or will have leak detection. Table 3-1 provides the planned riser usage for the tank C-101 WRS. The WRS designs for tanks C-105, C-110, and C-111 have not been completed; therefore, the riser usage for these tanks has not been established at this time. Riser usage for tank C-105 would be similar to that shown for tank C-101, but tanks C-110 and C-111 may be different because there are no concrete pit structures on those tanks. Volumes associated with tanks C-105, C-110 and C-111 retrievals have been evaluated and are provided in the flowsheet RPP-21753, *C Farm 100-Series Tanks, Retrieval Process Flowsheet Description*. A proposed equipment layout has been completed and is provided in Figure 3-3.

Table 3-1. Planned Riser Usage for Tank C-101.

Riser Number	Tank C-101
R1	Not used
R2	Camera and ventilation exhaust duct
R3	Not used
R4	Not used
R5	Not used
R6	Not used
R7	Camera and breather filter
R8	ENRAF* level gauge
R9	In-tank vehicle
R13	AMS
Condenser pit	MRS drain lines and vacuum return

AMS = articulated mast system.
MRS = mobile retrieval system.
* Enraf is the supplier of the identified level gauges; ENRAF is a trademark of Enraf, Inc., Enraf B.V., Delft, The Netherlands.

Figure 3-3. Potential New Equipment Layout.



3.1.2 Double-Shell Receiver Tanks

The planning as of the first quarter of 2006 includes using tank AY-101 as the receiver tank for waste retrieved from tank C-111, tank AN-106 as the receiver tank for waste retrieved from tank C-110, and tank AN-101 as the receiver tank for waste retrieved from tanks C-105 and C-101. Ongoing evaluations may result in identifying alternate receiver tank(s).

The supernate pump and slurry distributor installed in DST AN-106 in support of tank C-103 waste retrieval (RPP-21895) may continue to be used to pump supernate back to the C farm and distribute the sludge as received from tank C-105. A new supernate pump and a new slurry distributor are planned for DST AY-101 to support waste retrieval from C farm tanks.

Because the elevation of the AN tank farm is approximately 22 ft higher than the C tank farm and the elevation of the AY tank farm is approximately 32 ft higher than the C farm, the slurry distributor and the supernate pump incorporate anti-siphon devices to prevent unintentional flow from the DST to the SST.

All waste transfers, including transfer of waste from the C farm tanks to the DSTs and the transfer of supernate from DSTs back to the WRS vessel/pump skid above the C farm tanks, will be performed using transfer lines that provide secondary containment. The waste retrieval project currently plans to use overground hose-in-hose transfer lines (HIHTLs) and the *Resource Conservation and Recovery Act of 1976* (RCRA)-compliant DST transfer system.

3.1.3 Waste Retrieval System Operating Description

The overall WRS operating strategy will consist of retrieving waste beginning from the center of the tank and working outward with the AMS while limiting the volume of water introduced to the tank for any batch to only that necessary for efficient waste removal. The ITV will be deployed when needed to move waste to the center of the tank for removal. The waste retrieval process will be monitored using closed-circuit television to facilitate waste retrieval operations. The retrieval system will introduce limited volumes of water into the SSTs to help mobilize waste and provide lubrication in the vacuum lines. Recycled DST supernate will be used for waste dilution and transfer from the batch vessel to the DST receiver tank.

During routine operations, waste retrieval will be initiated by energizing the vacuum pumps to begin the pneumatic-assisted vacuum conveyance system. A high-pressure water spray (200 to 1,200 lb/in^2) mounted to the vacuum head can be used as necessary to break up or dislodge the waste. The introduction of water into the tank through the vacuum system is controlled by the operator and can range from 0 to approximately 12 gal/min. The ITV has a low-pressure water cannon (approximately 125 lb/in^2) that can be controlled by the operator over a range of 0 to approximately 75 gal/min. and a high-pressure scarifier (up to 1,500 lb/in^2) that can be controlled by the operator over a range of 0 to approximately 15 gal/min. System operators remotely position and move the vacuum head within the tank to retrieve waste. The addition of water into the tank through the mast or the ITV can be controlled so that on average the rate of removal is

greater than the rate of addition and there is not an accumulation of liquid in the tank. All operations within the tank are monitored and controlled using cameras mounted in the tank dome space. From the tank, the waste is vacuumed up into the batch vessel located in the topside vessel/pump skid. Waste removal rates using the vacuum are expected to range from 5 to approximately 40 gal/min. When the batch vessel is full, as measured by the tank level switch or tank weight, the WRS is switched from retrieval mode to transfer mode. Water, or recycled supernate, is used to dilute or the transfer solution as needed for the transfer to the DST or to flush the line if needed following the transfer.

During the transfer mode water, recycled supernate, may also be used to mobilize and fluidize heavier wastes inside of the batch vessel and dilute the waste to a consistency that can be pumped to the double-shell receipt tank.

During all field activities, standard operating procedures and safety precautions will be implemented to protect worker health and safety, the public, and the environment. In accordance with standard operating procedures, health physics and industrial health technicians will monitor conditions within the tank farm in accordance with approved monitoring plans.

During waste retrieval operations, waste retrieval progress will be monitored by estimating the volume of residual waste remaining in the tank. Engineering estimates will be based on initial waste volume estimates and material balance calculations. Following completion of waste retrieval, the residual waste volume will be calculated in accordance with an approved data quality objective(s) and sampling and analysis plan.

Waste retrieval operations will continue until less than 360 ft^3 of residual waste remains in the tank, and/or the limits of technology have been reached for this retrieval method.

The following information will be used to evaluate termination of retrieval and will be shared with Ecology before making a decision to terminate field retrieval activities:

- System performance and efficiency data
- In-tank visual confirmation of tank condition and waste retrieval
- Preliminary volume estimates using tank geometry and in-tank structural features
- Presentation and discussion of alternate system configurations and process modifications to enhance retrieval performance
- Presentation and discussion of residual sample location.

TFC-ENG-CHEM-P-47, *Single-Shell Tank Retrieval Completion Evaluation*, provides the methodology to follow for determining when an SST undergoing waste retrieval has reached the end of the retrieval process. Following is a summary of this procedure. This summary does not take the place of TFC-ENG-CHEM-P-47; for any differences between this summary and the latest version of the procedure, the procedure takes precedence. Refer to TFC-ENG-CHEM-P-47 for details of the summary steps.

When waste retrieval starts, engineering personnel will begin tracking retrieval performance (i.e., percent of waste retrieved) and provide a weekly status report. Weekly status information will be forwarded to Ecology to brief them on retrieval activities, including residual volume estimates and performance parameters. Ecology will be invited to view waste retrieval activities and video images of the in-tank operations.

Engineering shall recommend configuration or procedure changes to enhance recovery as warranted. Management will be notified after performance efficiency reduces to about 10% of the starting retrieval performance.

An attachment to the procedure provides guidance for retrieval performance and limit of technology evaluations. Establishment of when the limits of technology have been reached includes:

- Examination of in-tank images to observe/record waste contours and characteristics
- Estimation of waste retrieval performance efficiency and remaining waste volume
- Using performance data to demonstrate that a consistent pattern is present indicating limits of technology have been reached
- Evaluation of waste retrieval performance against system limitations.

Ecology is notified when it appears that the limits of technology have been reached. Status reports are continued until waste retrieval operations cease. An SST waste retrieval evaluation form and a retrieval report are then prepared and issued.

Following completion of waste retrieval, the residual waste volume will be determined using the methodology defined in RPP-23403 and RPP-PLAN-23827.

3.2 LIQUID ADDITIONS DURING WASTE RETRIEVAL

During waste retrieval, water will be used by the retrieval/transfer system to mobilize and remove waste from within the SST to the batch vessel contained in the vessel/pump skid. From the batch vessel water, or recycled DST supernate, will be used for dilution before transferring the waste to the designated receiver DST. Supernate input will be approximately 20 to 30 gal/min. and slurry flow rate outputs will be approximately 75 to 80 gal/min.

A process flowsheet, RPP-21753, has been prepared for the C farm 100-series tanks. The flowsheet document is based on simulations performed with the Hanford Tank Waste Operations Simulator model. The flowsheet uses the Hanford Tank Waste Operations Simulator to simulate the waste storage, retrieval, transfer, and treatment processes to provide an operating strategy for C farm waste retrieval. The flowsheet document shows the waste transfers needed to support C tank farm retrievals. Table 3-2 shows the estimated waste volumes to be retrieved from each of the four tanks addressed by this document. It also shows the estimated water volumes for

retrieving waste from each SST and the approximate number of batches required for waste retrieval. The values in Table 3-2 are based upon the referenced revision of the flowsheet and may change in subsequent revisions. The volume of DST supernate used is not shown; since this volume is not additive to the system, it is a transport fluid that is recycled, if utilized.

Table 3-2. Tanks C-101, C-105, C-110 and C-111 Waste Retrieval Summary Data.*

Tank	Initial Tank Waste Volume Prior to Retrieval (kgal)	Estimated Water Volume Used for Retrieval (kgal)	Estimated Number of Batches
C-101	88	161	620
C-105	132	189	800
C-110	177	221	990
C-111	58	140	500

Note: Water volumes and the batches shown are estimates only. Final values may be outside the ranges indicated. Recycled DST supernate volumes planned for use as a carrier fluid for waste transfers are not included in this table.

DST = double-shell tank.
SST = single-shell tank.

* Data source is RPP-21753. Water volume estimates are based on using 160 gal. of water for each 240-gal. batch of waste solids plus an allocation of 100,000 gal. of water per tank to account for additions that may occur over the course of waste retrieval The number of batches is based upon a 400 gal. batch volume.

RPP-21753, 2005, *C Farm 100-Series Tanks Retrieval Process Flowsheet Description*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

The timing for waste transfers is dependent upon personnel resource availability, equipment availability, and DST conditions. Once waste retrieval is started, it should follow the general pattern described, but no liquid additions or removals to/from those tanks can be predicted for more than a day or two in advance; therefore, no detailed timeline can be developed showing all liquid additions and removals. The addition of water during waste retrieval may be continuous or intermittent. Based upon experience with other waste retrievals, it will likely last 8 to 16 hours, then be followed by a day or more wait, then continue. Work continuity will be dependent upon resource availability and external influences.

Table 3-3 provides an estimate of the distribution of water used in the MRS process. The values in Table 3-3 are based upon the referenced revision of the flowsheet and may change in subsequent revisions. A simplified flowsheet schematic is shown in Figure 3-4.

Table 3-3. Estimated Water Usage for MRS Retrieval.

Stream	Percent of Total Water Usage*	Percent of Water Added to SST
Low-pressure water to AMS	5	10
High-pressure water to AMS	11	100
Air separator drain	3	100
Hydrotrans and batch vessel flush	2	20
Low-pressure water to ITV	52	100
High-pressure water to ITV	14	100
ITV decontamination water	1	100
Transfer line flush	12	0

AMS = articulated mast system.
ITV = in-tank vehicle.
* Based upon water usage shown in H-14-106761, *241-C-101 WRS Process Flow Diagram*. This water distribution is an estimate only and the numbers in the middle column could vary significantly from those shown. The water usage distribution for the remaining three tanks is expected to be approximately the same as for tank C-101.

The water additions shown in Table 3-3 represent the significant liquid streams. Most of the potential liquid additions to the tank from other WRS sources should be zero or quite small. The timing for water additions is not scheduled. The timing cannot be estimated more than a day or two in advance due to many competing factors; all that can be provided in advance is a rough description of the process that includes what the major water additions are and when they are made.

The vacuum waste retrieval process is performed while minimizing the liquid present in the retrieval tank. Water is used in the vacuum retrieval process for a variety of purposes that may include the following streams:

1. High-pressure water to scarifiers on AMS head and ITV used to mobilize or break up hard waste.

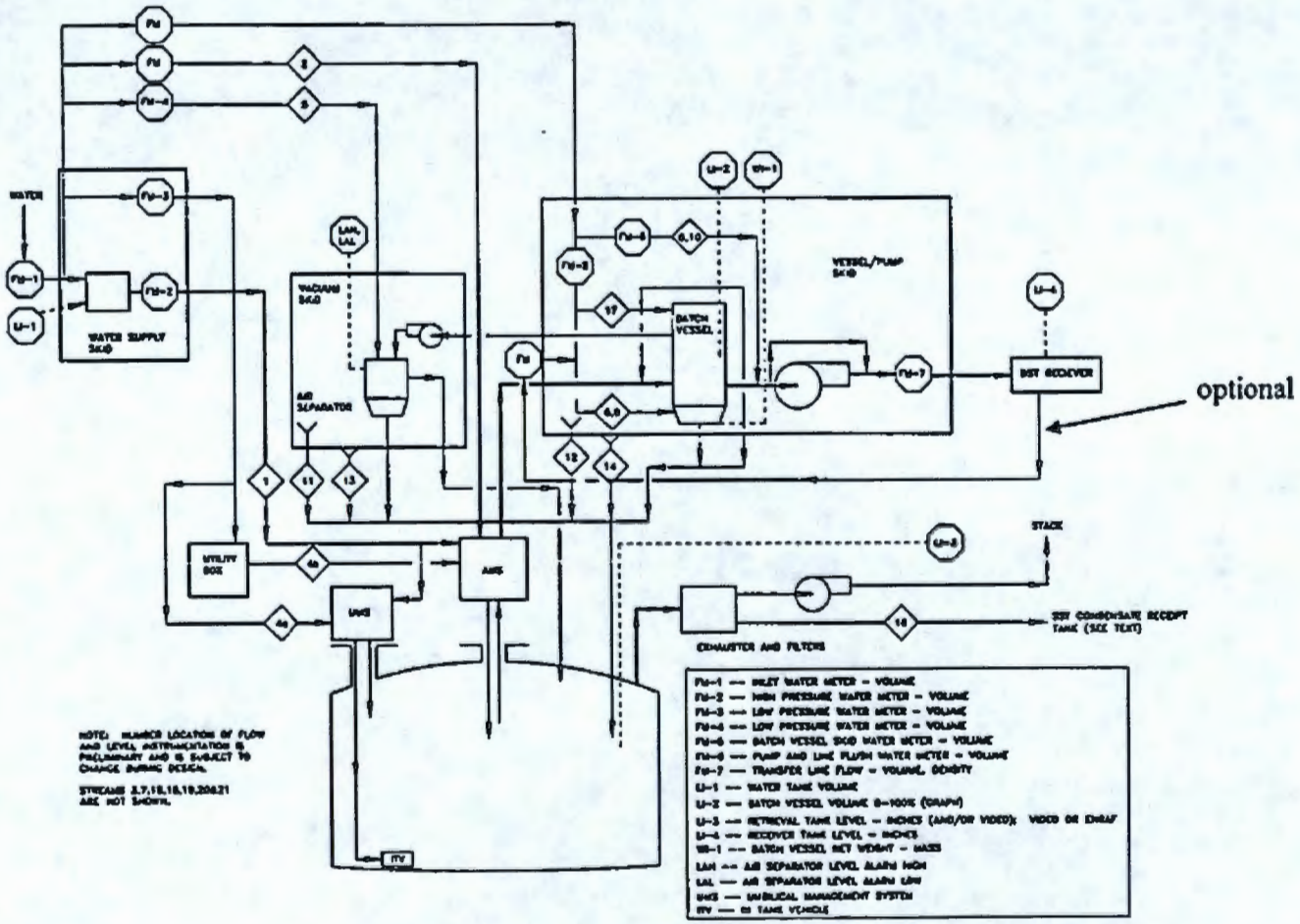
2. Low-pressure water to flush AMS union if needed.

3. Low-pressure water to backflush line from batch vessel to AMS.

4. Low pressure water to ITV to aid in transfer of waste to AMS head, and low-pressure water to AMS head to aid in transfer of waste from AMS head to batch vessel.

5. Low-pressure makeup water to air separator.

Figure 3-4. Tanks C-101, C-105, C-110, and C-111 Simplified Flowsheet Schematic Showing Measurement Locations.



6. Low-pressure water or DST supernate to mobilize waste in batch vessel for transfer to DST.

7. Low-pressure water to backflush line between air separator and batch vessel.

8. Low-pressure water or DST supernate to prime and flush transfer pump.

9. Low-pressure dilution water or DST supernate for waste transfer to keep waste density in transfer line within limits.

10. Low-pressure water or DST supernate to flush transfer line to DST.

In addition, liquid may drain back to the retrieval tank from the following sources:

11. Condensate drain from vacuum skid air conditioner.

12. Condensate drain from vessel/pump skid air conditioner.

13. Floor drainage from leak in vacuum skid.

14. Floor drainage from leak in vessel/pump skid.

15. Water held up in batch vessel piping that may 'bounce' into vacuum relief line to tank when vacuum is released.

16. Seal pot drainage from exhauster seal pot (if exhauster drains to the tank).

17. Low-pressure water to flush batch vessel if needed to reduce dose rate for skid entry.

18. Low-pressure water to calibrate instrumentation.

One more stream may be added to the retrieval tank following completion of waste retrieval. This solution will be transferred to a DST:

19. Final tank wall and bottom flush.

Two streams may be added to the retrieval tank following completion of waste retrieval:

20. Drainback from last air separator tank drain, miscellaneous piping drainage, exhauster seal pot drainage, and final flush water from hose-in-hose transfer line to DST (if air blow of line is unsuccessful).

21. Equipment decontamination flush if needed to reduce dose rate so equipment can be handled for the next configuration. This will also include low-pressure water to decontaminate the ITV if it needs to be removed for repair or reuse elsewhere. (If decontamination is done for repair during waste retrieval the water used obviously would be added prior to completion of waste retrieval.) Up to an estimated 200 gal of water may be added during post retrieval grab sampling.

Of these, streams 1, 2, 3, and the ITV usage fraction of stream 4, are sent to the retrieval tank during waste retrieval. A small fraction of the AMS fraction of stream 4 also goes to the tank, but the majority goes directly up the mast. Stream 1, the high-pressure water, is estimated to be greater than 90% of the sum of all four, the remaining three streams are either zero or small.

Streams 5, 11, 12, 13, 14, 15, 16, and a small fraction of stream 17 drain back to the retrieval tank. Stream 5, the air separator water, is estimated to be greater than 95% of the sum of all 8, the remaining 7 streams are either zero or small.

Streams 6, 7, 8, 9, 10 and the large majority of streams 4 and 17 are sent from the batch vessel skid directly to the receiving DST; they do not enter the retrieval tank.

Stream 18 is a yearly generation of a nominal 2,000 gal. of drain water. This will normally be pumped to the receiving DST. Under certain conditions, a fraction of this could be drained to the retrieval tank depending upon conditions and calibration status of equipment at the time calibrations are performed.

The need for a final tank flush will be assessed prior to cessation of waste retrieval operations. These tanks are of questionable integrity and adding additional water to them may not be prudent. However, attempts to remove as much tank waste as technically practical will be undertaken and flushing tank walls may be part of this effort. If it is estimated there is more than 360 ft^3 of waste remaining in the tank, and it is determined that the remaining material could be readily removed by flushing, without engendering a tank leak, the material located on the tank walls or bottom may be flushed to help reduce the residual waste volume. Much of the walls will likely be flushed down as the waste level decreases during retrieval, so a final tank flush, if needed, is expected to be mostly of the tank bottom. This flush, if needed, may be done using water from the AMS head or the ITV. Final flush water will be removed after it is added to the tank.

The volume of waste adhering to the tank walls is estimated by visually comparing waste accumulations with known dimensions in the tank. The majority of residual waste will likely be on the stiffener rings. The dimensions of these stiffener rings are known from engineering drawings. The fraction of a stiffener ring which contains waste is used along with an estimate of the cross-sectional area of a waste accumulation to calculate how much waste is on the stiffener ring. The volume of any other waste adhering to the walls is calculated from the visually estimated dimensions of the waste

Stream 21 liquid is dependent upon dose rate conditions following waste retrieval. If personnel exposures can be kept low while handling the equipment, there may be no flush required. High dose rates may require flushing until personnel can effectively handle the equipment, or the equipment may be left in the tank for ALARA considerations. The volume of water necessary for such flushing cannot be known in advance, but 3 equipment volumes of water passed through both skids would be less than 1,500 gal. A flush of the ITV would likely require 300 to 1,000 gal. of water, but the volume could be greater if there was significant waste stuck to the unit.

Liquid added to the retrieval tank is minimized and removed as soon as practical. Regardless of the retrieval duration the liquid is removed to the extent practical by the vacuum system when it

can drain to the AMS head location. Assuming a 16-ft radius for the AMS vacuum head, it should be able to remove liquid from the central region of the tank. The AMS vacuum head cannot reach the remaining portion of the tank, which is an area approximately 21 ft wide between the central region of the tank and the tank wall. The riser where the air separator liquid, batch vessel drain, and other drains return is near the tank wall, so local pooling could occur in this location until liquid height is sufficient to run off to the center of the tank. A localized pool sized 200 to 2,000 gal. could form. Eventually, as retrieval progresses the edge of the central depression will move outward and once the ITV is deployed any liquid pooling at the outer wall is expected to drain to the central depression where it can be removed. Once the central depression gets deeper than the depth of any depression under the liquid return riser, the interstitial liquid should flow to the central depression and pooling should equalize.

Most of the liquid added to the tank with the ITV or AMS scarifier will be added where the liquid can be accessed with the AMS. Liquid that is not removed by the AMS should sink into the waste until the waste becomes saturated. Based upon experience in saltwell pumping, tank sludges have an average capillary retention height of about 24 in. and an average 17% porosity. The waste surfaces vary with location in the tank, but tank C-101 has about 39 to 40 in. of waste, tank C-105 has about 52 to 53 in., tank C-110 has about 70 to 71 in., and tank C-111 has about 27 to 28 in.. The estimated interstitial liquid volume in each tank is provided in Table 2-4. .

Liquid will be removed as practical from the central depression, and as the depression gets deeper the volume of interstitial liquid in the tank will decrease. Minimizing the interstitial liquid is achieved by minimizing free liquid in the central depression to the extent practical during retrieval. The volume of free liquid present cannot be measured, but it can be effectively controlled by visually monitoring the waste surface during retrieval and vacuuming up the free liquid instead of waste solids when the free liquid appears to exceed a reasonable quantity.

Should the free liquid observed in the tank appear to cover more than one third of the waste surface, as estimated from observation with the video system, retrieval activities will be focused on surface liquid removal. The limiting condition for free liquid in the tank should be when a large volume of water is added to the tank and it pools up on the waste surface prior to a central depression being formed. A 100 Series SST with one third of the waste surface being free liquid will have about 900 gal. of free liquid per inch of depth. Assuming an average 2-in. depth of such a liquid pool, should there be a simultaneous failure of both vacuum pumps or some other equipment failure that prevents retrieval of liquid added to a tank, the likely volume of pooled liquid present in the tank until the equipment is fixed would be a nominal 1,800 gal. Should the batch vessel need to be drained during this time period, an additional 400 gal. could be added, giving a potential "worst case" estimate of about 2,200 gal of free liquid present in the tank. The assumption as to a 2-in. average liquid pool depth is subjective, but reasonable. These tanks primarily contain sludge, not saltcake, and sludge is more prone to seeking a reasonable level across the tank surface during settling than salt when crystallizing.

The one third value for the maximum free liquid accumulation on the waste surface is selected because it is a reasonable percentage that most personnel could subjectively determine. A value of less than one third could be chosen but the lower the value selected, the more difficult it becomes to judge effectively. It is not expected that the waste surface would reach one third free liquid. There should not be any significant liquid surface maintained in the tank during vacuum

retrieval since the presence of a liquid pool over the sludge should not enhance retrieval of waste solids. The free liquid quantity in the tank being retrieved will normally be kept to a minimum. As retrieval proceeds a depression is expected to be formed as the waste is vacuumed up with the AMS. Once a depression is formed there should be negligible free liquid on the waste surface except for in the depression area. A free liquid pool in the depression with a diameter of 10 ft. would contain about 50 gal of liquid per in. of depth. Assuming this was no more than a 2-in. depth would mean that there would be no more than 100 gal of free liquid present at a given time, or 500 gal if both blowers failed, it became necessary to simultaneously dump the batch vessel, and all the waste solids in the tank were saturated with interstitial liquid and couldn't absorb any of the batch vessel liquid.

The length of time this free liquid would remain in the tank would be dependent upon the time to repair the equipment (i.e., hours to months).

When vacuum operations are begun, water is added to the AMS as needed to enhance retrieval. At the same time, high-pressure spray water is added to the waste around the suction nozzle to breakup and/or fluidize the waste near the nozzle as needed. When the batch vessel has accumulated enough waste and water to make a transfer, vacuuming is halted along with any AMS or high-pressure water. Water or recycled supernate is then added to the batch vessel as needed to fluidize the waste for transfer, and the waste pumped to the receiver tank. During transfer, water or recycled supernate is added to the transfer line as necessary to maintain the average solution density below an engineering determined value. When the transfer is completed, the transfer line is flushed as required per procedure. The air separator for the vacuum blower discharge is also drained and water added for refill as needed during the process. This is done before or after a batch transfer when needed, or automatically when a high-level alarm is activated in the air separator. The ITV is not planned to be added to the tank until it is necessary to enhance waste retrieval with the mast. Once it is added, high-pressure water will be used as necessary to the ITV to break up hard waste in front of it. Low-pressure water is also added to the ITV to wash down tank walls and aid in pushing waste to the AMS head.

3.2.1 Basis for Using Supernate

Either water or recycled supernate will be used for diluting the C-101, C-105, C-110, and C-111 solids concentration if needed during waste transfer to the receiving DST, or for flushing the line after transfer. If water were used the retrieved waste volume may require additional waste transfers to other DSTs and evaporation of the liquid to reduce the volume. To evaporate all of the water to retain DST operating space, at least two evaporator campaigns lasting for between 40 and 60 days would be required for every million gallons of water. Extra evaporator campaigns and associated transfers could cause delays to waste retrieval operations.

The basis for the number of evaporator campaigns and their durations comes from the following group of assumptions:

- Currently an evaporator campaign may be 400,000 to 800,000 gal. Evaporation is done on a feed tank basis. If a DST were freed to hold only retrieval water-waste slurry, up to 1 million gal. could be evaporated per batch. If it were necessary to mix the dilute slurry

with a number of other tanks, a batch size may be reduced to only approximately 300,000 gal.

- The dilute sluicing fluid would require two passes through the evaporator to achieve full concentration.
- The first pass through the evaporator would achieve a 50% waste volume reduction.
- An average of 1 week of transfers is required to fill the feed tank with 1 million gal. of feed.
- A 1-million-gal. campaign could last approximately 12 days or more, and 2 days of campaign shutdown activities would be required before the next campaign could be started.

All of these assumptions are based on prior evaporator operating experience.

The number of campaigns is determined by starting with the initial volume of waste to be processed, 1.1 million gal. To this is added the volume of waste left after the first pass through the evaporator (i.e., 0.5 × 1.1 million gal. = 0.6 million gal.). Summing these volumes gives 1.7 million gal. Dividing by the 1-million-gal. campaign volume gives about 2 campaigns.

The duration of the campaigns is equal to the sum of duration of its elements (i.e., transfers [7 days] + evaporator campaign [12 days] + shutdown [2 days] = 21 days). The duration of 2 consecutive campaigns is 42 days. Adjusting this value for the operating efficiencies of between 70 and 90%, gives a total duration for 50 consecutive 1-million-gal. campaigns of between 46 and 60 days. This is a theoretical time only. To this must be added downtime for maintenance and other issues, and the additional problems associated with transferring 1.1 million gal. of waste within tank farms.

This evaluation of the impact of water-only waste transfers should be considered as the minimum possible impact. Other factors (e.g., staging transfers to accumulate the required volume of waste feed, problems associated with sampling and analysis) could cause additional delays of the evaporator operations and further impact waste retrieval operations.

This use of supernate recycle instead of water for waste transfer of the insoluble solids in tanks C-101, C-105, C-110, and C-111 results in the following benefits:

- Approximately 1 million gal. less liquid effluent discharged from the Liquid Effluent Treatment Facility (LETF) in the 200 East Area for every 1 million gal. of water saved.
- An estimated 13 to 22 fewer drums of waste sent to disposal from LETF for every 1 million gal. of water not added.
- An equivalent increase in DST room available for waste retrieved from SSTs. If this volume is not available, some SST waste retrievals besides those discussed in this document may be delayed, resulting in wastes remaining stored in noncompliant tanks for a longer period.

- A nominal 2 to 3 fewer evaporator campaigns for each 1 million gal. of water saved.
- Less fresh NaOH and $NaNO_2$ needed to bring the resulting DST solutions into the concentration limits specified for corrosion control in Administrative Control (AC) 5.16 (HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements*). Depending upon other constituent concentrations in the DST solutions following mixing with the insoluble solids slurry and flush water, between 0 and 44,000 kg of 100% NaOH will need to be added to the DST system to bring each 1 million gal. of insoluble solids slurry and flush water into specification. Some additional $NaNO_2$ may also be required depending upon other constituent concentrations in the DST solutions following mixing with the insoluble solids slurry and flush water.
- Elimination of the need to process the additional NaOH and $NaNO_2$ chemicals through the WTP. A 44,000-kg addition of sodium to the DST system would require about 15 days of WTP operating time.

3.3 TECHNOLOGIES CONSIDERED AND RATIONALE FOR SELECTION

Candidate waste retrieval technologies currently available for deployment at tanks C-101, C-105, C-110, and C-111 are (1) modified sluicing and (2) the MRS. Modified sluicing uses water or DST supernate to mobilize waste to a pump where it can be removed from a tank. Although modified sluicing is simpler and potentially costs less than the MRS for retrieving waste, it requires the use of greater volumes of liquid in the tank. The MRS consists of an AMS, which is a vacuum-based system deployed in the center of the tank with a crawler deployed to move sludge from the perimeter of the tank to the center of the tank where it can be removed with the vacuum system.

The MRS uses vacuum to remove waste to a batch vessel at the tank farm surface where liquid is added to slurry the retrieved waste for transfer to a DST. Limited volumes of water are used with the vacuum-based retrieval system to mobilize and dilute the waste. Waste retrieval with the MRS is a batch process, so even if waste retrieval efficiencies are lower than expected and retrieval takes longer than planned, the amount of water in the tank at any time during retrieval is relatively small. Because of this, the MRS is currently considered to be the preferred waste retrieval technology for tanks that are classified as 'assumed leakers.'

Because tanks C-101, C-110, and C-111 are classified as 'assumed leakers,' the MRS was selected as the waste retrieval technology. Although tank C-105 is classified as 'sound,' the integrity of the tank is uncertain because of an unknown source of contamination in the soil near the tank. Ecology has reviewed the available historical information and determined that the modified sluicing is unacceptable for deployment at tank C-105 at this time (Lyon [2004], "Use of Double Shell Tank 241-AN-106 Supernate for Waste Retrieval from Single-Shell Tanks (SST) 241-C-103 and 241-C-105"). Based on the available information, Ecology will not approve the use of modified sluicing without additional data defining the source of the vadose zone contamination near tank C-105. Following preliminary discussions with Ecology, the MRS was selected to minimize the potential leakage volumes that might occur during waste retrieval.

3.4 ANTICIPATED PERFORMANCE GOALS

The WRS for tanks C-101, C-105, C-110, and C-111 will be designed to retrieve as much waste from the tanks as technically practical with waste residues not to exceed 360 ft^3 or the limits of the technology, whichever is less in accordance with the requirements of HFFACO Milestone M-45-00 (see Table 3-3).

3.5 WASTE RETRIEVAL SYSTEM DIAGRAM

A diagram of the WRS in-tank components is provided in Figure 3-1. A plan view showing the abovegrade skid locations is provided in Figure 3-3. As noted in Section 3.1.1, the elevation in the AN and AY tank farms is approximately 22 ft higher than the elevation in the C tank farm.

3.6 WASTE RETRIEVAL SYSTEM FUNCTIONS AND REQUIREMENTS

This section defines the upper-level functions and corresponding requirements to which the tanks C-101, C-105, C-110, and C-111 WRS must be designed and operated. This work plan is not a system specification that defines design criteria for the WRS. However, the system specification for the tanks will be consistent with this work plan. The functions and requirements are provided in Table 3-4 and are focused on defining the upper-level requirements for the tanks.

3.7 ANTICIPATED IMPACTS OF TANK WASTE RETRIEVAL ON FUTURE PIPELINE/ANCILLARY EQUIPMENT RETRIEVAL

The existing buried waste transfer lines routed to tanks C-101, C-105, C-110, and C-111 have been isolated to prevent the inadvertent transfer of waste or intrusion of water into the tanks. Following waste retrieval activities for these tanks, the new transfer lines and auxiliary equipment will be flushed as needed and the equipment reused or disposed of as discussed in Section 3.9.

Any line flushes for the new transfer lines should direct the flush solution to the receiver DSTs. However, because of the physical location of C tank farm at a lower elevation than the DSTs, there will be some line drainback. The holdup for each transfer line is in the 150- to 200-gal. range. This solution would go back to the batch vessel skid and then to the tank just retrieved, unless a valve change could be made to direct the solution to another SST which had not yet completed retrieval that is covered by this tank waste retrieval work plan.

Flushing of any abovegrade skids should not be necessary following retrieval because any such flushing, which is expected to be transferred back to the SST being retrieved, would be expected to be performed before completion of retrieval. In the unlikely event the situation arises where a skid needs to be flushed following completion of retrieval, it is estimated that the flush volume would be in the 100- to 200-gal. range. This solution would go to the tank just retrieved, unless a

valve change could be made to direct the solution to another SST which had not yet completed retrieval that is covered by this tank waste retrieval work plan. If the solution went to the tank following completion of retrieval, the exhauster could be operated to evaporate the water as necessary.

When retrieval activities are completed, the exhauster(s) used will be disconnected for use elsewhere. This will require draining the exhauster seal pot back to the receiver tank for the drain line. Such drainage will be in the 0- to 20-gal. range.

It is currently planned to leave all in-tank equipment (e.g., the AMS) in the tank following waste retrieval. However, in the event it is necessary to remove such equipment, it may have to be washed down upon removal to remove excess contamination or to reduce exposure for personnel protection. The volume of water expected for such purposes would likely be in the 50- to 200-gal. range for any equipment besides the MRS crawler. Decontamination of the MRS crawler could take in the 300 to 1,000 gal. range, or more depending upon contamination location.

Existing risers, pits, and/or caissons associated with the tanks will be isolated following the retrieval activities. These isolation methods are designed to minimize water intrusion to the tank.

In accordance with RPP-13774, disposition of the ex-tank ancillary equipment, including pipelines, will be performed in accordance with a separate component closure activity plan. Flushing of old lines or pits would not be done unless required or permitted by the component closure activity plan. Should such flushing be required or necessary, it would not take place until closure activities were underway, so the impact of any line flush volumes would be accounted for in the approved tank fill process of the closure plan. See Section 7.1.3.2 for assumptions regarding characterization of residual waste in piping system components.

Following waste retrieval, it may be necessary to add small (0- to 50-gal.) volumes of water periodically to flush the ENRAF plummet before tank closure. No other activities are envisioned that will purposely add liquids back to a tank once waste retrieval is complete. Should it become necessary to add liquid to a retrieved tank for any reason other than those stated above, Ecology will be notified per existing notification channels.

Table 3-4. Tanks C-101, C-105, C-110, and C-111 Waste Retrieval System Functions and Requirements. (2 Sheets)

Function	Requirement	Basis*	Key Elements
Control gaseous and particulate discharges	The ventilation system exhaust shall be filtered to restrict emissions to the environment.	WAC 173-303 WAC 173-400 WAC 173-460 WAC 246-247 TFC-ESHQ-ENV-STD-03 TFC-ESHQ-ENV-STD-04	Mitigate potential release to the public and the environment.
Mitigate potential for leaks to occur during waste retrieval	Prevent inadvertent release from tank C-101, C-105, C-110, or C-111 to the environment.	RPP-13033, Section 3.3.2.3.4	Do not raise waste level above benchmark level. Benchmark level to be provided in process control plan.
Control waste level in tanks C-101, C-105, C-110, and C-111	The WRS shall be operated to prevent waste level from exceeding 185 in.	OSD-T-151-00013	Minimize liquid level to the extent practical.
Control waste level in DST receiver tank	The WRS shall be operated to maintain waste level within specified allowable maximum and minimum values.	OSD-T-151-0007	Provide for safe waste storage in DSTs.
Remove waste from tanks C-101, C-105, C-110, and C-111	The WRS shall be capable of removing as much waste as technically possible, with tank waste residues not to exceed 360 ft^3, or the limit of the waste retrieval technology, whichever is less.	WAC 173-303 HFFACO Milestone M-45-00	The WRS shall provide the ability to retrieve as much waste as technically possible.
Control and monitor the waste removal process in tanks C-101, C-105, C-110, and C-111	The WRS shall provide the monitor and control capability to control the waste retrieval and transfer process. This includes controlling and monitoring the following WRS process parameters: • Pressures • Flow rates • Differential pressures across exhaust ventilation filters • Leak detection systems.	RPP-13033 HNF-SD-WM-TSR-006 WAC 173-303 WAC 246-247 TFC-ENG-STD-26	Provide for safe and effective operation of the WRS.
Minimize waste generation	The WRS shall minimize waste generation to the greatest extent practical.	WAC 173-303 40 CFR 264.73(b)(9)	No numerical requirement.

Table 3-4. Tanks C-101, C-105, C-110, and C-111 Waste Retrieval System Functions and Requirements. (2 Sheets)

Function	Requirement	Basis*	Key Elements
Nuclear safety	The WRS shall be designed and operated to protect workers, the public, the environment, and equipment from exposure to radioactive tank waste and emissions during the retrieval campaign.	WAC 246-247 10 CFR 830 RPP-13033 HNF-SD-WM-TSR-006 HNF-IP-1266	Ensure protection of workers and the public from routine operations and potential accident conditions.
Occupational safety and health	The WRS shall be designed for safe installation, operation and maintenance.	WAC 173-303-283(3)(i) 29 CFR 1910 10 CFR 835 29 CFR 1926	OSHA standards. Occupational Radiation Protection.
WRS secondary containment and leak detection	For ex-tank equipment and piping, the WRS shall incorporate secondary containment and leak-detection design features.	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 DST.

DST = double-shell tank.
Ecology = Washington State Department of Ecology.
HFFACO = *Hanford Federal Facility Agreement and Consent Order.*
LDM = leak detection and monitoring.
OSHA = Occupational Safety and Health Administration.
SST = single-shell tank.
WRS = waste retrieval system.

* Basis documents reference information is provided in Section 9.0 of this document.

3.8 INFORMATION FOR NEW ABOVE GROUND TANK SYSTEMS

The vessel/pump skid that will be located above ground includes a batch vessel. The batch vessel will have a working volume of approximately 400 gal. The batch vessel will be designed to meet the requirements of Section VIII, Division 1 of the ASME B&PVC (2001), *International Boiler and Pressure Vessel Code*. All process piping will meet the requirements of ASME B31.3, *Process Piping*, and will be verified through calculations and testing. The specific design requirements for the vessel are provided in RPP-8144, *Level 2 Specification for the Tank 241-C-101 Waste Retrieval System*.

A written integrity assessment, reviewed and certified by an independent, qualified registered professional engineer (IQRPE) attesting that the batch vessel tank and associated transfer lines are suitable for use during waste retrieval operations will be prepared in accordance with WAC 173-303-640(3), "Design and Installation of New Tank Systems or Components," and submitted to Ecology following completion of the design field installation of the WRS. This includes verification that the batch vessel and associated transfer lines meet the requirements set forth in WAC 173-303-640(3) and WAC 173-303-640(4), "Containment and Detection of Releases." If additional batch vessel tank systems or additional transfer line systems are used, each system will be evaluated by an IQRPE.

Before initiating waste retrieval operations, the vessel/pump skid will be visually inspected to assess the physical condition of the vessel/pump skid components. During waste retrieval operations, personnel will make regular rounds to physically observe and monitor equipment for evidence of equipment problems or signs of a waste release. Also during waste retrieval operations, the inside of the vessel/pump skid will be a primary radiation source and will not be physically inspected. Radiation monitors and video cameras are installed inside of the skid to provide dose rate and visual monitoring of the skid internals. The leak detection system installed at the vessel/pump skid will be monitored at all times during waste retrieval operations. The response to a leak from the vessel/pump skid would include an orderly shutdown of the retrieval system followed by an evaluation of the monitoring data and equipment. In the event that a leak did occur from within the vessel/pump skid, any waste remaining would drain back into the tank being retrieved, the skid would be decontaminated as required, and the equipment repaired or replaced, as necessary. Should a leak occur from the batch vessel into the vessel's secondary containment the released material will be removed within twenty-four hours or in as timely a manner as possible, in compliance with WAC 173-303-640(7)(b)(ii).

3.9 DISPOSITION OF WASTE RETRIEVAL SYSTEM FOLLOWING WASTE RETRIEVAL

3.9.1 Disposition of New Waste Retrieval System Components

Following completion of waste retrieval, the in-tank equipment may be left in place for disposition during component closure actions. The abovegrade equipment (e.g., transfer lines, equipment skids) will be reused to the extent possible for future waste retrieval activities in the C tank farm. Transfer lines and the equipment skids will be flushed to reach acceptable exposure rates for disconnecting and relocating the equipment. Any abovegrade equipment that needs to be removed and is not suitable for reuse will be packaged and disposed of onsite in accordance with the approved waste acceptance criteria for the Hanford Site burial grounds and TFC-OPS-WM-C-10, *Contaminated Equipment Management Practices*. The HIHTLs will be managed in accordance with RPP-12711, *Temporary Waste Transfer Line Management Program Plan*.

3.9.2 Disposition of Existing Ancillary Equipment

Ancillary equipment associated with tanks C-101, C-105, C-110, and C-111 is limited to waste transfer lines and equipment installed in pits and abovegrade risers. The current status of the ancillary equipment associated with tanks C-101, C-105, C-110, and C-111 is described in Section 2.6. Any contaminated equipment located within risers that needs to be removed following waste retrieval will be packaged and disposed of onsite in accordance with the approved waste acceptance criteria for the Hanford Site burial grounds and TFC-OPS-WM-C-10.

In accordance with the SST system closure plan (RPP-13774), disposition of the ex-tank ancillary equipment, including pipelines, will be performed in accordance with a separate component closure activity plan. Closure plans will be incorporated into the SST permit.

3.10 AIR MONITORING PLAN

ORP and CH2M HILL, pursuant to federal requirements for protection of their workers, will develop and implement IH monitoring plans for exhauster stack emissions for the retrieval of tanks C-101, C-105, C-110, and C-111. The plans will be developed and implemented pursuant to the requirements of TFC-PLN-43, *Tank Farm Contractor Health And Safety Plan*. The constituents of potential concern (COPCs) for which exhauster stack sampling and analysis will be conducted will be identified in the IH monitoring plans for each tank retrieval. The COPCs identified in the IH monitoring plans will be all or a subset, as determined to be appropriate by CH2M HILL IH, of those constituents listed in RPP-20949, *Data Quality Objectives for the Evaluation of Tank Chemical Emissions for Industrial Hygiene Technical Basis*, Table 4-1, developed with input from Ecology. Once the initial subset of COPCs is identified and listed in the IH monitoring plans, no COPC shall be dropped from that list without 90 days prior notification to and approval from Ecology. If ORP notifies Ecology of its desire to cease

exhauster stack sampling for a COPC initially identified and listed in an IH monitoring plan and no response is received from Ecology within 90 days, the COPC will be deleted from the IH monitoring plan and sample and analysis activities for that COPC will cease. New COPCs may be added to an IH monitoring plan without notification to or approval from Ecology and without modifying or revising this tank waste retrieval work plan.

The sampling and analysis methods shall be U.S. Environmental Protection Agency (EPA), National Institute for Occupational Safety and Health-, or Occupational Safety and Health Administration (OSHA)-approved methods or an equivalent CH2M HILL-approved method, as identified in RPP-20949. The exhauster stack samples will be analyzed at the 222-S Laboratory, the Waste Sampling and Characterization Facility, or an equivalent laboratory consistent with the quality assurance/quality control procedures for that laboratory. Further, laboratory analysis data will be kept on file at the laboratory consistent with the laboratory record keeping procedures for that laboratory for a period of not less than 5 years and will be available to Ecology, within 24 hours, upon request.

Ecology and ORP understand and agree that the activities discussed above do not restrict ORP and CH2M HILL from taking any and/or all steps necessary as ORP and CH2M HILL deem appropriate to protect its workforce in response to data and information generated by an IH monitoring plan or incidents as they might arise during waste retrieval. Ecology and ORP also understand and agree that the preceding sampling and analysis discussion is presented to ensure ORP is achieving the agreed to sampling and analysis for the protection of the public and its workers and does not modify the exemption from the requirements of 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities," and 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities," Subpart CC, granted to ORP under 40 CFR 265.1080(b)(6). Therefore, this discussion does not imply any change to the respective authority of either Ecology or ORP regarding the sampling, analysis, monitoring, and control of airborne emissions from Hanford Site tanks.

4.0 LEAK DETECTION, MONITORING, AND MITIGATION

The integrated leak detection, monitoring, and mitigation (LDMM) strategy for tanks C-101, C-105, C-110, and C-111 has been developed to manage the risk posed by potential waste leakage during waste retrieval operations and to meet the requirements specified in the HFFACO M-45 series milestones. The strategy for LDMM is summarized in the following sections and is based on retrieving as much waste as technically practicable while minimizing the potential for leaks. The purpose is to ensure that the tanks' waste retrieval and LDMM strategy:

- Is technically practicable and defensible
- Adheres to the requirements of this work plan
- Uses LDMM technologies and strategies that are consistent with the waste retrieval technology selected for deployment in tanks C-101, C-105, C-110, and C-111
- Minimizes waste releases to the environment should a leak occur
- Provides for detecting a leak in a timely manner
- Provides for determining leak volume in a timely manner
- Provides technically defensible data to support the appropriate response action
- Minimizes the potential risks to human health and the environment.

4.1 EXISTING TANK LEAK MONITORING

This section describes tank leak monitoring activities that have been historically performed or are currently being performed.

4.1.1 Drywell Monitoring

There are 70 drywells surrounding the 100-series tanks in the C tank farm. Under the current waste storage mode, drywell logging is performed in accordance with GJO-HGLP 1.8.1, *Hanford Tank Farms Vadose Zone Monitoring Project, Baseline Monitoring Plan.* The selections of boreholes and the logging intervals are based on a priority scoring methodology defined in GJO-HGLP-1.8.1. Recent borehole logging results performed as a part of the baseline characterization of the C tank farm, including information describing the background contamination levels present around the drywells surrounding tanks C-101, C-105, C-110, and C-111, are presented in GJPO-HAN-18, *Hanford Tank Farms Vadose Zone: C Tank Farm Report* and in DOE-EM/GJ641-2004, *Hanford Tank Farms Vadose Zone Monitoring Project:*

Quarterly Summary Report for Second Quarter Fiscal Year 2004. Evaluation of historical drywell monitoring data is provided in RPP-14430.

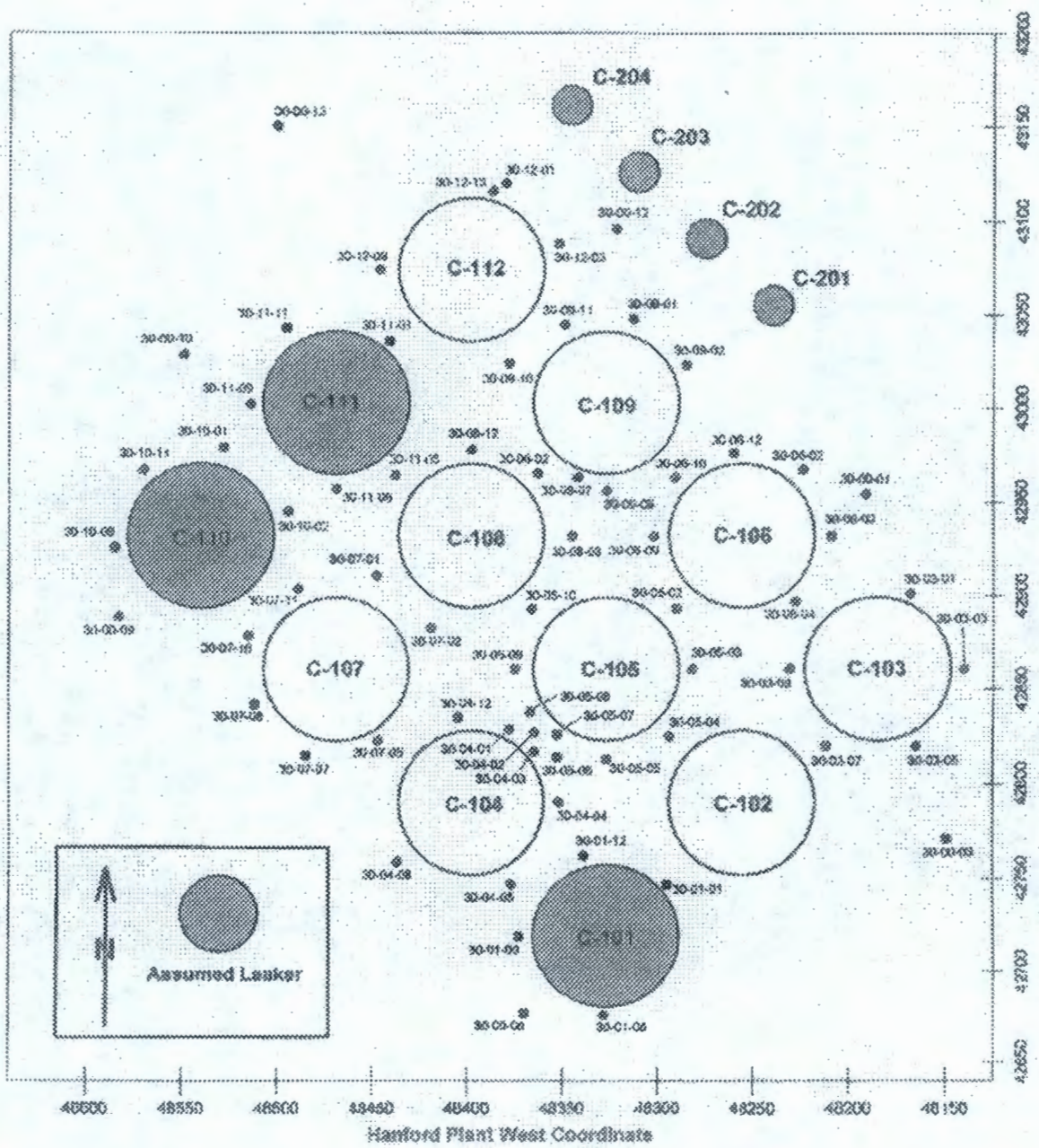
There are six drywells spaced around tank C-101 that are between 2 and 20 ft from the edge of the tank (Figure 4-1). The six drywells include 30-01-01, 30-01-06, 30-00-06, 30-01-09, 30-04-05, and 30-01-12. Five of the drywells are 100 ft deep. One drywell (30-00-06) is drilled to 150 ft deep but can only be logged to 111 ft because of grouting (GJ-HAN-85, *Vadose Zone Characterization Project at the Hanford Site Tank Farms Tank Summary Data Report for Tank C-101*).

Ten drywells are spaced around tank C-105 that are between 2 and 12 ft from the edge of the tank (Figure 4-1). The ten drywells include 30-05-02, 30-05-03, 30-05-04, 30-05-05, 30-05-06, 30-05-07, 30-04-02, 30-05-08, 30-05-09 and 30-05-10. Three of the drywells are between 50 and 70 ft deep, 3 drywells are 100 ft deep, and 4 are between 120 and 135 ft deep (GJ-HAN-83, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-105*).

Seven drywells are spaced around tank C-110 that are between 5 and 19 ft from the edge of the tank (Figure 4.1). The seven drywells include 30-10-01, 30-10-02, 30-07-11, 30-07-10, 30-00-09, 30-10-09 and 30-10-11. Six of these seven drywells are 100 ft deep with drywell 30-00-09 being 58 ft deep.

Seven drywells are spaced around tank C-111 that are between 5 and 25 ft from the edge of the tank (Figure 4.1). The seven drywells include 30-11-01, 30-11-05, 30-11-06, 30-10-02, 30-10-01, 30-11-09 and 30-11-11. All seven of the drywells are 100 ft deep (GJ-HAN-93, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-111*).

Figure 4-1. Plan View of the C Tank Farm Showing Drywells.



4.1.2 Groundwater Monitoring

The groundwater beneath the C tank farm has been monitored since 2001 in accordance with the RCRA groundwater monitoring plan established in 2001 (PNNL-13024, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*). Figure 4-2 provides a plan view of the C tank farm and the surrounding RCRA groundwater monitoring wells. There are nine groundwater monitoring wells surrounding the C tank farm (four new wells constructed in 2003). Since June 2002, groundwater sampling for the groundwater wells 299-E-27-7, 299-E-27-12, 299-E-27-13, 299-E-27-14, and 299-E-27-15 has been performed on a quarterly basis (PNNL-13024, ICN-1). Since December 2003, new groundwater monitoring wells 299-E-27-4, 299-E-27-21, 299-E-27-22, and 299-E-27-23 have also been sampled on a quarterly basis. Quarterly samples are analyzed at a minimum for anions, cyanide, inductively coupled plasma metals, gross beta, technetium, and total uranium, and a low-level gamma scan is performed (PNNL-14548, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*).

The quarterly groundwater monitoring that is currently performed is adequate for the purpose of supplementary data collection during waste retrieval. Ecology will continue to be provided quarterly groundwater monitoring sample results in the PNNL quarterly and annual groundwater monitoring reports. If a leak is detected during retrieval, groundwater monitoring frequency will be re-evaluated per the regulatory requirements in WAC 173-303, "Dangerous Waste Regulations." As identified in Section 7.0, the calculated time to peak concentrations in the groundwater from a leak that occurs during waste retrieval is approximately 80 years. Based on this duration, the groundwater monitoring data will not be used for retrieval process control. It is anticipated that, over a period of time, the groundwater monitoring data will support tank and tank farm closure. Quarterly groundwater monitoring results are reported annually. Recent results from the groundwater monitoring at the C tank farm are reported in PNNL-14548.

4.1.3 In-Tank Monitoring

The waste levels in tanks C-101, C-105, C-110, and C-111 while in storage mode are monitored for intrusion on a quarterly basis using an ENRAF level gauge (OSD-T-151-00031, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection*). Because all of the interim stabilization criteria have been met for tanks C-101, C-105, C-110, and C-111, no in-tank leak detection monitoring is currently being performed for them.

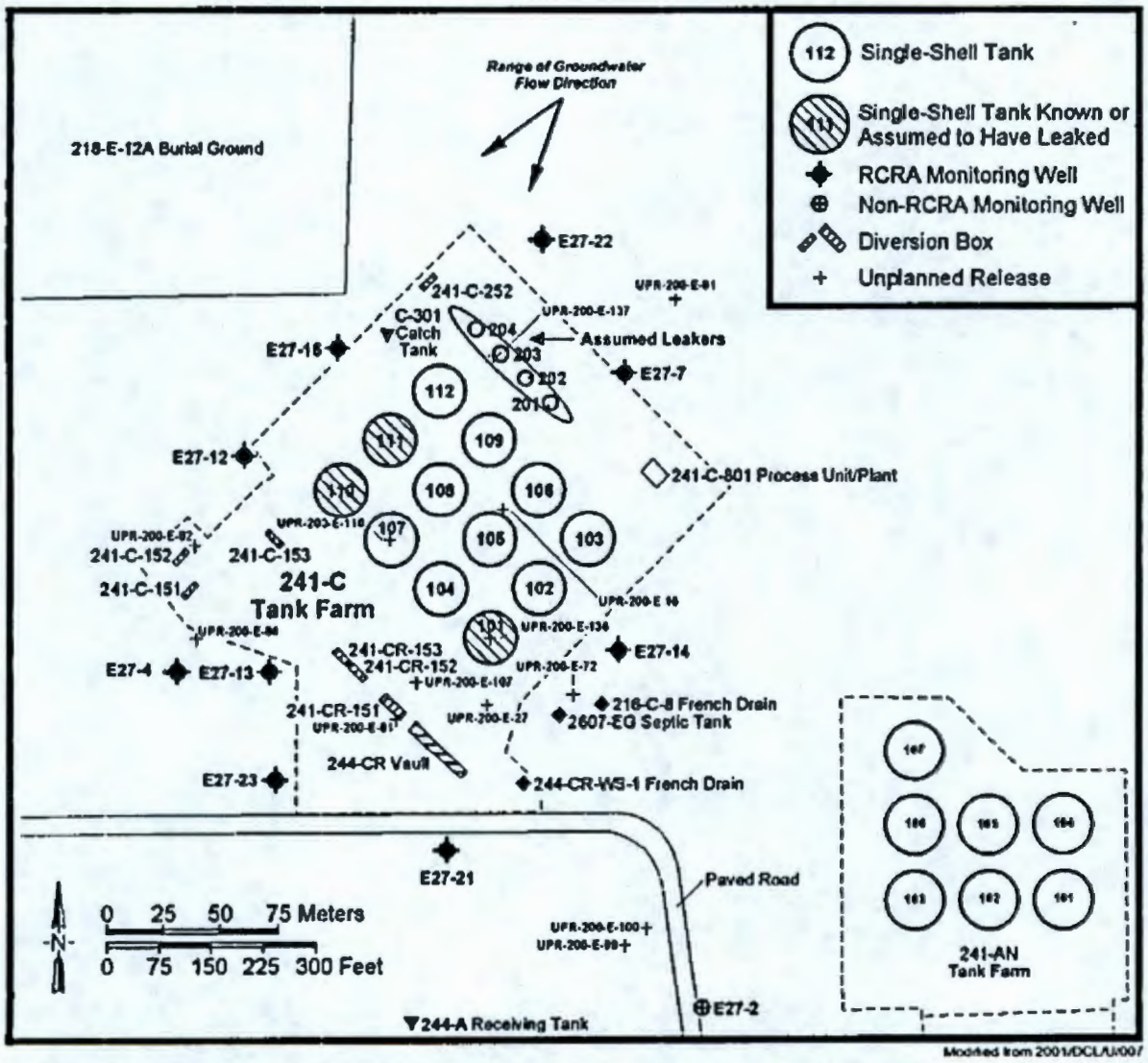
Level monitoring in tanks C-101, C-105, C-110, and C-111 during waste retrieval operations will be performed visually using the internal tank video system. No data is recorded as a result of this monitoring, it is just an observation of the waste surface during retrieval. If there is an operable Enraf level gauge on the tank, the Enraf plummet could be lowered to obtain a waste surface measurement if the waste retrieval system is not in operation for an extended period.

The waste level in the receiver DSTs is monitored using an ENRAF level gauge for primary level monitoring as described in OSD-T-151-00031, Section 4.0. Additionally, three annulus

leak detector probes provide indication of tank leaks as described in OSD-T-151-00031, Section 4.0.

Exhauster condensate generated during waste retrieval operations in tanks C-101, C-105, C-110 or C-111 is added to a tank in waste retrieval status. LDM for the tank receiving the condensate will be performed as specified in the tank's work plan.

Figure 4-2. Waste Management Area C and Regulated Structures.*



* Adapted from Figure B.18 in PNNL-14548, 2004, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*, Pacific Northwest National Laboratory, Richland, Washington.

4.2 LEAK DETECTION AND MONITORING SYSTEM

This section provides a description of the leak detection and monitoring (LDM) system that will be deployed at tanks C-101, C-105, C-110, and C-111 during waste retrieval along with a description of how it will be operated.

4.2.1 Leak Detection and Monitoring for Single-Shell Tanks

The primary method for leak detection and leak monitoring for tanks C-101, C-105, C-110, and C-111 involves periodic gamma and neutron moisture surveys of the drywells surrounding the tanks. Established drywell logging methods will be used as the primary method of leak detection. In-tank process control parameters will be used to supplement the ex-tank methods and provide secondary leak detection. The following sections summarize these methods.

Leak detection in the waste transfer system and in the respective receiver DSTs will be performed using standard leak detection methods in the transfer pits and DST annulus.

The results from drywell monitoring, as well as a summary and analysis of this monitoring, including tools used, calibration, boreholes logged, depth of logging, frequency, logging rate, and data analysis will be submitted to Ecology within the retrieval data report per Appendix I of the HFFACO.

4.2.1.1. Ex Tank Leak Detection for Single-Shell Tanks. Existing logging systems or the new monitoring system described below will be used to monitor soil conditions surrounding the tanks for increases in gamma activity and/or moisture content that may be evidence of tank leakage. These systems will be deployed by qualified personnel in accordance with the applicable procedures. Before waste retrieval operations begin, calibrated gamma and neutron moisture probes will be deployed over the full depth of each drywell. The pre-retrieval logging results will provide a baseline for selection of specific regions of interest (as well as the region near the base of the tanks) for logging during waste retrieval.

Moisture logging will be performed weekly during active waste retrieval operations. Due to operational constraints, this weekly reading may be missed occasionally. Ecology will be informed of missed drywell monitoring. Weekly moisture monitoring may be suspended if no active retrieval operations have been conducted during the previous seven days. If weekly moisture monitoring is suspended, moisture monitoring shall be performed at least every six weeks until active retrieval operations are begun again or all active retrieval operations on the tank are complete.

The drywells will be rebaselined with full depth gamma and moisture scans within three to six months after retrieval operations have been completed, and will be monitored quarterly for a

year thereafter to ensure that no new contaminant plumes have developed as a result of the retrieval activity, and that any existing plumes have not been exacerbated.

During waste retrieval, moisture monitoring using a neutron probe will be performed over specific regions of interest in selected drywells for increases in soil moisture content. The neutron moisture probe is used to monitor the moisture (e.g., water) content in the sediments around the drywells. The specific regions of interest include the interval at the base of the tank that is 35 to 50 ft below grade and any layers with fine sediments. The base of the tank farm excavation represents a zone of material compacted by tank farm construction activity that may affect lateral movement of water in the vadose zone. Likewise, any fine sediment layers would be expected to control accumulation of any moisture associated with a new leak plume. In the event of an unexplained increase in soil moisture content, additional monitoring with other systems will be used as practical to determine if there have been any changes in gamma-emitting radionuclide concentration surrounding the drywells.

Current plans include monitoring of the following drywells:

- **Tank C-101** – 30-01-01, 30-01-06, 30-00-06, 30-01-09, 30-04-05, and 30-01-12
- **Tank C-105** – 30-05-02, 30-05-03, 30-05-04, 30-05-05, 30-05-06, 30-05-07, 30-04-02, 30-05-08, 30-05-09 and 30-05-10
- **Tank C-110** – 30-10-01, 30-10-02, 30-07-11, 30-07-10, 30-00-09, 30-10-09, 30-10-11, 30-00-22, 30-00-24, and 30-00-11
- **Tank C-111** – 30-11-01, 30-11-05, 30-11-06, 30-10-02, 30-10-01, 30-11-09, 30-11-11, 30-08-12 and 30-00-10.

There is a potential that access to some drywells may be precluded by the placement of equipment, shielding, ALARA (as low as reasonably achievable) concerns, or alterations to the tank farm surface as a part of ongoing waste retrieval activities. Any resulting changes to LDM activities described in this tank waste retrieval work plan will be approved by Ecology within 24 hours of submittal through the Change Notice form.

The following background information describes the suite of drywell logging tools, what they measure, and general measurement capabilities that can be used to monitor conditions around the drywells. Details of the drywell monitoring activities, including identification of logging tools and target logging intervals, will be defined in the process control plan or specific procedures.

The spectral gamma logging system (SGLS) is the logging system used to establish baseline conditions from 1995 to 2000. This logging system is based on an liquid nitrogen cooled high purity germanium (HPGe) detector, which provides excellent gamma energy resolution for identification and quantification of individual radionuclides from background levels (method detection limit about 0.1 pCi/g cesium-137 under typical conditions) up to about 10,000 pCi/g cesium-137. A high rate detector with internal and external shields is available to extend the measurement range to about 10^9 pCi/g cesium-137. The SGLS truck is also used to operate the neutron moisture logging system, which measures in situ vadose zone moisture over the range of

0 to about 25 vol% moisture content. The neutron moisture logging system uses the same source-detector relationship as the handheld moisture gauge.

The radionuclide assessment system was specifically designed for routine monitoring against the baseline established from the SGLS data. The radionuclide assessment system uses a series of three interchangeable NaI(Tl)-based scintillation detectors for measurement over the range from background levels to about 10^5 pCi/g cesium-137. The radionuclide assessment system records counts in specific energy ranges as well as total gamma activity. Although it does not have the energy resolution capability of the SGLS, it is mounted on a smaller truck and collects data at a faster rate.

The handheld moisture gauge is a commercially available system (model 503DR Hydroprobe manufactured by CPN International, Inc.) designed for manual measurement of in situ moisture content at one or more points in the subsurface. Use of the handheld moisture gauge does not require truck access into the tank farm and is more practical for frequent use during waste retrieval.

A new readily transportable drywell logging system capable of concurrent gamma and moisture measurement is being acquired for use in support of waste retrieval operations in the tank farms. The retrieval monitoring system (RMS) will have calibrated neutron moisture and gross (total) gamma detectors on a combined probe. It will provide dual data logs over preselected depth intervals in the drywells. The overall size and portability of the RMS will minimize interference with surface activity, and the capability of collecting both moisture and gamma data in a single log run will result in a significant reduction in the cost of monitoring activities. The new logging system also provides for electronic data recording. Drywells with very high gamma activity, such as 30-05-07, may still require the use of the high rate logging system, but it is likely that a high rate detector can be developed for the RMS.

The RMS is a modular, portable logging unit capable of concurrent measurement of gross gamma activity and neutron moisture content. It is based on a commercially available logging system. The source-detector arrangement for neutron moisture measurement has been modified to provide data comparable to that currently obtained from the handheld moisture gauges and the neutron moisture logging system. It is anticipated that the RMS will have a measurement range from background up to 100,000 pCi/g cesium-137 and 0 to 25 vol% moisture content.

4.2.1.2. In-Tank Volume (Material) Balance (During Operation). Material balances will be performed for all transfers between tanks in accordance with the process control plan. Primary inputs to the material balance include water additions, waste volumes retrieved as measured in the batch vessel, volume of supernate transferred from the DST receiver tank to the waste transfer system, and the volume of waste within the respective receiver tank.

The accuracy of the material balance will be limited because waste volume data for the tank from which waste is being retrieved can only be estimated. Given the operational strategy to minimize liquids in tank C-101, C-105, C-110, or C-111 during waste retrieval operations, there will not be a liquid level measurement available. Given the dished bottoms of the tanks and the location of the level instrumentation near the side, waste levels cannot be measured below approximately

12,000 gal. In the absence of a means to collect real-time volume measurements for the tank, estimates will be developed using the in-tank camera combined with material balance data.

A simplified flowsheet showing measurement locations is provided in Figure 3-4. The material balance can be used to identify large discrepancies in the waste retrieval process but will not be able to identify smaller leaks. Therefore, material balance calculations will only be used as a backup leak detection method.

4.2.2 Leak Detection Monitoring for Abovegrade Equipment Skids

There are two abovegrade skids that will contain waste or drainwater solutions: (1) the batch vessel skid, which contains the batch vessel and associated transfer pumps, and (2) the vacuum skid, which contains the vacuum blowers and air separator vessel. The planned LDM for these skids includes the following features:

- Each skid will have a sealed containment floor with a drain. The drain will be routed back to the tank being retrieved. The drain lines will contain leak detectors that will activate in the event liquid is detected and shut down any waste transfers.
- Each skid will have internal video capability. These can be used to help determine the source of a detected leak.

4.2.3 Leak Detection in Transfer Lines and Pits

Supernate will be transferred from the DST receiver tank(s) to the waste transfer system at the vessel/pump skid, and liquid waste and slurries will be transferred from the vessel/pump skid to their respective receiver tank using temporary hose-in-hose overground transfer lines and pits. Leak detectors located in pits and pump pits will be monitored during waste transfers. Leaks are also detected by monitoring flows and by radiation monitoring of the hose-in-hose transfer line in accordance with the requirements of RPP-13033, *Tank Farms Documented Safety Analysis*, and RPP-12711. Pits associated with the receiver tank will also be monitored.

Leakage from the primary overground transfer hose (inner hose) will be contained by the secondary confinement system (outer hose). The secondary confinement system has been designed to drain any fluid released from the primary hose to a common point for collection, detection, and removal. Leak detection elements are installed in pits at the ends of the transfer lines. If a leak occurs, the liquid will contact the detector, which will actuate an alarm and shut down the transfer pumps either automatically or manually.

4.2.4 Leak Detection in the Receiver Double-Shell Tanks

The existing leak detection systems in the receiver DSTs will be used as required in OSD-T-151-00031. A leak from the primary vessel of the receiver DST will be detected by a conductivity probe installed in the annulus.

4.3 RATIONALE FOR SELECTION OF LEAK DETECTION AND MONITORING TECHNOLOGY

The LDM technologies selected for deployment at tanks C-101, C-105, C-110, and C-111 represent the best available technology that is consistent with the planned approach for waste retrieval. The vacuum-based waste retrieval technology will limit the volume of liquid in the tank at any point in time, which will limit the area of the tank liner in contact with retrieval liquid and the potential for leakage. The primary leak detection method uses available drywells and established technologies to monitor for liquid losses in the soils surrounding the tanks. With between 6 and 10 drywells located near each of the tanks, there is sufficient coverage around the tanks. Additionally, mass balance will be used as a backup to the primary method.

4.4 LEAK DETECTION FUNCTIONS AND REQUIREMENTS

This section defines the upper-level functions and corresponding requirements to which the leak detection systems for tanks C-101, C-105, C-110, and C-111 must be designed and operated. The system specification for the C farm 100-series tanks that defines design criteria will be consistent with this work plan. The functions and requirements for LDM are detailed in Table 4-1.

Table 4-1. Tanks C-101, C-105, C-110, and C-111 Leak Detection and Monitoring Functions and Requirements.

Function	Requirement	Basis	Key Elements
Detect leaks during waste removal from tanks C-101, C-105, C-110, and C-111	The LDM system shall be capable of detecting liquid waste releases during all waste removal operations.	WAC 173-303	Utilize both in-tank and ex-tank LDM technologies to detect loss of liquid from a tank; see Section 4.0
Monitor leaks from tanks C-101, C-105, C-110, and C-111 during waste removal	The 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	Use both in-tank and ex-tank LDM technologies and operating strategies that will allow estimates of leak volumes and migration rates to be developed in the event of a leak
Mitigate leaks during tanks C-101, C-105, C-110, and 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 4.6
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 DST

DST = double-shell tank.
LDM = leak detection and monitoring.
WRS = waste retrieval system.

40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*, as amended.

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

HNF-SD-WM-TSR-006, 2005, *Tank Farms Technical Safety Requirements*, Rev. 4H, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-13033, 2005, *Tank Farms Documented Safety Analysis*, Rev. H, CH2M HILL Hanford Group, Inc., Richland, Washington.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

4.5 ANTICIPATED TECHNOLOGY PERFORMANCE

There is no single value that can be stated as the maximum leak that could go undetected by drywell monitoring for tank C-101, C-105, C-110, or C-111. There are a wide range of variables that influence the effectiveness of drywell monitoring. A Monte Carlo-type analysis of drywell

monitoring performance for SST leak detection was prepared that considered the impact of all significant variables (RPP-10413, *Tank S-112 Saltcake Waste Retrieval Demonstration Project Leak Detection, Monitoring, and Mitigation Strategy*, Appendix B). The calculations indicated that, assuming an optimum 10-ft distance between the tank leak location and the drywell, the 95th percentile leak size is 300 gal. This means if the leak is 10 ft from the drywell, 95% of the calculated leak volumes at detection are 300 gal. or less. When the leak to drywell spacing is set at 45 ft, the 95th percentile leak volume size is 18,000 gal. When it is assumed that there are three drywells around the tank and the leak to drywell distance is varied randomly for the analysis, the 95th percentile leak size is 7,980 gal. The variation between the low and high end of the 300- to 18,000-gal. range illustrates the impact of the variables which include, but are not limited to, the distance between leak location and the drywell, leak rate, monitoring equipment capabilities, soil properties, and soil moisture content. Many additional factors can influence the leak rate. The selected monitoring frequency can also impact the leak size at discovery.

Per Section 4.1.1, there are 6 drywells around tank C-101 that are between 2 and 20 ft from the tank. There are 10 drywells between 2 and 12 ft around tank C-105, 7 drywells around tank C-110 between 5 and 19 ft from the tank, and 7 drywells around tank C-111 that are between 5 and 25 ft from the tank. Although a few of the drywells are more than 10 ft from the tanks, there are more than the 3 drywells assumed present in RPP-10413, and it is reasonable to assume that the 7,980-gal. 95th percentile leak size should be applicable to these 4 tanks.

From Figure 4-1, it can be seen that the drywells are not uniformly spaced around the perimeter of each tank. For tank C-101, there is a little more than 120 degrees between the two drywells on the southeast side of the tank. Ignoring the fact that there are six drywells around this tank instead of the three equally spaced (120 degrees apart) drywells assumed in RPP-10413 to estimate the 95th percentile leak size of 7,980 gal., the calculated 95th percentile leak size would be expected to be moderately above 7,980 gal. for this tank. The word 'moderately' is not quantifiable without a re-evaluation of RPP-10413 for this drywell arrangement. A re-evaluation of the 95th percentile maximum leak volume that could be spotted for such drywell arrangement is not warranted because a re-evaluation of RPP-10413 will only provide a number. This number will not provide additional information on how to minimize a potential leak. The keys to leak mitigation strategy are detailed in Section 4.6.

The frequency of the drywell monitoring to be performed during waste retrieval operations is provided in Section 4.2.1.1. Data collected with the handheld moisture gauge will be analyzed within a few days to provide timely feedback for process control. Data collected with the truck-mounted logging system will be analyzed within a few weeks under normal operations. Material balance calculations will be performed on a nominal daily basis when waste retrieval and transfers are being performed.

The size of a leak that could be noted using only material balance data has not been formally evaluated for sludge removal from these four C farm tanks. RPP-10413 evaluated a mass balance uncertainty analysis for tank S-112. This tank was estimated to contain approximately 615,000 gal. of waste before retrieval. The vast majority of this waste was saltcake. The four C farm tanks that are the subject of this tank waste retrieval work plan are estimated to contain 88,000 to 178,000 gal. of waste that is predominantly sludge. At least 34 variables were evaluated in RPP-10413 for tank S-112, and the conclusion of that document was that the leak

volume uncertainty for tank S-112 had a greater than 80,000-gal. 95% confidence interval uncertainty range at the point where 80% of the original waste was retrieved. RPP-10413 also states that mass balances can detect leaks on the order of 10,000 gal. if both the sending and receiving tanks have a liquid surface.

For the four C farm tanks covered by this tank waste retrieval work plan, this 10,000 to 80,000 gal. range is not totally applicable. Although the receiving DST will have a full liquid surface, SST level readings with a 100% liquid surface will not be routinely obtained. A number of the parameters evaluated in RPP-10413 that have a significant impact on saltcake dissolution will not be significant for the four C farm tanks that contain mostly sludge. This, coupled with the lower waste volumes in the C farm tanks, could reduce the 80,000 gal. upper range value somewhat. Thus, while a quantitative value cannot be stated for what size of a leak being noted with mass balance data for these four tanks, it can qualitatively be stated that a leak less than 10,000 gal. would likely not be spotted. The potential for spotting a larger leak increases with the leak size, but there is no technical evaluation at this time that would permit stating a quantitative value for an upper 95% confidence interval for these four tanks.

Due to the uncertainty and variance in the performance of the technology, there is no instantaneous method to measure leak migration rates.

The transfer lines associated with transfers covered in this document and DSTs are RCRA compliant.

While it is estimated that an 8,000 gal. leak can be spotted via drywell monitoring at a 95% confidence level, the actual volume of a leak will also be dependent upon the quantity of liquid in a tank available to leak.

The liquid volume available for a leak is the volume of interstitial liquid present in the sludge above the capillary height (assumed to be about 24 in.) plus the volume of any free liquid above the sludge. As the waste retrieval process proceeds, it is expected that the waste will eventually become saturated, but retrieving via a central depression and taking steps to minimize free liquid in the depression will reduce the volume of interstitial liquid accordingly.

Per Section 3.2, the tank free liquid will be controlled to less than a nominal one-third of the waste surface, as estimated from the video camera. See Section 3.2 for a discussion of the volume of free liquid which may be present in a tank during vacuum retrieval under various conditions.

Tanks C-101, C-110, and C-111 had liquid removed to the extent practical after leaks were suspected, per WHC-MR-0132. As liquid is removed, the driving force for a leak is reduced, and if liquid is reduced to below the leak location (if the location is on the tank side wall) the leak would be zero. However, if the leak location was below the waste level and the hole had corroded to a larger opening in the intervening years, the leak rate could increase if suitable head pressure was provided. Conservatively assuming a leak location on the bottom of a tank and assuming a nominal 1.5 gal/hr leak rate, the tank could leak approximately 250 gal. of liquid for every week of retrieval, as long as there was free liquid and/or drainable interstitial liquid of sufficient head to result in a leak. If work progresses quickly with no delays and is completed in

less than 2 months, the leak volume to the soil would be expected to be in the 0 to 2,000-gal. range. If retrieval takes a year the leak volume would be expected to be in the 0 to 13,000-gal. range.

By minimizing the free liquid in a tank, the driving force for any leak is minimized.

4.6 MITIGATION STRATEGY

The leak mitigation strategy (i.e., reduction of leak loss potential) is to minimize the liquid volume within the tank during waste retrieval operations. Conditions to control a leak potential involve the following:

- The in-tank liquid inventory during waste retrieval will be less than liquid levels present in the tanks before interim stabilization activities were undertaken.
- Waste will be retrieved from the center region of the tank first.
- Liquid inventories will be removed between waste retrieval campaigns.
- Leak assessment protocols will be per the procedures related to tank leak assessments and resolution of material balance issues:
  - Leak assessment protocols are specified in TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process*, and include:
    - i. **Review available information and identify additional information needs.** Available information includes in-tank and ex-tank measured data (e.g., surface level, flow rate, barometric pressure); tank process history; historical drywell logs; photographs; etc.
    - ii. **Develop specific leak and non-leak hypotheses.** Analysts and subject matter experts develop leak and non-leak hypotheses through a concurrence approach.
    - iii. **Assess leak probability.** The probability for each leak and non-leak hypothesis is calculated. The probability assessment is reviewed and concurred with by the analysts.
    - iv. **Prepare leak assessment report.** The leak assessment report includes the information reviewed, discussion of hypotheses considered, summary of analysts' assessments, summary of mathematical probabilities, and final determination.
  - Resolution of transfer material balance issues is per TFC-ENG-CHEM-D-44, *Resolution of Waste Transfer Material Balance Discrepancies*. This procedure lists 6 potential sources of a positive transfer material balance discrepancy, nine

potential sources of a negative transfer material balance discrepancy, 11 potential sources that might cause either a positive or negative transfer material balance discrepancy, and 7 other factors that might be considered as part of the evaluation.

- Conduct frequent surveys of drywells to provide early recognition of a potential leak condition.

The 'timeliness' of any leak response action is dictated by the drywell monitoring performance. Until a potential leak is noted there is no leak response, only the steps enumerated above minimize the leak potential and leak volume. Once a potential leak is noted, the leak response actions are carried out in a timely manner. These steps are:

- Stop all liquid additions to the tank. There is no specific timeline for this, it would occur as soon as direction was sent to field personnel to halt liquid additions. This direction would be sent as soon as operations management was notified following drywell scan data review that showed an unexplained anomaly.

- Implement TFC-ENG-CHEM-D-42 leak assessment process. No specific completion times are stated for the referenced steps in the leak assessment process.

- During the leak assessment process, continue to retrieve liquid from the tank as practical. There is also no timeline for this step; this operation would continue if it was already being performed. If waste retrieval operations were not being performed and there was free liquid in the tank that could be removed, this removal would commence as soon as resources could be assembled to begin pumping, and the route to the receiver DST, and the DST itself, were available and able to accept the transfer.

In parallel with the above steps, there are also steps to follow for reporting of a leak. These steps and any required reporting times are discussed later in this section.

- Should a belowgrade leak from the tank be indicated during waste retrieval, liquid additions to the tank will be suspended and the liquid inventory within the tank will be removed as soon as practical to the extent possible. Ecology will be informed within 72 hours that a leak assessment was initiated and that retrieval operations have been suspended to validate if a leak has occurred.

The response to a potential leak will be the same regardless of the leak rate. If the leak assessment concludes that no leak is indicated, waste retrieval operations will resume under normal operating procedures. Should a leak be validated, the operating contractor will notify the appropriate regulatory agencies in accordance with TFC-ESHQ-ENV_FS-C-01, *Environmental Notification*. This includes notification to Ecology pursuant to the requirements of WAC 173-303.

Should a leak be detected in the aboveground skids, the waste transfer pumps would be shut down and the leakage would drain to the tank being retrieved (tank C-101, C-105, C-110, or C-111). The leaks would be repaired or the leak location bypassed before resuming waste retrieval operations.

Should a visible (aboveground) leak or release be detected during waste retrieval operations, any transfers in progress would be stopped immediately and response actions defined in HNF-IP-0263-TF, *Building Emergency Plan for Tank Farms*, would be implemented. A visible leak or spill would only occur as a result of an accident or equipment failure. HNF-IP-0263-TF identifies the facility hazards, including hazardous materials, and defines facility-specific emergency planning and response. The emergency plan also describes incident response actions including the initial response actions to immediately protect the health and safety of persons in the affected area, determining if emergency notification is necessary, and taking steps necessary to ensure that a secondary release, fire, or explosion does not occur. The response actions also include steps taken to collect and contain released waste per the regulatory requirements of WAC 173-303.

If the event or condition meets one of the occurrence reporting criteria, TFC-OPS-OPER-C-24, *Occurrence Reporting and Processing of Operations Information*, provides a number of steps to follow leading up to the point where the environmental notification procedure TFC-ESHQ-ENV_FS-C-01 is applied. Procedures are in place that direct immediate actions necessary to stabilize the facility/operation to a safe condition and preserve conditions for subsequent investigation (TFC-OPS-OPER-C-24). The applicable steps related to Ecology notification excerpted from TFC-ESHQ-ENV_FS-C-01 include:

- Notify Tank Farm Contractor Environmental personnel of the leak.
- Determine if the spill or release exceeds 40 CFR 302, "Designation, Reportable Quantities, and Notification," reportable quantity for the material.
- Determine if a RCRA contingency plan needs to be implemented.
- Notify Ecology and the Washington State Department of Health if the reportable quantity has been exceeded and/or the RCRA contingency plan has been implemented. (Note: These notifications are performed per specific requirements on a checklist.)

There are six steps to follow for DST RCRA leak detection. The response to a potential DST leak would be the same regardless of whether the leak was due to a transfer leak into the annulus or a leak of the DST primary tank. Notifications are performed per specific requirements on a two-page checklist and faxed to the listed parties no later than noon of the next business day. The following specific conditions associated with DST leak detection that require Ecology notification are excerpted from TFC-ESHQ-ENV_FS-C-01:

- Leak detection equipment preventive maintenance or functional testing that will exceed 24 hours down time
- Leak detection equipment repair that will require more than 90 days to complete
- Annulus leak detector alarms that are not due to operational activities; alarms caused by intrusion that do not clear within 4 hours of annunciation must be reported
- Operating annulus continuous air monitor readings that equal or exceed the continuous air monitor alarm set point, and are not due to atmospheric radon or its decay products, or

not due to operational activities (e.g., annulus contamination due to vacuum imbalance between annulus and primary tank ventilation system or other operational activity).

4.6.1 Leak Mitigation for Waste Retrieval Tank Leak

Leak minimization for a waste retrieval tank leak will be provided by actions taken during waste retrieval. These include the following:

- Addition of water to the retrieval tank is minimized and liquid pools that form are removed as practical.
- Waste is retrieved to the extent practical by working from the center of the tank outwards.
- Retrieval activities are performed only while a video camera is in place to observe the AMS suction nozzle, ITV, and waste surface.
- Equipment handling controls are used to minimize the potential for dropping equipment into the tank, which could penetrate the tank bottom during installation.
- Maintaining a benchmark level in each tank (the waste level shall not exceed this benchmark); the benchmark levels shall be defined in the process control plan.

If there is a need to operate the system longer than currently planned to demonstrate the limit of the technology to recover waste that is difficult to retrieve, the basic leak minimization step is still to limit the volume of any free liquid in the tank.

4.6.2 Leak Mitigation for Aboveground Skid Leakage

A leak within the skids will drain back to the SST being retrieved, not to the environment. Should a leak occur within the skid, the waste retrieval process would be halted automatically when the leak detectors activate and shut down the transfer pumps. The process could also be halted manually if the leak is spotted earlier by a video camera. The leak would then be fixed or the leak location bypassed before the process was restarted. The response to a leak is the same regardless of leak rate. An occurrence report may be issued depending upon whether the leak met the reporting requirements of TFC-OPS-OPER-C-24.

Any leakage within the skids is contained by the secondary containment. In the unlikely event that equipment failure causes leakage to the environment from the secondary containment, the steps in procedure TFC-ESHQ-ENV_FS-C-01 would be implemented for reporting requirements and in adherence with WAC 173-303.

4.6.3 Leak Mitigation for Receiving Tank Leak

The following is a summary of leak mitigation actions for a DST. A more detailed discussion can be found in HNF-3484, *Double-Shell Tank Emergency Pumping Guide*, and RPP-5482, *Time Deployment Study for Annulus Pumping*.

Actions taken in the event of a leak of waste from primary tank piping into the secondary containment system of the DST system, or other receiver tank, during a waste transfer from an SST to a DST include (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 is no longer increasing, and (3) removing the waste from the secondary containment system as soon as practicable. Tanks that develop leaks at or near the tank bottom may also require saltwell jet pumping to remove trapped liquids from between solid layers in the tank.

The only receiver tank for the tank C-101, C-105, C-110, and C-111 wastes is a DST. There are no double-contained receiver tanks or catch tanks along the transfer route between the batch vessel/pump skid and tank AN-101 or tank AN-106. Transfer line leakage will drain back to the batch vessel/pump skid and from there to the SST being retrieved.

The above leak detection and mitigation systems are approved and implemented through the DST RCRA permitting process.

4.6.4 Leak Mitigation for Transfer Line Leak

Transfer line leakage occurring near the HIHTL connection in the DST farm would likely drain to the DST receiver tank. All other transfer line leakage will drain back to either the SST being retrieved or the containment structure on the transfer line. Leakage to the containment structure is transferred to the SST being retrieved. Response to transfer leak detection alarms will be performed per procedures to be developed before waste retrieval operations commence. Leak detection is performed in a similar manner to, and response is similar to that for, existing tank farm transfers. There is nothing unique to the tank waste retrieval leak detection system logic when compared to existing tank farms transfer leak detection. Leak mitigation is provided by the design of equipment that channels all leakage into an outer encasement that drains to an alarmed location and a collection tank. The transfer is shut down when the alarm occurs.

5.0 REGULATORY REQUIREMENTS IN SUPPORT OF RETRIEVAL OPERATIONS

Retrieval of waste from the SSTs will be performed under the requirements of HFFACO, *Atomic Energy Act of 1954*, RCRA, Chapter 70.105 RCW and its implementing regulations, and WAC 173-303. The SSTs do not provide secondary containment and are not compliant with RCRA and Chapter 70.105 RCW interim facility standards of Subpart J of 40 CFR 265. The SSTs are currently authorized to continue operations under the Chapter 70.105 RCW pending closure in accordance with WAC 173-303-610, "Closure and Post Closure," under the authority of HFFACO Milestone M-45-00, "Complete Closure of all Single-Shell Tank Farms." Except as otherwise modified by HFFACO Milestone M-45-00, DOE conducts day-to-day operations of the SSTs in accordance with the interim status facility standards established in WAC 173-303-400(3), "Interim Status Facility Standards." WAC 173-303-400(3) incorporates by reference the interim status performance standards set forth by the EPA in 40 CFR 265. Additionally, the SSTs are governed by federal regulations promulgated under the authority of the *Atomic Energy Act of 1954* and various DOE directives. These requirements are implemented through operating plans and procedures by the Tank Farm Contractor.

Interim status facility standards in WAC 173-303-400(3)(a) incorporate, by reference, the interim status standards set forth by the EPA in 40 CFR 265 Subpart J for tank systems. Elements of the interim status standards relevant to the WRS along with the WRS features and/or operating plans and procedures are summarized in Table 5-1.

Those components of the aboveground system using DST supernate to transfer SST waste to the receiving DST will be handled consistently with the current method of addressing polychlorinated biphenyl (PCB) waste in the DST system.

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
265.15 [WAC 173-303-320], General Inspection Requirements	(a) The owner or operator must inspect his facility for malfunctions and deterioration, operator errors, and discharges (b) The owner or operator must develop and follow a written schedule for inspecting all monitoring equipment, safety and emergency equipment, security devices, and operating and structural equipment that are important to preventing, detecting, or responding to environmental or human health hazards. (c) The owner or operator must remedy any deterioration or malfunction of equipment or structures which the inspection reveals on a schedule which ensures that the problem does not lead to an environmental of health hazard. (d) The owner or operator must record inspections in an inspection log or summary.	RPP-16922, Section 10, contains the Interim Status inspection schedule for both the SST and DST systems. The inspection requirements are implemented through Operator Rounds and Shift Office tickle files. Deficiencies discovered by operators are entered into the Problem Evaluation Request system and resolved through the Tank Farm Contractor work control process contained in TFC-OPS-MAINT-C-01.
265.16 [WAC 173-303-330], Personnel Training	(a) Facility personnel must successfully complete a program of classroom instruction or on-the-job training that teaches them to perform their duties in a way that ensures the facility's compliance with the requirements of this part. (b) Facility personnel must successfully complete the program required in paragraph (a) of this section within six months after the date of their employment or assignment to a facility, or to a new position at a facility, whichever is later. Employees hired after the effective date of these regulations must not work in unsupervised positions until they have completed the training requirements of paragraph (a) of this section. (c) Facility personnel must take part in an annual review of the initial training required in paragraph (a) of this section (d) The owner or operator must maintain records at the facility (e) Training records must be kept until closure of the facility	TFC-PLN-07 contains the training requirements for tank farm workers. Completion of the requirements is recorded in the ITEM. ITEM records are also used to support regulatory agency inquiry during compliance inspections. Tank farm employees who enter the TSD portion of the facility also complete, at a minimum, 24-hour hazardous waste worker training. Employees who may come in contact with tank waste complete the 40-hour hazardous waste worker training. Both groups complete annual 8-hour hazardous waste worker refresher training.
Subpart D [WAC 173-303-350] [WAC 173-303-360], Contingency Plan and Emergency Procedures	265.51 [WAC 173-303-350 (1)]: Each owner or operator must have a contingency plan. 265.52 [WAC 173-303-350 (2) and (3): (a) The contingency plan must describe the actions facility personnel must take in response to fires, explosions, or any unplanned sudden or non-sudden release of hazardous waste or hazardous waste constituents to air, soil, or surface water	The Tank Farm Contingency Plan, which supports both the SST and DST systems, is contained in HNF-IP-0263-TF. Supporting the contingency plan are the abnormal operating procedures and the emergency response procedures. Required notifications are contained in TFC-ESHQ-ENV_FS-C-01.

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
	(b) If the owner or operator has already prepared a Spill Prevention, Control, and Countermeasures (SPCC) Plan or some other emergency or contingency plan, he need only amend that plan to incorporate hazardous waste management provisions. (c) The plan must describe arrangements agreed to by local police departments, fire departments, hospitals, contractors, and State and local emergency response teams. (d) The plan must list names, addresses, and phone numbers of all persons qualified to act as emergency coordinator (e) The plan must include a list of all emergency equipment at the facility (f) The plan must include an evacuation plan for facility personnel 265.53 [WAC 173-303-350 (4)]: A copy of the contingency plan must be maintained at the facility. 265.54 [WAC 173-303-350 (5)]: A contingency plan must be reviewed, and immediately amended, if necessary, whenever: (a) Applicable regulations are revised (b) The plan fails in an emergency (c) The facility changes (d) The list of emergency coordinators changes (e) The list of emergency equipment changes 265.55 [WAC 173-303-360 (1)]: At all times, there must be at least one employee either on the facility premises or on call with the responsibility for coordinating all emergency response measures. 265.56 [WAC 173-303-360 (2)]: (a) Whenever there is an imminent or actual emergency situation, the emergency coordinator must immediately: (1) Activate internal facility alarms or communication systems (2) Notify appropriate State or local agencies (b) Whenever there is a release, fire or explosion, the emergency coordinator must immediately identify the character, exact source, amount, and real extent of any released hazard. (c) The emergency coordinator must assess possible hazards to human health or	The contingency plans are maintained in the Waste Feed Operations and the Closure Project shift office. The on-duty Shift Manager serves as the Building Emergency Director. Emergency pumping of the DST is guided by emergency pumping guide HNF-3484. The Building Emergency Plan is maintained and updated as required by the Waste Feed Operations Support group.

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
	the environment (d) If the emergency coordinator determines that the facility has had a release, fire, or explosion which could threaten human health, or the environment, outside the facility, he must report his findings. (e) The emergency coordinator must take all reasonable measures necessary to ensure that fire, explosions, and releases do not occur, recur, or spread to other hazardous waste at the facility (f) If the facility stops operations in response to a fire, explosion or release, the emergency coordinator must monitor for leaks, pressure buildup, gas generation, or ruptures in valves, pipes, or other equipment, wherever this is appropriate (g) Immediately after an emergency, the emergency coordinator must provide for treating, storing, or disposing of recovered waste, contaminated soil or surface water, or any other material that results from a release, fire, or explosion (h) The emergency coordinator must ensure that no waste that may be incompatible with the released material is treated, stored, or disposed of until cleanup procedures are completed and all emergency equipment listed in the contingency plan is cleaned and fit for its intended use before operation is resumed (i) The owner or operator must notify the Regional Administrator, and appropriate State and local authorities, that the facility is in compliance with paragraph (h) before operations are resumed (j) The owner or operator must note in the operating record the time, date, and details of any incident that requires implementing the contingency plan. Within 15 days after the incident, submit a written report on the incident to the Regional Administrator.	

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
265.73 [WAC 173-303-380], Facility Recordkeeping	(a) The owner or operator must keep a written operating record	The written operating record for tank farms consists of the following: • Completed operator rounds • Shift Manager log books • Completed corrective maintenance and preventative maintenance procedures and packages
265.191, Assessment of existing tank systems integrity	(a) For each existing tank system that does not have secondary containment meeting the requirements of 265.193, the owner or operator must determine that the tank system is not leaking or is unfit for use. (b) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated to ensure that it will not collapse, rupture, or fail. (d) If, as a result of the assessment conducted a tank system is found to be leaking or unfit for use, the owner or operator must comply with the requirement of 265.196.	(a) and (b): RPP-10435 prepared and submitted under HFFACO Milestone M-23-24. (d) HFFACO M-45 series milestones
265-192, Design and Installation of New Tank Systems or Components	(a) Owners or operators of new tank systems or components must ensure that the foundation, structural support, seams, connections, and pressure control (if applicable) are adequately designed and that the tank system has sufficient structural strength, compatibility with the waste to be stored or treated, and corrosion protection so that it will not collapse, rupture, or fail. The owner or operator must obtain a written assessment, reviewed and certified by an independent, qualified, registered professional engineer attesting that the system has sufficient structural integrity and is acceptable for the storing and treating of hazardous waste. (b) The owner or operator of a new tank systems must ensure that proper handling procedures are adhered to in order to prevent damage to the system during installation. Prior to covering, enclosing, or placing a new tank system or component in use, an independent, qualified installation inspector or an independent, qualified, registered professional engineer, either of whom is trained and experienced in the proper installation of tank systems, must inspect the system or component. (c) New tank systems or components and piping that are place underground and	The HIHTL design and installation is verified and certified by an IQRPE. Aboveground retrieval systems are verified and certified by an IQRPE (e.g., RPP-16666). System design and IQRPE certification ensure that parts (a), (b), (c), (d), and (e) are met. Cathodic protection is not installed on the HIHTL.

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
	that are backfilled must be provided with a backfill material that is a noncorrosive, porous, homogeneous substance that is carefully installed so that the backfill is placed completely around the tank and compacted to ensure that the tank and piping are fully and uniformly supported. (d) All new tanks and ancillary equipment must be tested for tightness prior to being covered, enclosed, or placed in use. (e) Ancillary equipment must be supported and protected against physical damage and excessive stress due to settlement, vibration, expansion or contraction (f) The owner or operator must provide the type and degree of corrosion protection necessary to ensure the integrity of the tank system during use of the tank system. The installation of a corrosion protection system that is field fabricated must be supervised by an independent corrosion expert to ensure proper installation (g) The owner or operator must obtain and keep on file at the facility a written statement by those persons required to certify the design of the tank system and supervise the installation of the tank system in accordance with the requirements of this section to attest that the tank system was properly designed and installed and that repairs were performed. These written statements must also include the certification statement.	
265.193, Containment and Detection of Releases	(a) In order to prevent the release of hazardous waste or hazardous constituents to the environment, secondary containment must be provided (b) Secondary containment must be: (1) Designed, installed, and operated to prevent any migration of waste or accumulated liquid out of the system to the soil, ground water, or surface water at any time during the use of the tank system (2) Capable of detecting and colleting releases and accumulated liquids until the collected liquid can be removed. (c) To meet the requirements of paragraph (b) of this section, secondary containment must be at a minimum: (1) Constructed of or lined with materials that are compatible with the waste(s) to be placed in the tank system and must have sufficient strength and thickness to prevent failure due to pressure gradients,	The retrieval system equipment is designed with compliant secondary containment. Design documentation is available for inspection.

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
	physical contact with the waste to which it is exposed, climatic conditions, the stress of installation, and the stress of daily operation. (2) Placed on a foundation or base capable of providing support to the secondary containment system and resistance to pressure gradients above and below the system and capable of preventing failure due to settlement, compression, or uplift. (3) Provided with a leak-detection system that is designed and operated so that it will detect the failure of either the primary and secondary containment structure or any release if hazardous waste or accumulated liquid in the secondary containment system within 24 hours, or at the earliest practicable time if the existing detection technology or site conditions will not allow detection of a release within 24 hours. (4) Sloped or otherwise designed or operated to drain and remove liquids resulting from leaks, spills, or precipitation. Spilled or leak waste and accumulated precipitation must be removed form the secondary containment system with 24 hours, or in as timely a manner as is possible to prevent harm to human health or the environment, if removal of the released waste or accumulated precipitation cannot be accomplished with 24 hours. (d) Secondary containment for tanks must include one or more of the following devices; (1) A line (external to the tank) (2) A vault (3) A double-walled tank (4) An equivalent device as approved by the Regional Administrator. (e) [Applies to the design of external liners, vaults, and double-walled tanks.] (f) Ancillary equipment must be provided with full secondary containment except for: (1) Aboveground piping (exclusive of flanges, joints, valves, and connections) that are visually inspected for leaks on a daily basis (2) Welded flanges, welded joints, and welded connections that are visually inspected for leaks on a daily basis (3) Sealless or magnetic coupling pumps and sealless valves that are	

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
	visually inspected for leaks on a daily basis (4) Pressurized aboveground piping systems with automatic shutoff devices that are visually inspected for leaks on a daily basis.	
265.194, General Operating Requirements	(a) Hazardous wastes or treatment reagents must not be placed in a tank system if they could cause the tank, its ancillary equipment, or the containment system to rupture, leak, corrode, or otherwise fail. (b) The owner or operator must use appropriate controls and practices to prevent spills and overflows from tank or containment systems. They include at a minimum: (1) Spill prevention controls (2) Overfill prevention controls (3) Maintenance of sufficient freeboard in uncovered tanks to prevent overtopping by wave or wind action or by precipitation	Control of the waste retrieval process is defined in the process control plan for each retrieval: (1) System design. (2) Retrieval systems that have an intermediate receiving vessel have controls (automatic and procedural) to prevent overfill of the intermediate receiver tank/vessel. The receiving DST has primary tank level instrumentation which is monitored during transfers. (3) Not applicable.
265.195, Inspections	(a) The owner or operator must inspect, where present, at least once each operating day: (1) Overfill/spill control equipment (2) The aboveground portions of the tank system, if any, to detect corrosion or release of waste (3) Data gathered from monitoring equipment and leak-detection equipment (e.g., pressure and temperature gauges, monitoring wells) to ensure that the tank system is being operated according to its design (4) The construction materials and the area immediately surrounding the externally accessible portion of the tank system including secondary containment structures to detect erosion or signs of release of hazardous waste (b) The owner or operator must inspect cathodic protection systems, if present, according to, at a minimum, the following schedule to ensure that they are functioning properly (1) the proper operation of the cathodic protection system must be confirmed within six months after initial installation and annually thereafter	RPP-16922, Section 10, contains the interim status inspection requirements for the tank farms. The inspection requirements are implemented through Operator Round Sheets. Visual inspection of piping components is not practical due to presence of shielding; potential leaks are indicated by instrumentation. Visual inspections of shielded secondary containment systems for aboveground piping components are performed during operator rounds. Inspection and verification of operation of the cathodic protection systems is accomplished through Tank Farm Contractor approved procedures. The completed cathodic protection procedures and operator round sheets are part of the written operating record.

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
	(2) All sources of impressed current must be inspected and/or tested, as appropriate, at least bimonthly (c) The owner or operator must document in the operating record of the facility an inspection of those items *(above)*	
265.196 [WAC 173-303-400(3)(c)(vii)], Response to leaks or spills and disposition of leaking or unfit-for-use tank systems	A tank system or secondary containment system from which there has been a leak or spill, or which is unfit for use, must be removed from service immediately, and the owner or operator must satisfy the following requirements; (a) Cessation of use; prevent flow or addition of wastes (b) Removal of waste from tank system or secondary containment system (c) Containment of visible releases to the environment (d) Notifications, reports	Response to leak or spills is defined in Section 4.6.
WAC 173-303-283 (3), Performance standards	The owner/operator must design, construct, operate, or maintain a dangerous waste facility that to the maximum extent practical given the limits of technology prevents: (a) Degradation of ground water quality; (b) Degradation of air quality by open burning or other activities; (c) Degradation of surface water quality; (d) Destruction or impairment of flora and fauna outside the active portion of the facility; (e) Excessive noise (f) Conditions that constitute a negative aesthetic impact for the public using rights of ways, or public lands, or for landowners of adjacent properties; (g) Unstable hillsides or soils as a result of trenches, impoundments, excavations, etc.; (h) The use of processes that do not treat, detoxify, recycle, reclaim, and recover waste material to the extent economically feasible; and (i) Endangerment of the health of employees, or the public near the facility.	The following plans and procedures and their implementation provide the preventative measures required: (a) Groundwater monitoring plan (PNNL-13024). (b) No open burning is allowed. (c) Berms and gutters are in place to prevent surface runoff and surface run-on. (d) No destruction or impairment of flora and fauna occur outside of the tank farms. (e) Noise is monitored per CH2M HILL procedures. (f) The tank farms are within the dangerous waste facility (i.e., Hanford site). (g) Appropriate permits are obtained before excavation work is started. No excavation work is associated with tank waste retrieval. (h) The waste retrieval process is designed, constructed and will be operated to treat

Table 5-1. 40 CFR 265 (WAC 173-303-400) Interim Status Standards Applicable to Waste Retrieval.* (9 Sheets)

Regulation	Requirement	Compliance Method
		and recover waste to the limits of technology in accordance with HFFACO milestone M-45-00 (see Section 3.4). (i) The public is protected by the NOC per WAC 173-303-400 & 460. Workers are protected per TFC-PLN-43.
WAC 173-303-400, Interim Status Facility Standards	Incorporates by reference 40 CFR 265 with the exception of 265.1 (c)(4), 265.149-150 and 265.430. Replaces federal terms in 40 CFR 265 (i.e., regional administrator, hazardous) with state terms (i.e., department, dangerous)	Applicable operating plans and procedures are referenced throughout the document; too numerous to appropriately reference herein.

* Documents references information is provided in Section 9.0 of this document.

CH2M HILL = CH2M HILL Hanford Group, Inc.
DST = double-shell tank.
HFFACO = *Hanford Federal Facility Agreement and Consent Order.*
HIHTL = hose-in-hose transfer line.
IQRPE = independent, qualified, registered professional engineer.
ITEM = Integrated Training Electronic Matrix.
NOC = notice of construction.
SST = single-shell tank.
TSD = treatment, storage, and disposal.

6.0 PRELIMINARY ISOLATION EVALUATION

This section provides a preliminary isolation evaluation for tanks C-101, C-105, C-110, and C-111. Intrusion prevention measures were completed in the 1980s for these tanks. The identification of tank penetrations and methods used to isolate intrusion pathways is described in Section 2.0. Isolation details for intrusion measures that have been completed for the tanks are provided on the following drawings:

- *Piping Waste Tank Isolation C-Tank Farm Plot Plan* (H-2-73338, Sheet 1)
- *Piping Waste Tank Isolation 241-C-101* (H-2-73340, Sheet 1)
- *Piping Waste Tank Isolation 241-C-105* (H-2-73345, Sheet 1)
- *Piping Waste Tank Isolation 241-C-110* (H-2-73350, Sheet 1)
- *Piping Waste Tank Isolation 241-C-111* (H-2-73341, Sheet 1).

Installation of waste retrieval equipment in tanks C-101, C-105, C-110, and C-111 will involve placement of equipment through new or existing tank risers. Following completion of waste retrieval, the in-tank equipment may be removed or may be left in place for disposition during tank closure activity actions. New isolation drawings or modifications to existing drawings will be prepared to define methods for isolating potential intrusion pathways following completion of waste retrieval. The current planning baseline includes interim closure of tanks C-101, C-105, C-110, and C-111 in 2007.

Intrusion monitoring will be conducted per OSD-T-151-00031 until specific post-retrieval monitoring requirements are defined. Pre-retrieval isolation is discussed in Section 2.6.

7.0 PRE-RETRIEVAL RISK ASSESSMENT

This section provides long-term human health risk information to support operational decisions in the event a leak is detected during waste retrieval operations for tanks C-101, C-105, C-110, and C-111. The need to consider long-term human health impacts in developing tank waste retrieval work plans was established in the HFFACO M-45 milestone series through Change Request M-45-04-01.

According to Appendix I of the HFFACO, the information provided in the work plans will include the following:

> *A pre-retrieval risk assessment of potential residuals, consideration of past leaks, and potential leaks during retrieval, based on available data and the most sophisticated analysis available at the time. The purpose of this risk assessment is to aid operational decisions during retrieval activities. This risk assessment will not be used to make final retrieval or closure decisions. Minimally it will contain the following:*
>
> - *Long-term human health risk associated with potential leaks during retrieval and potential residual waste after completion of retrieval.*
> - *Potential impacts to groundwater, including a waste management area (WMA)-level risk assessment.*
> - *Potential impacts based on an intruder scenario.*
> - *Process management responses to a leak during retrieval and estimated potential leak volume.*
> - *The pre-retrieval risk analysis will be based on the following criteria:*
> - *Using the WMA fenceline for point of compliance.*
> - *Identify the primary indicator contaminants (accounting for at least 95% of impact to groundwater risk) and provide the incremental lifetime cancer risk (ILCR) and hazard index (HI).*
> - *Using ILCR and HI for the industrial and residential human scenarios as the risk metric.*
> - *Calculated concentration(s) of primary indicator contaminant(s) in groundwater (mg/L and pCi/L).*

The risk information provided in this section was developed to meet the requirements identified in the HFFACO Appendix I. Information is provided for two main categories of impacts: (1) long-term human health risk associated with use of groundwater and (2) long-term human health risk associated with inadvertent post-closure human intrusion. Uncertainty or sensitivity evaluations of the impact of changes in assumptions, (e. g. concentration or K_d variation) will be

provided in DOE/ORP-2005-01, *The Office Of River Protection Single Shell Tanks Performance Assessment.*

Groundwater pathway impacts are discussed in Section 7.1. Inadvertent intruder impacts are discussed in Section 7.2. Calculation detail is provided in RPP-22521, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan.*

7.1 GROUNDWATER PATHWAY IMPACTS

The groundwater pathway impacts evaluation emphasized the development of a set of graphical tools to provide a basis for making informed decisions in the event a leak is detected or unexpected retrieval conditions arise during waste retrieval operations. The format used for the retrieval leak impact graphs was developed with Ecology during a joint workshop on March 31, 2004. The graphs are tank-specific and are intended to provide a means to rapidly convert retrieval leak monitoring data into a rough approximation of potential groundwater pathway impacts for a particular retrieval leak.

The methodology used to develop the retrieval leak impact graphs is described in Section 7.1.1. Tank-specific retrieval leak impact results are discussed in Section 7.1.2. Retrieval leak impact graphs for the individual tanks are provided in Appendices A through D. A WMA-level perspective on groundwater pathway impacts is provided in Section 7.1.3 to help place the potential retrieval leak impacts from the individual tanks into the context of the potential impacts for the C tank farm as a whole.

7.1.1 Retrieval Leak Evaluation Methodology

The retrieval leak graphs were developed using the following methodology:

- Focus on potential long-term groundwater pathway human health risk at the downgradient tank farm fenceline
- Use radiological incremental lifetime cancer risk (ILCR) and noncarcinogenic chemical hazard index (HI) as the primary human health impact metrics
- Use industrial and residential exposure scenarios
- Identify the significant contributors (95% of total) for each health impact metric and generate a separate graph for each significant contributor
- Derive effects of contaminant release and transport from previous studies
- Use the best available published data and information to the maximum extent possible.

The human health impact values used to generate the retrieval leak impact graphs are estimates based on Equation 7-1.

$$R_i = I_i \times C_i \times H_i \qquad (7\text{-}1)$$

Where:

i = indicator contaminant
R_i = risk metric (radiological ILCR or chemical HI)
I_i = inventory (Ci or kg released into the environment [e.g., retrieval leakage])
C_i = unit groundwater concentration factor (pCi/L per Ci, or mg/L per kg)
H_i = health effects conversion factor (ILCR per pCi/L, or HI per mg/L).

Sections 7.1.1.1 through 7.1.1.4 discuss the individual terms in Equation 7-1, including identification of indicator contaminants, development of contaminant inventories, simulation of contaminant transport, and identification of exposure scenarios and health effects conversion factors.

7.1.1.1. Indicator Contaminants. Retrieval leak impact graphs were generated for a subset of significant contaminants rather than for all contaminants. Significant contaminants were the contaminants estimated to dominate or drive the total impact for a particular human health impact metric. Significant contaminants serve as indicators of the magnitude of total impacts from all contaminants.

An indicator contaminant approach was used to ensure that the resulting graphical tools would provide a reasonable estimate of total impacts but at the same time be sufficiently simple to facilitate rapid decision making without requiring a lot of additional calculation in the event a leak is detected during waste retrieval. The primary human health impact metrics used were radiological ILCR and noncarcinogenic chemical HI. Nonradiological ILCR was also included for information purposes.

Indicator contaminants for each human health impact metric were identified based on the results of the WMA C risk assessment presented in RPP-13774. The *WMA C Closure Action Plan* provided as Appendix C to RPP-13774 includes the results of a comprehensive WMA C long-term groundwater pathway human health risk assessment that was supported by a site-specific numerical vadose zone and groundwater modeling effort. The *Risk Assessment for WMA C Closure Plan*, provided as Addendum C1 to RPP-13774, shows contaminant-specific impact contributions at the WMA C downgradient fenceline by source term for technetium-99, iodine-129, nitrate, nitrite, total uranium, and hexavalent chromium. Also shown are the total impacts by source term based on the contributions from all contaminants given in DOE/ORP-2003-02, *Inventory and Source Term Data Package*, for which a toxicity factor was available. Exposure scenarios and risk factors used for the RPP-13774 analysis were obtained from HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment*.

The HNF-SD-WM-TI-707 evaluation provides unit dose factors, unit risk factors, and unit HI factors for a comprehensive set of contaminants of potential concern for Hanford Site risk

assessment. A total of 93 radionuclides and 161 chemicals are evaluated. The unit factors were derived from standard formulas using data considered to be the most current or technically sound. For radionuclides, the cancer morbidity risk coefficients in EPA-402-R-99-001, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, were used. For chemicals, the non-cancer toxicity reference doses and cancer induction slope factors adopted by the EPA and listed in the Integrated Risk Information System (IRIS) (http://www.epa.gov/iris) were used. Where toxicity parameters were not available in IRIS, values from the EPA-540/R-97/036, *Health Effects Assessment Summary Tables (HEAST) FY 1997 Update* and the Risk Assessment Information System (RAIS) (http://risk.lsd.ornl.gov) maintained by the Oak Ridge National Laboratory were used. To provide an indication of the importance of missing toxicity parameters, the evaluation also includes estimates of the missing parameters for chemicals that have a reference dose or slope factor for ingestion, but none for inhalation, or vice versa.

Table 7-1 is a summary from the RPP-13774 base case analysis results showing the contaminant contributions by source term for each of the human health impact metrics. Table 7-1 shows the peak impacts from WMA C potential residual tank waste, past leaks (including one tank leak and three ancillary pipeline leaks), and potential retrieval leaks (assuming an 8,000-gal. leak from each of the C farm 100-series tanks).

Table 7-1. Contaminant Contributions to Peak Groundwater Pathway Human Health Impacts at Waste Management Area C Fenceline. (2 Sheets)

Source Term	Time of Peak (Yr AD)	Radiological Incremental Lifetime Cancer Risk		Nonradiological Incremental Lifetime Cancer Risk		Noncarcinogenic Chemical Hazard Quotients and Hazard Index	
		Industrial	Residential	Industrial	Residential	Industrial	Residential
Past leaks [a]	2117	Tc-99 6.9E-06 (85%) I-129 7.1E-07 (9%) C-14 5.4E-07 (6%) H-3 8.8E-10 (<1%) Total 8.1E-06 (100%)	Tc-99 1.7E-04 (95%) I-129 3.7E-06 (2%) C-14 3.9E-06 (3%) H-3 3.7E-09 (<1%) Total 1.8E-04 (100%)	Cr(VI) 1.1E-07 (100%) Total 1.1E-07 (100%)	Cr(VI) 2.4E-07 (100%) Total 2.4E-07 (100%)	Cr(VI) 1.7E-02 (52%) NO_2 1.4E-02 (43) NO_3 1.7E-03 (5%) F 1.4E-05 (<1%) Total 3.3E-02 (100%)	Cr(VI) 9.7E-02 (49%) NO_2 9.1E-02 (46%) NO_3 1.1E-02 (5%) F 9.7E-05 (<1%) Total 2.0E-01 (100%)
Retrieval leaks [b]	2082	Tc-99 5.7E-06 (89%) I-129 6.1E-07 (9%) C-14 1.3E-07 (2%) H-3 2.9E-10 (<1%) Total 6.5E-06 (100%)	Tc-99 1.4E-04 (98%) I-129 3.2E-06 (2%) C-14 9.0E-07 (<1%) H-3 1.2E-09 (<1%) Total 1.4E-04 (100%)	Cr(VI) 1.7E-07 (100%) Total 1.7E-07 (100%)	Cr(VI) 3.8E-07 (100%) Total 3.8E-07 (100%)	Cr(VI) 2.8E-02 (41%) NO_2 2.6E-02 (39) NO_3 4.1E-03 (5%) F 1.0E-02 (15%) Total 6.7E-02 (100%)	Cr(VI) 1.5E-01 (36%) NO_2 1.7E-01 (40%) NO_3 2.6E-02 (6%) F 7.3E-02 (18%) Total 4.2E-01 (100%)

Table 7-1. Contaminant Contributions to Peak Groundwater Pathway Human Health Impacts at Waste Management Area C Fenceline. (2 Sheets)

Source Term	Time of Peak (Yr AD)	Radiological Incremental Lifetime Cancer Risk		Nonradiological Incremental Lifetime Cancer Risk		Noncarcinogenic Chemical Hazard Quotients and Hazard Index	
		Industrial	Residential	Industrial	Residential	Industrial	Residential
Residual tank waste [c]	5614	Tc-99 9.0E-07 (89%) I-129 1.0E-07 (10%) C-14 1.2E-08 (1%) H-3 0.0 (0%) Total 1.0E-06 (100%)	Tc-99 2.2E-05 (97%) I-129 5.2E-07 (2%) C-14 8.8E-08 (<1%) H-3 0.0 (0%) Total 2.3E-05 (100%)	Cr(VI) 2.8E-08 (100%) Total 2.8E-08 (100%)	Cr(VI) 6.3E-08 (100%) Total 6.3E-08 (100%)	Cr(VI) 4.5E-03 (48%) NO_2 3.4E-03 (36%) NO_3 4.5E-04 (5%) F 1.1E-03 (11%) Total 9.4E-03 (100%)	Cr(VI) 2.5E-02 (44%) NO_2 2.2E-02 (38%) NO_3 2.9E-03 (5%) F 7.8E-03 (13%) Total 5.7E-02 (100%)

HFFACO= *Hanford Federal Facility Agreement and Consent Order.*

[a] Source = RPP-13774, Addendum C1, Tables 33 and 34 and additional model output data (includes contributions from one tank leak [C-105] and three unplanned releases [UPR-200-E-81, UPR-200-E-82, UPR-200-E-86]).

[b] Source = RPP-13774, Addendum C1, Tables 36 and 37 and additional model output data (includes contributions from hypothetical 8,000-gal. retrieval leak from each C-100-series tank).

[c] Source = RPP-13774, Addendum C1, Tables 30 and 31 and additional model output data (includes contributions from HFFACO-specified post-retrieval residual waste volume in C-100 and C-200-series tanks).

RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

The RPP-13774 analysis results indicate the only contributors to total WMA C radiological ILCR at the fenceline at the time of peak would be the highly mobile (distribution coefficient [K_d] = 0 mL/g) radionuclides: technetium-99, iodine-129, and carbon-14 and tritium, with technetium-99 being the major driver. Technetium-99 was predicted to contribute approximately 85% to 98% of the total radiological ILCR depending on the source term and receptor scenario. Technetium-99 was therefore selected as the radiological ILCR indicator contaminant for this evaluation. It is recognized that technetium-99 contributes slightly less than 95% of the total radiological ILCR for the industrial scenario; however, technetium-99 clearly predominates the radiological impacts in all cases and is therefore considered an appropriate choice of indicators for radiological ILCR.

The RPP-13774 analysis results indicate the only contributors to the total WMA C noncarcinogenic chemical HI at the fenceline at the time of peak would be the highly mobile (K_d = 0 mL/g) chemicals: hexavalent chromium, nitrite, fluoride, and nitrate, with hexavalent chromium and nitrite being the major drivers. The RPP-13774 analysis conservatively assumed that all chromium inventory was hexavalent chromium. Hexavalent chromium and nitrite combined were predicted to contribute approximately 76% to 95% of the total HI depending on source term and receptor scenario. Hexavalent chromium and nitrite were therefore selected as the noncarcinogenic chemical HI indicator contaminants for this evaluation. It is recognized that hexavalent chromium and nitrite combined contribute slightly less than 95% of the total HI for certain source terms and receptor scenarios; however, these two chemicals combined clearly predominate the noncarcinogenic chemical impacts in all cases and are therefore considered an appropriate choice of indicators for noncarcinogenic chemical HI.

Total uranium was simulated in the RPP-13774 analysis as a moderately mobile (K_d = 0.6 mL/g) contaminant and was not projected to arrive at the fenceline until approximately 5,000 years after closure. At the time of first arrival, the uranium concentration was due primarily to contributions from past leaks and hypothetical retrieval leaks. Uranium from residual waste was not projected to arrive at the fenceline until late in the 10,000-year simulation period. Peak human health impacts were projected to occur within 100 years after closure for past leaks and retrieval leaks and within 3,500 years after closure for residual waste. The peak values in all cases was driven by contributions from the highly mobile (K_d = 0 mL/g) contaminants. Uranium had not yet broken through to the water table at the time of peak for any source term and therefore made no contribution to the peaks. Uranium exhibited increasing concentrations at the end of the 10,000-year simulation and was a primary contributor to the impacts calculated at the end of the simulation. The impacts at the end of the simulation were lower than the peak impacts by an order of magnitude or more.

The RPP-13774 analysis also included an assessment of nonradiological cancer risk. Cancer risks from radionuclides and carcinogenic chemicals are typically reported as separate metrics rather than being summed because of differences in how risk is estimated for these two categories of substances. A total of 24 nonradiological chemical contaminants are included in the BBI. Of these, only one, hexavalent chromium, has a published cancer slope factor.

Nonradiological ILCR was assessed in the RPP-13774 analysis based solely on hexavalent chromium exposure. The nonradiological ILCR results from RPP-13774 are shown in Table 7-1 for information purposes to provide an indication of the potential magnitude of nonradiological

ILCR. The results indicate that nonradiological ILCR peaks would be on the order of 10^{-7} for the past leak and retrieval leak source terms and 10^{-8} for the residual waste source term. However, because it is based on only one contaminant, nonradiological ILCR was not carried forward as a separate evaluation metric (i.e., was not used to generate a separate set of retrieval leak impact graphs). The degree to which hexavalent chromium ILCR provides an indication of total ILCR is uncertain because of the limited number of chemical analytes reported in the BBI. There is additional uncertainty regarding chromium speciation and the degree of conservatism introduced by assuming that all chromium is hexavalent chromium.

Note that hexavalent chromium is classified as both a chemical toxicant (evaluated using HI) and a carcinogen (evaluated using ILCR). It is classified as toxic via both ingestion and inhalation but carcinogenic only via inhalation. The inhalation intake for the groundwater pathway exposures is based on re-suspended soil and volatilized water. The soil is assumed to be contaminated by irrigation with contaminated groundwater for both the industrial and residential scenarios. Water volatilization is assumed to occur during showering with contaminated groundwater. Further discussion of exposure parameters and scenarios is provided in HNF-SD-WM-TI-707.

Table 7-1 is intended to show all contaminants that contributed to the total metric for each source type (past leaks, retrieval leaks, residual waste) at the time of peak for that source type. As such, the contributions should sum to 100%. All BBI contaminants were included in the RPP-13774 analysis; however, not all contaminants contributed to the peaks. This was because for a contaminant to contribute to the peak it had to have 1) a reported inventory (in BBI), 2) a Kd = 0 (in PNNL-13895 or other available database), and 3) a toxicity factor (in HNF-SD-WM-TI-707). The contaminants shown in Table 7-1 meet all three of these criteria. Some BBI contaminants with toxicity factors, such as uranium, were assigned a non-zero Kd (uranium Kd = 0.6) based on best available data. Results indicated that these contaminants do not reach the water table until approximately the year 6500, well after the peaks for all three source types. The non-zero Kd contaminants therefore do not contribute to any of the source term peaks and are not shown on Table 7-1. All contaminants shown in Table 7-1 were assigned Kd = 0. Some BBI contaminants with Kd = 0, such as chloride, reached groundwater by the time of the source term peaks but did not have reported toxicity factors and therefore did not contribute to the total metric and are not shown on Table 7-1.

7.1.1.2. Potential Retrieval Leak Inventories. This document presents much of the risk data assuming an 8,000-gal. retrieval leak volume. This quantity is used only as a point of reference, and for consistency and comparison with the volume assumed in the WMA C Closure Plan (RPP-13774, Appendix C) risk assessment. The choice of the reference volume is arbitrary and does not affect how the risk values would be used in the event of a retrieval leak. The 8,000 gal. is a hypothetical volume that represents neither an anticipated leak volume nor a leak detection limit. The WRS design and operational strategy for tanks C-101, C-105, C-110, and C-111 are designed to minimize the leak potential from the tank structure during waste retrieval. If a leak is detected, however, the risk graphs provided in Appendices A through D will allow the leak impacts to be estimated regardless of leak volume.

The retrieval leak impact graphs provided in the appendices were generated by applying Equation 7-1 over a range of hypothetical retrieval leak inventories for each indicator contaminant (RPP-22521). Because potential retrieval leak volumes are uncertain, the inventory range was selected to encompass a small leak on the low end and a large leak on the high end. Points of reference were added to the graphs to show the estimated current tank inventory and the estimated inventory associated with a hypothetical 8,000-gal. retrieval supernate leak. The 8,000-gal. volume was used only for information purposes to provide a point of reference on the graphs.

Development of the tank-specific inventories shown as points of reference on the graphs for the individual tanks is discussed in the appendices. Current inventory values were taken from the BBI by downloading from the Tank Waste Information Network System (TWINS) database. Hypothetical retrieval leak inventory values were calculated from the best available published data source.

7.1.1.3. Contaminant Transport Simulations. The RPP-13774 analysis provides the most sophisticated currently available predictions of potential long-term groundwater impacts associated with tank waste retrieval and closure activities for WMA C. The groundwater contaminant concentrations used for the retrieval leak impact graphs were derived directly from the modeling output data from the RPP-13774 analysis.

Flow and transport were simulated in the RPP-13774 analysis using two-dimensional cross-sectional models. The cross-sections extended laterally to the tank farm fenceline and vertically downward through the vadose zone into the upper portion of the underlying aquifer. The simulations all assumed a final closure barrier was in place by 2050. The barrier was assumed to function at its design estimate recharge rate (0.5 mm/yr) for 500 years, after which recharge was assumed to increase to 3.5 mm/yr. The simulated cross-sectional groundwater concentrations were distributed uniformly along the length of the downgradient WMA C boundary. The simulations were carried out for a 10,000-year assessment period (i.e., from the year 2000 to the year 12000). The base case simulation results indicated the peak groundwater concentrations from retrieval leaks would arrive at the WMA C downgradient fenceline in the year 2082.

The RPP-13774 transport simulations were performed for the following four types of contaminant sources within WMA C:

- Past leaks from tanks
- Past leaks from ancillary equipment (i.e., past pipe leaks)
- Potential leaks during waste retrieval
- Residual waste remaining in tanks and ancillary equipment.

A total of 14 individual simulation cases were included in the analysis. Each case described the behavior of seven surrogate contaminants of varying distribution coefficients under variable waste release modes for the selected sources. The simulations were all performed using a unit source inventory (i.e., 1 Ci or kg). The contaminants simulated represented seven different measures of contaminant mobility through the use of distribution coefficients (K_d = 0, 0.01, 0.03, 0.1, 0.3, 0.6, and 1.0 mL/g). By using a range of distribution coefficients, the analysis examined a wide variety of contaminants by applying the appropriate inventory and decay rate to the unit results for the contaminant of interest. The indicator contaminants for the current evaluation (technetium-99, hexavalent chromium, nitrite) were all assigned to the highly mobile (K_d = 0 mL/g) surrogate contaminant group.

Table 7-2 shows the RPP-13774 unit-source simulation results for the highly mobile (K_d = 0 mL/g) contaminant group in the retrieval leak source term. The values shown are the predicted peak contaminant concentrations in groundwater at the downgradient WMA C fenceline from release of 1 Ci of radionuclide or 1 kg of chemical. The retrieval leak impact graphs were generated by multiplying the simulated unit-source results by the retrieval leak inventory to obtain an estimate of peak groundwater concentration (Equation 7-1).

Table 7-2. Mobile Contaminant (K_d = 0 mL/g) Unit Inventory Simulation Results for Waste Management Area C Retrieval Leak Source Term.

Contaminant	Peak Groundwater Concentration at WMA C Fenceline*	Units	Time of Peak (Yr AD)
Radionuclide	8.4E+01	pCi/L	2082
Chemical	8.4E-05	mg/L	2082

WMA = waste management area.

* Addendum C1, Figure 9, from RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

7.1.1.4. Exposure Scenarios. Human health impacts were generated and displayed on the retrieval leak impact graphs for an industrial and a residential exposure scenario, consistent with the requirements in HFFACO Appendix I. Both scenarios are based on scenarios described in DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*. The health effects conversion factors for both scenarios are shown in Table 7-3 for the three indicator contaminants.

Table 7-3. Groundwater Unit Health Effects Factors for Industrial and Residential Exposure Scenarios.

Contaminant	Units	Industrial [a]	Residential [b]
Technetium-99	ILCR per pCi/L	1.38E-08	3.36E-07
Hexavalent chromium	HQ per mg/L	3.88E+00	2.34E+01
Nitrite	HQ per mg/L	9.89E-02	6.36E-01

HI = hazardquotient.
ILCR = incremental lifetime cancer risk.
[a] Source: HNF-SD-WM-TI-707, Rev. 4, Tables 22 and 23.
[b] Source: HNF-SD-WM-TI-707, Rev. 4, Tables 26 and 27.
HNF-SD-WM-TI-707, 2004, *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment*, Rev. 4, CH2M HILL Hanford Group, Inc., Richland, Washington.

The conversion factors shown in Table 7-3 were taken from tables provided in HNF-SD-WM-TI-707. For technetium-99, the conversion factors provide the lifetime cancer morbidity risk per unit concentration in the groundwater. For hexavalent chromium and nitrite, the conversion factors provide the noncarcinogenic chemical HQ per unit concentration in the groundwater. The factors were applied to the retrieval leak impact calculations as shown in Equation 7-1.

The industrial scenario represents 20 years of occupational exposure in an industrial setting. The receptor is an individual whose work activity is primarily indoors but also includes outdoor activities such as building and grounds maintenance. Contaminants enter the worker primarily through use of groundwater for drinking water and showering. External exposure to irrigated soil and soil inhalation are also included.

The residential scenario represents 30 years of exposure in a residential setting. The receptor is an individual who resides on the land, grows fruits and vegetables, and raises livestock and poultry for personal consumption. Contaminants enter the receptor through use of groundwater for domestic needs (drinking, cooking, and showering); for irrigation (ingestion of produce, soil, and water; inhalation of soil and water; and external exposure); and for watering livestock (ingestion of meat, poultry, and dairy products).

Uncertainty in the exposure scenarios contributes to the overall uncertainty in long-term risk predictions. To address uncertainty, exposure scenario parameters are generally biased to yield higher exposure and risk values. Inputs to the scenario unit risk factors that could contribute to exposure scenario uncertainty include the various models used (e.g., food chain model, toxicokinetic model) and model parameters (e.g., food chain transfer factors, exposure factors, dose factors, risk factors). Complete descriptions of the exposure scenario parameters, assumptions, and unit risk factor calculations can be found in HNF-SD-WM-TI-707.

7.1.2 Retrieval Leak Impact Analysis Results

Tank-specific retrieval leak impact graphs generated using the methodology described above are provided in Appendices A through D for tanks C-101, C-105, C-110, and C-111, respectively.

Three graphs, one for each indicator contaminant, are provided for each tank. An example calculation is also provided to illustrate how the formula given in Equation 7-1 was applied in generating the graphs.

7.1.3 Waste Management Area C Risk Assessment

This section provides information to allow the potential retrieval leak impacts from the individual tanks to be placed in the context of the potential impacts from the C tank farm as a whole. The information presented was summarized from the WMA C risk assessment results presented in RPP-13774.

Sections 7.1.3.1 through 7.1.3.3 summarize the RPP-13774 analysis results by source term in terms of the projected peak impacts at the WMA C downgradient fenceline from potential retrieval leaks, residual waste, and past leaks.

The RPP-13774 risk assessment was a first-iteration risk assessment developed to show the current understanding of the risks associated with waste retrieval and closure activities for WMA C. The RPP-13774 analysis contained significant limitations and uncertainties. To address these uncertainties, the parameters used for the analysis were in general biased to yield higher risk values. The RPP-13774 analysis provides a list of the uncertainties associated with the risk assessment and how each uncertainty could impact the assessment results. It is expected that as waste retrieval from the C-100-series tanks progresses, new information will become available that could reduce the uncertainties presented in RPP-13774.

7.1.3.1. Potential Retrieval Leaks. Potential WMA C retrieval leak impacts are summarized in Table 7-4 from the results of the base case analysis presented in RPP-13774. Table 7-4 shows the predicted peak groundwater concentration, radiological ILCR, nonradiological ILCR, and noncarcinogenic chemical HI for the indicator contaminants at the downgradient fenceline from the WMA C retrieval leak source term.

The retrieval leak source term was simulated in the RPP-13774 analysis based on a hypothetical 8,000-gal. retrieval leak from each of the twelve C farm 100-series tanks. The four C farm 200-series tanks were assumed not to leak during waste retrieval. A sensitivity case with a larger waste retrieval leak volume was also included.

The retrieval leak inventories used for the RPP-13774 analysis were generated with the HTWOS model assuming a raw water sluicing scenario. For this retrieval work plan, retrieval leak inventories for tanks C-101, C-105, C-110, and C-111 were estimated using data from the waste retrieval flowsheet calculation presented in RPP-21753. The RPP-21753 flowsheet calculation assumes waste is retrieved from these tanks with the MRS using raw water. The estimated retrieval leak inventories for these tanks are shown as reference points on the retrieval leak impact graphs presented in Appendices A through D.

The RPP-13774 base case simulation results indicate the peak groundwater concentrations from retrieval leaks would occur at the WMA C downgradient fenceline in the year 2082.

Groundwater concentrations were calculated as cumulative fenceline average concentrations over the entire downgradient length of the WMA C fenceline. The peak groundwater concentrations from retrieval leaks were projected to overlap in time and be additive with the peak groundwater concentrations from past leaks but were not projected to be additive with the peaks from residual waste.

The RPP-13774 retrieval leak assessment results shown in Table 7-4 included an 8,000-gal. retrieval leak from tank C-106. Subsequent to the completion of the RPP-13774 analysis, a waste retrieval campaign was completed for tank C-106 using modified sluicing and acid dissolution. No leakage from tank C-106 was detected during that campaign. Results of a tank C-106 post-retrieval risk assessment are reported in RPP-20577, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106*.

Table 7-4. Peak Impacts at the Waste Management Area C Fenceline from Potential Retrieval Leaks.

Contaminant	Time of Peak (Yr AD) [a]	Incremental Lifetime Cancer Risk [b]		Hazard Quotients and Index [c]		Groundwater Concentration [d]	Drinking Water Standard (MCL)
		Industrial	Residential	Industrial	Residential		
Technetium-99	2082	5.7E-06	1.4E-04	NA	NA	420 pCi/L	900 pCi/L
Hexavalent chromium	2082	1.7E-07	3.8E-07	2.8E-02	1.5E-01	0.0064 mg/L	0.1 mg/L [e]
Nitrite	2082	NA	NA	2.6E-02	1.7E-01	0.26 mg/L	3.3 mg/L [f]
Total radiological	2082	6.5E-06	1.4E-04	NA	NA	NA	NA
Total nonradiological	2082	1.7E-07	3.8E-07	6.7E-02	4.2E-01	NA	NA

EPA = U.S. Environmental Protection Agency.
MCL = maximum contaminant level.
NA = not applicable.

[a] Source: RPP-13774, Addendum C1, Tables 36 and 37.
[b] Source: RPP-13774, Addendum C1, Table 36.
[c] Source: RPP-13774, Addendum C1, Table 37.
[d] Source: RPP-13774, Addendum C1, Table 38.
[e] The MCL for chromium is from 40 CFR 141.62(b) and is for total chromium.
[f] Concentration for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

7.1.3.2. Residual Waste. Potential WMA C residual tank waste impacts are summarized in Table 7-5 from the results of the base case analysis presented in RPP-13774. The table shows the predicted peak groundwater concentration, radiological ILCR, nonradiological ILCR, and noncarcinogenic chemical HI for the indicator contaminants at the downgradient fenceline from the WMA C residual tank waste source term.

The RPP-13774 simulation results indicate the peak groundwater concentrations from residual tank waste would arrive at the fenceline approximately 3,600 years after closure (in the year 5614). The peak groundwater concentrations from residual tank waste were not projected to overlap in time or be additive with the peak groundwater concentrations from retrieval leaks or past leaks.

The base case residual waste simulations used a diffusion-dominated release model for 360 ft^3 and 30 ft^3 of post-retrieval residual tank waste in the twelve C-100-series tanks and four C-200-series tanks, respectively. The residual waste inventories were estimated using the selective phase removal method, which takes into account removal of selected phases of waste (e.g., sludge, supernate) during retrieval. Groundwater concentrations were calculated as cumulative fenceline average concentrations over the entire downgradient length of the WMA C fenceline.

The nature and amount of waste left in WMA C ancillary equipment and pipelines is unknown. The RPP-13774 analysis included an assumed inventory for the waste in these components to show their expected relative contribution to the total WMA C impacts. Waste in the ancillary equipment tanks (244-CR vault and C-301 catch tank) was assumed to be retrieved to a residual volume proportional to that required under the HFFACO for the 200-series tanks. The ancillary equipment tanks are smaller than the 200-series tanks and the ancillary tank residual volume was calculated by multiplying the 200-series tanks residual volume goal (30 ft^3) by the ratio of the volume of the ancillary equipment tank to the 200-series tanks (55,000 gal.). Currently, there is no BBI inventory associated with these ancillary tanks. Ancillary tank residual inventories were calculated as the product of the residual volume and the averaged contaminant-specific concentration from the combined contents of the C farm 100- and 200-series tank solids.

The WMA C piping system comprises multiple layers of waste transfer piping that were installed over time within WMA C. An estimated total volume of 1,000 ft^3 of waste transfer piping was assumed for the RPP-13774 analysis. To estimate a residual waste inventory related to the piping system, 25% of the pipe (250 ft^3) was assumed to be plugged and filled with residual solids. Currently, there is no BBI inventory associated with the ancillary piping components. Contaminant concentrations in the residual solids were calculated from the combined contents of the C farm 100- and 200-series tank waste solids.

Table 7-5. Peak Impacts at the Waste Management Area C Fenceline from Potential Residual Tank Waste.

Contaminant	Time of Peak (Yr AD) [a]	Incremental Lifetime Cancer Risk [b]		Hazard Quotients and Index [c]		Groundwater Concentration [d]	Drinking Water Standard (MCL)
		Industrial	Residential	Industrial	Residential		
Technetium-99	5610	9.0E-07	2.2E-05	NA	NA	66 pCi/L	900 pCi/L
Hexavalent chromium	5614	2.8E-08	6.3E-08	4.5E-03	2.5E-02	0.001 mg/L	0.1 mg/L [e]
Nitrite	5614	NA	NA	3.4E-03	2.2E-02	0.034 mg/L	3.3 mg/L [f]
Total radiological	5614	1.0E-06	2.3E-05	NA	NA	NA	NA
Total nonradiological	5614	2.8E-08	6.3E-08	9.4E-03	5.7E-02	NA	NA

EPA = U.S. Environmental Protection Agency.
MCL = maximum contaminant level.
NA = not applicable.

[a] Source: RPP-13774, Addendum C1, Tables 30 and 31.
[b] Source: RPP-13774, Addendum C1, Table 30.
[c] Source: RPP-13774, Addendum C1, Table 31.
[d] Source: RPP-13774, Addendum C1, Table 38.
[e] The MCL for chromium is from 40 CFR 141.62(b) and is for total chromium. [f] Concentration for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

The impacts shown in Table 7-5 are for residual tank waste and do not include the contributions from residual waste in WMA C ancillary equipment and pipelines. The residual waste in those components was estimated to cause a small increase to the impacts shown in Table 7-5. For example, for the industrial scenario, the total radiological ILCR increased to 1.1×10^{-6}, the total nonradiological ILCR increased to 3.1×10^{-8}, and the total HI increased to 1.0×10^{-2}. The RPP-13774 analysis indicated the peak impacts from ancillary tank residuals would arrive coincident with the peak from SST residuals (in the year 5614) and the peak from piping system residuals would arrive approximately 700 years earlier than the peak from SST residuals.

The diffusion-dominated residual waste release model used in the base case simulations was representative of a stabilized, grouted waste form. Additional sensitivity cases were simulated using an advection-dominated residual waste release model representative of an unstabilized waste form covered with backfill sand and gravel or failed grout. Peak groundwater concentrations for the advection-dominated release model were projected to arrive at the WMA C fenceline approximately 1,000 years earlier (in the year 4653) and be approximately an order of magnitude higher than the peaks for the base case diffusion-dominated release model.

Subsequent to the completion of the RPP-13774 analysis, a waste retrieval campaign was completed for tank C-106 using modified sluicing and acid dissolution. No leakage from tank C-106 was detected during that waste retrieval campaign. Results of a tank C-106 post-retrieval risk assessment based on samples collected from the residual waste remaining in tank C-106 following the retrieval campaign are reported in RPP-20577. The RPP-20577 analysis results indicate that the impacts from tank C-106 residual waste would be a factor of 4 lower than the corresponding impacts calculated in the RPP-13774 analysis.

7.1.3.3. Past Leaks. WMA C past leak impacts are summarized in Table 7-6 from the results of the base case analysis presented in RPP-13774. The table shows the predicted peak groundwater concentration, radiological ILCR, nonradiological ILCR, and noncarcinogenic chemical HQ for the indicator contaminants at the downgradient fenceline from the WMA C past leak source term.

The RPP-13774 base case simulation results indicate that peak groundwater concentrations from past leaks would arrive at the WMA C downgradient fenceline in the year 2092 for past tank leaks and the year 2117 for past ancillary equipment leaks. The past leaks source term was based on vadose zone contamination associated with past unplanned releases in the vicinity of tank C-105 and three ancillary pipelines (UPR-200-E-81, UPR-200-E82, UPR-200-E-86).

Other reported unplanned ancillary equipment releases in WMA C were considered but disregarded in the RPP-13774 analysis because they were determined not to represent significant sources of contamination compared to the sources analyzed. Table 5 in Addendum C1 of RPP-13774 lists sources considered in the WMA C risk assessment conceptual model. This same table indicates whether the source was included in the risk assessment and, if not included, the reason why. A number of UPRs that occurred in the general area of the four SSTs whose retrieval is described in this TWRWP were not included in the risk assessment. These are UPR-200-E-16, UPR-200-E-27, UPR-E-68, UPR-E-72, UPR-E-91, UPR-E-99, UPR-E-100, UPR-200-E-107, UPR-200-E-118, and UPR-200-E-136. (Depending on future sampling or closure

decisions, these UPRs may be included in future C farm risk assessments.) The reasons given in Table 5 of RPP-13774 Addendum C1 for why they were not included in the risk assessment are:

- **UPR-200-E-16:** A small (approximately 50 gal.) overground transfer line leak near the north side of tank C-105. This UPR was not included in the risk analysis because its limited volume was significantly smaller than that in three other UPRs that were included.

- **UPR-200-E-27:** An airborne release. This UPR was not included in the risk analysis because it was an airborne release that did not result in significant soil contamination.

- **UPR-200-E-68:** An airborne release. This UPR was not included in the risk analysis because it was an airborne release that did not result in significant soil contamination.

- **UPR-200-E-72:** This is a solid waste burial consisting of miscellaneous trash and debris. It is located outside of WMA C.

- **UPR-200-E-91:** A contaminated soil area which has been remediated.

- **UPR-200-E-99:** An airborne release. This UPR was not included in the risk analysis because it was an airborne release that did not result in significant soil contamination.

- **UPR-200-E-100:** An airborne release. This UPR was not included in the risk analysis because it was an airborne release that did not result in significant soil contamination.

- **UPR-200-E-107:** A small (4 to 5 gal.) amount was sprayed on the ground from erroneous operation of an air valve; this UPR is believed to be near tank C-110. This UPR was not included in the risk analysis because its limited volume was significantly smaller than that in three other UPRs that were included.

- **UPR-200-E-118:** An airborne release from tank C-107. This UPR was not included in the risk analysis because it was an airborne release that did not result in significant soil contamination.

- **UPR-200-E-136:** A reported 24,000-gal. leak from tank C-101. (The same UPR also includes a reported 400-gal. leak from tank C-203). This UPR was not included in the risk analysis because this reported leak has not been verified through either geophysical logging or sampling in the vadose zone and/or groundwater. See footnote 4 to Table 5 of RPP-13774 Addendum C1 for a more detailed explanation. (Also see Section 2.4.1.)

Although the peak from past tank leaks was projected to arrive ahead of the peak from unplanned pipeline releases by approximately 26 years, the contributions from these sources were summed and reported as a single peak arriving in the year 2117. Groundwater concentrations were calculated as cumulative fenceline average concentrations over the entire downgradient length of the WMA C fenceline. The peak groundwater concentrations from past leaks were projected to overlap in time and be additive with the peak groundwater concentrations from retrieval leaks but were not projected to be additive with the peaks from residual waste. The peak from retrieval leaks was projected to arrive in 2082 compared with 2092 for the past tank leak. This

occurred because the retrieval leak volume used in the RPP-13774 analysis was 8,000 gal. whereas the past leak (tank C-105) volume assumed for risk assessment purposes was 1,000 gal. An 8,000-gal. volume has a greater driving force and lower tendency to spread laterally in the vadose zone than a 1,000-gal. volume.

Transport of existing vadose zone contamination was simulated in the RPP-13774 analysis based on water flow from natural recharge only (i.e., surface infiltration of meteoric water). The effect on existing contamination of artificial recharge, such as a retrieval leak or water line leak, was not evaluated. Should the fluid released in a retrieval leak intercept an existing vadose zone plume, there is a potential for the contamination to be flushed more quickly to the water table. The effect of the flushing on peak groundwater concentration and arrival time would depend on a number of factors, including initial plume depth and the rate, volume, and location of the retrieval leak. There is no potential for a retrieval leak to affect the movement of contamination from the three unplanned pipeline releases included in the WMA C risk assessment (UPR-200-E-81, UPR-200-E-82, UPR-200-E-86). These releases all occurred along the southwest boundary of WMA C, well away from the nearest tank row. There is a potential for a retrieval leak to affect the movement of the existing vadose zone contamination in the vicinity of tank C-105. If this were to occur, the WMA C past leak impacts could differ from the projected impacts shown in Table 7-6, which were calculated assuming meteoric infiltration.

Table 7-6. Peak Impacts at the Waste Management Area C Fenceline from Past Leaks.

Contaminant	Time of Peak (Yr AD) [a]	Incremental Lifetime Cancer Risk [b]		Hazard Quotients and Index [c]		Groundwater Concentration [d]	Drinking Water Standard (MCL)
		Industrial	Residential	Industrial	Residential		
Technetium-99	2117	6.9E-06	1.7E-04	NA	NA	497 pCi/L	900 pCi/L
Hexavalent chromium	2117	1.1E-07	2.4E-07	1.7E-02	9.7E-02	0.004 mg/L	0.1 mg/L [e]
Nitrite	2117	NA	NA	1.4E-02	9.1E-02	0.14 mg/L	3.3 mg/L [f]
Total radiological	2117	8.1E-06	1.8E-04	NA	NA	NA	NA
Total nonradiological	2117	1.1E-07	2.4E-07	3.3E-02	2.0E-01	NA	NA

EPA = U.S. Environmental Protection Agency.
MCL = maximum contaminant level.
NA = not applicable.

[a] Source: RPP-13774, Addendum C1, Tables 33 and 34.
[b] Source: RPP-13774, Addendum C1, Table 33.
[c] Source: RPP-13774, Addendum C1, Table 34.
[d] Source: RPP-13774, Addendum C1, Table 38.
[e] The MCL for chromium is from 40 CFR 141.62(b) and is for total chromium.
[f] Concentration for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

Seven C farm tanks (C-101, C-110, C-111, and the four C-200-series tanks) are currently classified as assumed leakers in HNF-EP-0182 (see Figure 4-1). However, the past leak source term modeled in the RPP-13774 risk assessment included only leaks and discharges that have been verified either through geophysical logging or sampling in the vadose zone and/or groundwater.

Spectral gamma logging data reported in RPP-14430 shows little evidence of vadose zone contamination consistent with a tank leak in the vicinity of the tanks classified as leakers in HNF-EP-0182. Although no leaks have been reported from tank C-105, there is contamination reported in the vadose zone from routine geophysical monitoring between this tank and tank C-104. The measured vadose zone contamination in the vicinity of tank C-105 was therefore included in the RPP-13774 risk assessment, along with the measured vadose zone contamination associated with three verified leaks from ancillary equipment associated with WMA C. Additional information on WMA C vadose zone contamination can be found in RPP-14430; RPP-15317; GJPO-HAN-18; and GJO-98-39-TARA GJO-HAN-18, *Vadose Zone Characterization Project at the Hanford Tank Farms, Addendum to the C Tank Farm Report.* Additional perspective on the integrity of tanks in WMA C can be found in RPP-10435.

7.2 INTRUDER RISK

Inadvertent waste site intrusion risk is an assessment of the health impacts from unknowingly intruding into a waste site at some point in the future following closure. Intruder impact estimates are included in this work plan to provide perspective on potential post-closure risks associated with closing tanks C-101, C-105, C-110, and C-111 assuming waste is retrieved to the HFFACO interim retrieval goal of 360 ft^3 of residual waste and the residuals are closed in place (Ecology et al. 1989).

Inadvertent intruder impacts were analyzed using the same methodology used to analyze WMA C intruder impacts in DOE/ORP-2003-11, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington*. That report used exposure scenarios defined in HNF-SD-WM-TI-707 and was based on intruder analyses presented in earlier Hanford Site performance assessments (WHC-EP-0645, *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds*; WHC-EP-0875, *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Burial Grounds*; DOE/RL-97-69, *Hanford Immobilized Low-Activity Tank Waste Performance Assessment*; DOE/ORP-2000-24, *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version*).

7.2.1 Intruder Scenarios and Performance Objectives

The DOE/ORP-2003-11 analysis included several inadvertent intrusion scenarios, all of which assumed that no institutional memory of the closed facility remains following closure. The credible post-closure intrusion scenarios identified were:

- An intruder who inadvertently drills into the closed site and brings some of the waste to the surface, receiving an acute dose (driller scenario).
- A post-drilling resident who lives where waste has been exhumed and scattered over the surface, receiving a chronic dose (post-intrusion residential scenarios). Three such residential scenarios were included:
  - Suburban resident with a garden
  - Rural farmer with a dairy cow
  - Commercial farmer.

Detailed descriptions of the scenarios are presented in DOE/ORP-2003-11 and HNF-SD-WM-TI-707. A basement scenario, in which exposure occurs during excavation for a basement or building foundation, was not considered credible in DOE/ORP-2003-11 and was not analyzed. This was because the top of the waste is 35 ft or more below the surface and neither basements for home residences nor foundations for commercial structures are likely to extend this far below the surface.

The performance objective identified in DOE/ORP-2003-11 for the driller scenario was 500 mrem effective dose equivalent (EDE) for a one-time exposure. The performance objective for the post-intrusion residential scenarios was 100 mrem/yr EDE for a continuous exposure. Doses were calculated at 100-year intervals over the period from 0 to 1,000 years after closure. The time of compliance (or soonest time when the intrusion was assumed to occur) for the DOE/ORP-2003-11 analysis was 500 years after closure was assumed to occur in the year 2050.

7.2.2 Methodology

The main elements of the intruder calculation method used for this analysis can be summarized as follows:

- Use a time of compliance of 500 years after closure (consistent with DOE/ORP-2003-11)
- Use radiological dose as the health impact metric
- Calculate acute dose using the driller scenario
- Calculate chronic dose using the suburban resident with a garden and rural farmer with a dairy cow scenarios
- Assume the borehole diameter is 6.5 in. for well driller and suburban resident with a garden and 10.5 in. for rural farmer with a dairy cow
- Assume the tanks each contain a volume of 360 ft^3 of residual waste at closure

- Assume the residual tank waste is embedded in a grout matrix that renders a fraction of the exhumed waste unavailable for inhalation and ingestion
- Assume intrusion occurs before contaminants have migrated from the closed facility in any significant quantity.

The commercial farmer scenario was disregarded for this analysis. The commercial farmer was identified in the DOE/ORP-2003-11 analysis as the most likely exposure scenario given the present day land use in the Hanford environs; however, the DOE/ORP-2003-11 analysis used the rural farmer with a dairy cow for purposes of assessing compliance with performance objectives. The rural farmer with a dairy cow was more conservative than the commercial farmer but less conservative than the suburban resident with a garden. The DOE/ORP-2003-11 analysis considered a rural farmer with a dairy cow a more appropriate scenario for assessing performance than a suburban resident with a vegetable garden. The DOE/ORP-2003-11 analysis results indicated the commercial farmer dose would be a factor of 50 below that of the rural farmer with a dairy cow. Both the suburban resident with a garden scenario and the rural farmer with a dairy cow scenario are evaluated in this tank waste retrieval work plan.

Sections 7.2.2.1 and 7.2.2.2 discuss the calculation methodology for the two primary components of the intruder calculation, inventory, and dose. Tank-specific results for tanks C-101, C-105, C-110, and C-111 are provided in Appendices A through D, respectively. Calculation detail is provided in RPP-22521.

7.2.2.1. Inventory. The starting inventories for the intruder calculation were the estimated radionuclide inventories remaining in the tanks following retrieval to the HFFACO interim retrieval goal of 360 ft^3 (2,700 gal.) of residual waste. These inventories were taken from RPP-15317 and are based on the selective phase removal inventory estimation method. Inventories for all 46 radionuclides reported in the BBI are provided in RPP-15317 and were used in the calculation. Tank-specific residual waste starting inventories are given in the appendices.

Exhumed inventories were calculated by assuming the waste in the borehole has the same contaminant concentrations as the tank residuals, and that the height of the waste in the borehole is the same as the height of the waste in the tank residuals. Using these assumptions, the undecayed exhumed inventories for each radionuclide were estimated by multiplying the tank residual inventory by the square of the ratio of the borehole radius to the tank radius. The mathematical basis for this is shown in Equations 7-2 through 7-5.

$$I_{EX} / V_{EX} = I_T / V_T \tag{7-2}$$

$$I_{EX} / (\pi r^2 h) = I_T / (\pi R^2 h) \tag{7-3}$$

$$I_{EX} = I_T (\pi r^2 h) / (\pi R^2 h) \tag{7-4}$$

$$I_{EX} = I_T (r / R)^2 \tag{7-5}$$

Where:

I_{EX} = exhumed inventory (undecayed) (Ci)
I_T = tank residual inventory (Ci)
V_{EX} = exhumed volume (m^3)
V_T = tank residual volume (m^3)
r = borehole radius (m)
R = tank radius (m)
h = waste height (m).

To account for radiological decay, the exhumed inventory was multiplied by a radiological decay factor, as shown in Equation 7-6.

$$I_{EX}(t) = I_{EX}\,\mathrm{Exp}(-\lambda t) \tag{7-6}$$

Where:

$I_{EX}(t)$ = exhumed inventory decayed as a function of time (Ci)

I_{EX} = exhumed inventory (undecayed) (Ci)

Exp = exponential function (natural logarithm base (e) raised to some power)

λ = radioactive decay constant, per year, calculated as ln(2)=0.6931 divided by the radionuclide half life in years

t = elapsed time since closure in years.

7.2.2.2. Dose. For each intruder scenario considered, the dose contribution from each radionuclide was calculated by multiplying the exhumed inventory (decayed) by a unit dose factor. The total dose for each scenario was then calculated as the sum of the dose contributions from all radionuclides included in the starting inventory. Unit dose factors for each radionuclide under each intruder scenario were taken from HNF-SD-WM-TI-707. Unit dose factors for the subset of radionuclides that drive intruder doses are shown in Table 7-7. Complete intruder scenario descriptions and unit dose factor calculations are provided in HNF-SD-WM-TI-707.

Table 7-7. Unit Dose Factors for Inadvertent Intruder Scenarios. [a]

Radionuclide	Driller (mrem per Ci/kg) [b]	Suburban Resident with a Garden (mrem/yr per Ci exhumed) [b]	Rural Farmer with a Dairy Cow (mrem/yr per Ci exhumed) [b]
Strontium-90+D	8.12E+04	3.59E+03	9.73E+01
Technetium-99	5.66E+02	5.06E+02	2.54E+00
Tin-126+D	3.09E+07	9.66E+03	3.86E+02
Cesium-137+D	8.78E+06	3.13E+03	1.25E+02
Plutonium-239	3.86E+05	7.02E+02	1.21E+01
Plutonium-240+D	3.86E+05	7.02E+02	1.21E+01
Americium-241	5.83E+05	7.60E+02	1.41E+01

+D = includes short-lived radioactive progeny in secular equilibrium with parent nuclide.

[a] Source: Tables 7, 8, and 10 of HNF-SD-WM-TI-707, 2004, *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment*, Rev. 4, CH2M HILL Hanford Group, Inc., Richland, Washington.

[b] Values shown are total dose (sum of internal and external dose) after reducing internal dose by 90% to account for the waste form.

The total dose factors (sum of internal and external doses) given in HNF-SD-WM-TI-707 for the driller scenario assume 100% of the exhumed waste is available for inhalation and ingestion. The residual waste grout matrix is assumed to prevent a fraction of the exhumed inventory from being inhaled or ingested. Internal dose factors used in this calculation were therefore reduced by 90% (multiplied by 0.1) to account for the grouted waste form, as recommended in HNF-SD-WM-TI-707.

The driller scenario unit dose factors are given in terms of the dose per unit contaminant concentration in the drill cuttings (mrem per Ci/kg) (Table 7-7). The radiation dose to this individual is the dose (EDE) from acute exposure over a 40-hour drilling operation. The driller dose factors were multiplied by the average radionuclide concentration in the drill cuttings (Ci/kg) to obtain the dose. The average radionuclide concentrations in the drill cuttings were calculated by dividing the exhumed inventories (decayed) by the mass exhumed. The mass exhumed was calculated using Equation 7-7.

$$M_{EX} = \pi r^2 h \rho \qquad (7\text{-}7)$$

Where:

M_{EX} = exhumed mass (kg)
r = borehole radius (m)
h = borehole height (depth to water table) (m)
ρ = average density of well cuttings (kg/m^3).

As for the driller scenario, the total dose factors (sum of internal and external doses) given in HNF-SD-WM-TI-707 for the two post-intruder resident scenarios (suburban resident with a

garden and rural farmer with a dairy cow) were adjusted downward to account for a grout matrix by applying a waste form factor of 0.1 to the internal dose factors.

The post-intruder resident scenario unit dose factors are given in terms of the dose received during the first year per curie exhumed (mrem/yr per Ci) (Table 7-7). The radiation dose to this individual is the 50-year committed effective dose equivalent from the first year of exposure. The post-intruder dose factors were multiplied by the curies exhumed (decayed) to obtain the dose.

The post-intruder dose factors consider the decrease in soil concentration during the year due to radioactive decay and leaching from irrigation (HNF-SD-WM-TI-707). Irrigation is assumed to occur only during the first half of the year. External exposure, soil ingestion, and soil inhalation occur only during the irrigation period, with none during the second half of the year. Vegetables, fruit, and grain in the suburban resident with a garden scenario and animal fodder (hay and grain) in the rural farmer with a dairy cow scenario are assumed to be harvested throughout the irrigation season. To represent this, harvest is assumed to occur midway through the irrigation season (at 0.25 year). Plant concentrations are proportional to soil concentrations at this time.

7.2.3 Intruder Analysis Results

Tank-specific intruder impacts generated using the methodology described above are provided in Appendices A through D for tanks C-101, C-105, C-110, and C-111, respectively.
Each appendix provides total dose values for the driller, suburban resident with a garden, and rural farmer with a dairy cow intrusion scenarios, along with the radionuclide-specific dose contributions from the radionuclides that dominate the total dose.

8.0 LESSONS LEARNED

A comprehensive lessons-learned effort was completed to meet the requirements of RPP-10901, *S-102 Initial Waste Retrieval Functions and Requirements*. RPP-10901 summarizes lessons learned from the Hanford Site, DOE, and general industries applicable to waste retrieval from underground storage tanks. Additionally, lessons learned from RPP-18629, *Performance Evaluation for C-106, S-102/112 and C-200 Series Tank Retrieval Activities* were reviewed. The lessons learned identified in RPP-10901 and RPP-18629 were reviewed and the following have been incorporated into the tanks C-101, C-105, C-110, and C-111 system design:

- Select equipment materials compatible with the environmental conditions of their intended application to minimize failures resulting from corrosion, stress, and exposure to radiation. Provide adequate temperature controls (e.g., heat tracing, air conditioning) to ensure equipment performs as designed. Select radiation resistant sealants and gaskets.
- Cold test all fluid connections and components before deployment to ensure leak tightness.
- Incorporate features to flush components that transport slurries to prevent/correct blockages. Design the features to operate with minimal changes to the system and operator intervention.
- Design systems to facilitate maintenance and support functions while incorporating safety and ALARA features.
- Provide access to instrumentation and other components requiring servicing and maintenance that does not require breaching the confinement system.
- Simplify system control screens to maximize operator efficiency and recognition of key operational parameters/data.
- Incorporate features to unplug piping systems in the event of a line blockage.
- Conduct comprehensive field walkdowns before system design to validate design assumptions and document as-found field conditions.
- Identify and specify equipment shipping, handling, and lifting requirements to facilitate safe and efficient handling and deployment of equipment.
- Conduct comprehensive post-shipping inspections to identify equipment damage and defects.
- Minimize the use of threaded joints in equipment design.
- Identify and obtain all spare parts required for system maintenance, and for equipment repairs for anticipated failures.

Additionally, during deployment of the vacuum system at the C farm 200-series tanks it was discovered that the efficiency of the waste retrieval system is reduced when the vacuum line length exceeds approximately 90 ft.

9.0 REFERENCES

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29 CFR 1926, "Safety and Health Regulations for Construction," *Code of Federal Regulations*, as amended.

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

40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Storage, Treatment, and Disposal Facilities," *Code of Federal Regulations*, as amended.

40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*, as amended.

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APPENDIX A

TANK C-101 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

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LIST OF TERMS

Terms

None required; terms are defined within the document text.

Abbreviations, Acronyms, and Initialisms

DST	double-shell tank
HQ	hazard quotient
ILCR	incremental lifetime cancer risk
WMA	waste management area

Units

Ci	curie
ft3	cubic feet
gal.	gallon
kg	kilogram
mg/L	milligrams per liter
mrem/yr	millirem per year
pCi/L	picocuries per liter

A1.0 TANK C-101 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

This appendix provides tank-specific pre-retrieval risk assessment results for 241-C-101 (tank C-101). The information presented was developed using the methodology described in Section 7.0. Groundwater pathway impacts are presented in Section A2.0. Inadvertent intruder impacts are presented in Section A3.0.

A2.0 GROUNDWATER PATHWAY IMPACTS

The groundwater pathway evaluation involved the development of a set of graphical tools to provide a basis for making informed decisions in the event a leak is detected or unexpected retrieval conditions arise during waste retrieval operations. This section provides and discusses the retrieval leak impact graphs generated for tank C-101. The methodology used to generate the graphs is described in Section 7.1.1. Calculation detail for the graphs is provided in RPP-22521, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan.*

A2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures A-1 through A-3 provide the tank C-101 waste retrieval leak impact graphs for the three indicator contaminants (technetium-99, hexavalent chromium, and nitrite) identified in Section 7.1.1.1.

Figure A-1. Tank C-101 Technetium-99 Risk Plot.

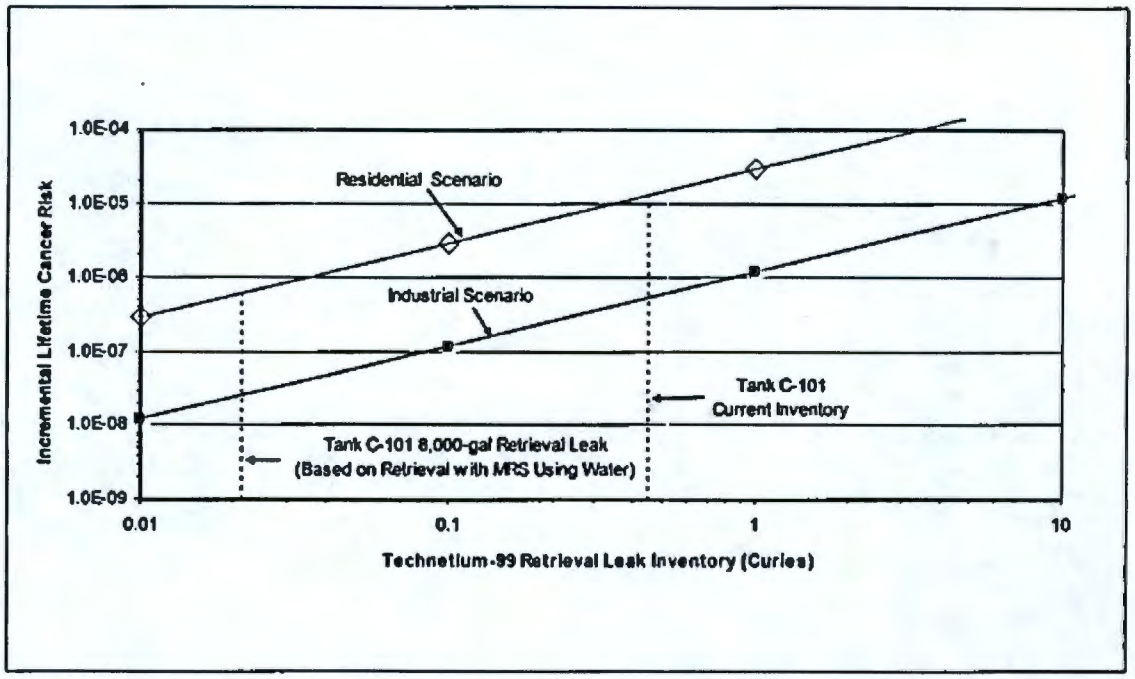

Figure A-2. Tank C-101 Hexavalent Chromium Hazard Quotient Plot.

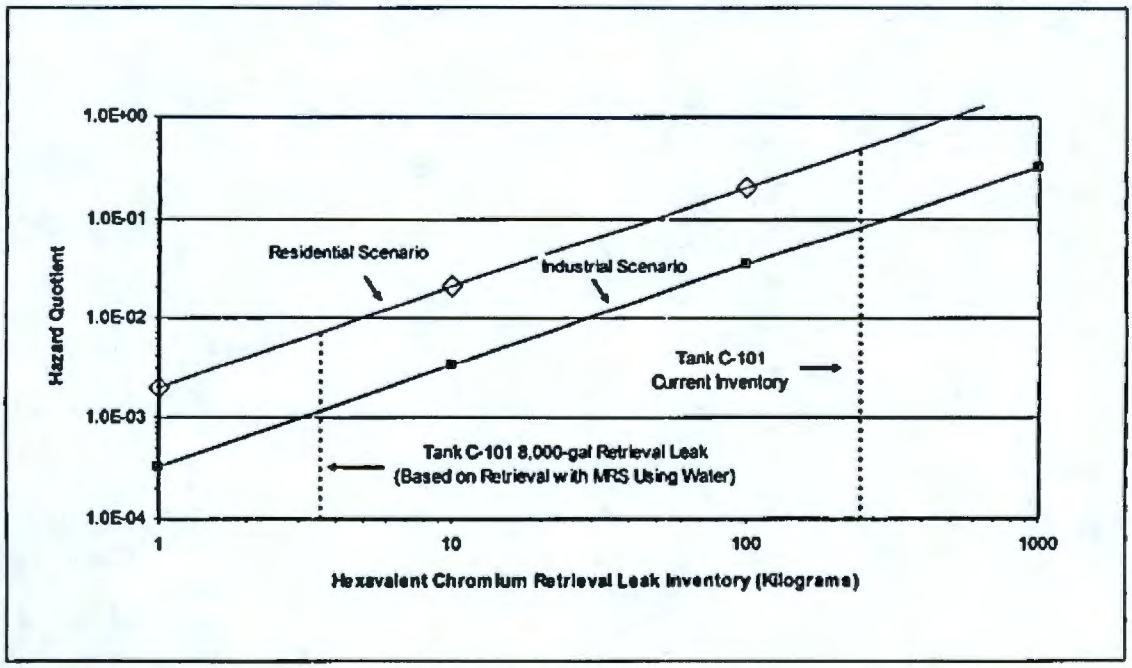

Figure A-3. Tank C-101 Nitrite Hazard Quotient Plot.

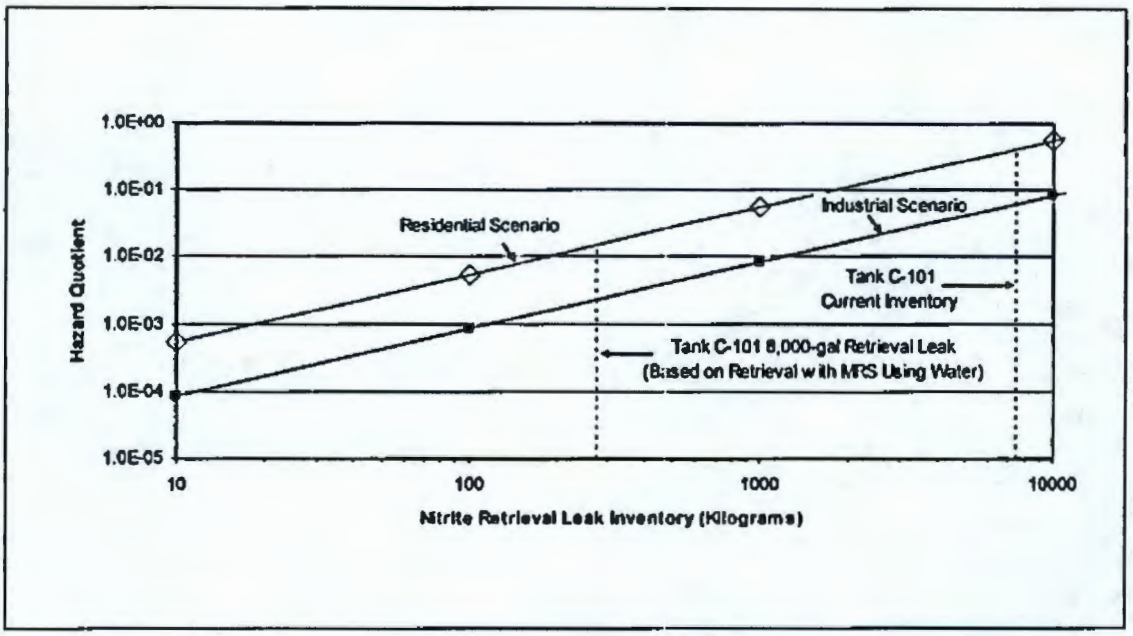

Figure A-1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-101 during waste retrieval. Figures A-2 and A-3 show the peak groundwater pathway hazard quotient (HQ) from hexavalent chromium and nitrite, respectively, as a function of the amount of hexavalent chromium and nitrite leaked from tank C-101 during waste retrieval.

The ILCR and HQ values shown on the graphs were based on the predicted peak groundwater concentrations at the waste management area (WMA) C downgradient fenceline. As discussed in Section 7.1.1.3, the projected arrival time of the peaks is approximately the year 2082 based on the supporting contaminant transport analysis in RPP-13774, *Single-Shell Tank System Closure Plan*. The graphs provide a retrieval leak risk picture for tank C-101 but do not include contributions from other WMA C sources. Projected impacts from other WMA C sources are discussed in Section 7.1.3.

Two sloped lines representing the industrial and residential scenarios were plotted on each graph. The datapoints for these lines were calculated as described in Section 7.1.1 over a range of technetium-99, hexavalent chromium, and nitrite values. Because potential retrieval leak volumes are uncertain, the inventory range was selected to encompass a small leak on the low end and a large leak on the high end.

Vertical dashed lines were added to each graph as points of reference to show the estimated current tank C-101 inventory and the inventory associated with a potential 8,000 gal. retrieval leak. The 8,000-gal. volume was a hypothetical volume used only as a point of reference and for consistency with previous analyses. It was not intended to represent anticipated retrieval leak volumes or leak detection limits for tank C-101.

In the event a leak is detected during waste retrieval, the leak monitoring system would be used to estimate the leak volume. The potential human health impacts from the leak could then be evaluated from the leak volume and estimated contaminant concentrations in the leak along with the graphs shown in Figures A-1 through A-3. Using the graphs, the impacts from leak inventories greater or lesser than those shown for the 8,000-gal. reference volume can be estimated rapidly by extrapolating from the impacts shown for the reference volume.

A2.2 INVENTORY

The reference lines shown in Figures A-1 through A-3 to indicate current inventory and retrieval leak inventory were developed from the best available data and information. Current inventories were taken from the best-basis inventory (BBI) by downloading from the Tank Waste Information Network System (TWINS) database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gal.) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-101 with the mobile retrieval system (MRS) using water. The retrieval leak fluid concentrations for this retrieval scenario were developed using data from RPP-21753, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*. The RPP-21753 flowsheet description provides representative contaminant concentrations for the fluids inside the SST, the MRS batch vessel, and the receiver double-shell tank (DST) during retrieval with the MRS. Retrieval leak inventories were developed from the representative SST fluid concentrations from RPP-21753 (Table A-1).

Table A-1. Tank C-101 Retrieval Leak Inventory Estimate.

Contaminant	Leak Fluid Concentration *	Inventory in 8,000-gal. Retrieval Leak
Technetium-99	7.07E-07 Ci/L	2.14E-02 Ci
Hexavalent Chromium	1.18E-04 kg/L	3.57E+00 kg
Nitrite	9.08E-03 kg/L	2.75E+02 kg

* Appendix D, Table D-3 from RPP-21753, 2005, *C Farm 100-Series Tanks, Retrieval Process Flowsheet Description*, CH2M HILL Hanford Group, Inc., Richland, Washington.

A2.3 SUMMARY OF IMPACTS FROM HYPOTHETICAL 8,000-GALLON RETRIEVAL LEAK

The technetium-99 inventory associated with a hypothetical 8,000 gal. retrieval leak from tank C-101 was estimated to be approximately 0.0214 curie (RPP-22521). As shown in Figure A-1, this corresponds to an ILCR of approximately 2.48×10^{-8} for the industrial scenario and 6.05×10^{-7} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 1.80 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000 gal. retrieval leak from tank C-101 was estimated to be approximately 3.57 kg (RPP-22521). As shown in Figure A-2, this corresponds to an HQ of approximately 1.16×10^{-3} for the industrial scenario and 7.02×10^{-3} for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 3.00×10^{-4} mg/L.

The nitrite inventory associated with an 8,000 gal. retrieval leak from tank C-101 was estimated to be approximately 275 kg (RPP-22521). As shown in Figure A-3, this corresponds to an HQ of approximately 2.29×10^{-3} for the industrial scenario and 1.47×10^{-2} for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 2.31×10^{-2} mg/L.

A2.4 EXAMPLE CALCULATION

To illustrate the calculation method used for the retrieval leak impact graphs, the following example is provided. The example uses the industrial scenario ILCR result of 2.48×10^{-8}. Using Equation 7-1 from Section 7.1.1, the industrial scenario ILCR was calculated as the product of the technetium-99 inventory (Table A-1), the technetium-99 retrieval leak unit groundwater concentration factor (Table 7-2), and the technetium-99 industrial scenario unit risk factor (Table 7-3), as follows:

$$\text{ILCR} = (0.0214\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 2.48 \times 10^{-8}$$

Complete calculation details are provided in RPP-22521.

A3.0 INADVERTANT INTRUDER IMPACTS

The starting inventories for the tank C-101 intruder calculation were the estimated radionuclide inventories remaining in the tank following retrieval to the Ecology et al. (1989), *Hanford Federal Facility Agreement and Consent Order* (HFFACO) interim retrieval goal of 360 ft^3 (2,700 gal.) of residual waste. These inventories were taken from RPP-15317, *241-C Waste Management Area Inventory Data Package* and are based on the selective phase removal inventory estimation method. Inventories for all 46 radionuclides reported in the BBI are provided in RPP-15317 and were used in the calculation (RPP-22521). Inventories for the subset of BBI radionuclides that were shown in DOE/ORP-2003-11, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* to dominate intruder doses at 500 years after closure are shown in Table A-2.

Table A-2. Tank C-101 Inventory of Dose-Driving Contaminants in 360 ft^3 of Residual Waste*.

Radionuclide	Units	Tank C-101
Technetium-99	Ci	2.13E-02
Strontium-90	Ci	8.75E+03
Tin-126	Ci	3.97E-04
Cesium-137	Ci	1.11E+03
Plutonium-239	Ci	1.64E+01
Plutonium-240	Ci	2.74E+00
Americium-241	Ci	2.54E-01

* Table 7-1 from RPP-15317, 2003, *241-C-Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table A-3 summarizes the intruder analysis results for tank C-101. These results were generated using the methodology described in Section 7.2. Complete calculation detail is provided in RPP-22521. Contaminant-specific doses are shown for the subset of radionuclides that dominate the total dose. The total dose shown represents the sum of the dose contributions from all radionuclides considered.

The dose values in Table A-3 are for intrusion at 500 years after closure assuming a grout-stabilized residual waste volume of 360ft^3. Table A-3 indicates that tank C-101 would not exceed the performance objectives of 500 mrem effective dose equivalent for acute exposure and 100 mrem/yr effective dose equivalent for chronic exposure at 500 years after closure. The total doses at 500 years after closure would be dominated by plutonium-239 and plutonium-240.

Table A-3. Tank C-101 Intruder Dose.

Radionuclide	Well Driller (mrem EDE)	Suburban Resident with a Garden (mrem/yr EDE)	Rural Farmer with a Dairy Cow (mrem/yr EDE)
Strontium-90	0.000	0.007	0.001
Technetium-99	0.000	0.001	0.000
Tin-126	0.000	0.000	0.000
Cesium-137	0.002	0.002	0.000
Plutonium-239	0.105	0.592	0.027
Plutonium-240	0.017	0.095	0.004
Americium-241	0.001	0.005	0.000
Other Radionuclides	0.001	0.002	0.000
TOTAL	0.126	0.704	0.032

Note: The number of significant digits shown in Table A-3 is not intended to imply a level of accuracy greater than the input values.

EDE = effective dose equivalent.

A4.0 REFERENCES

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APPENDIX B

TANK C-105 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

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Table B-2. Tank C-105 Inventory of Dose-Driving Contaminants in 360 ft^3 of Residual Waste*. 6

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LIST OF TERMS

Terms

None required; terms are defined within the document text.

Abbreviations, Acronyms, and Initialisms

DST	double-shell tank
HQ	hazard quotient
ILCR	incremental lifetime cancer risk
WMA	waste management area

Units

Ci	curie
ft3	cubic feet
gal.	gallon
kg	kilogram
mg/L	milligrams per liter
mrem/yr	millirem per year
pCi/L	picocuries per liter

B1.0 TANK C-105 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

This appendix provides tank-specific pre-retrieval risk assessment results for 241-C-105 (tank C-105). The information presented was developed using the methodology described in Section 7.0. Groundwater pathway impacts are presented in Section B2.0. Inadvertent intruder impacts are presented in Section B3.0.

B2.0 GROUNDWATER PATHWAY IMPACTS

The groundwater pathway evaluation involved the development of a set of graphical tools to provide a basis for making informed decisions in the event a leak is detected or unexpected retrieval conditions arise during waste retrieval operations. This section provides and discusses the retrieval leak impact graphs generated for tank C-105. The methodology used to generate the graphs is described in Section 7.1.1. Calculation detail for the graphs is provided in RPP-22521, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*.

B2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures B-1 through B-3 provide the tank C-105 waste retrieval leak impact graphs for the three indicator contaminants (technetium-99, hexavalent chromium, and nitrite) identified in Section 7.1.1.1.

Figure B-1. Tank C-105 Technetium-99 Risk Plot.

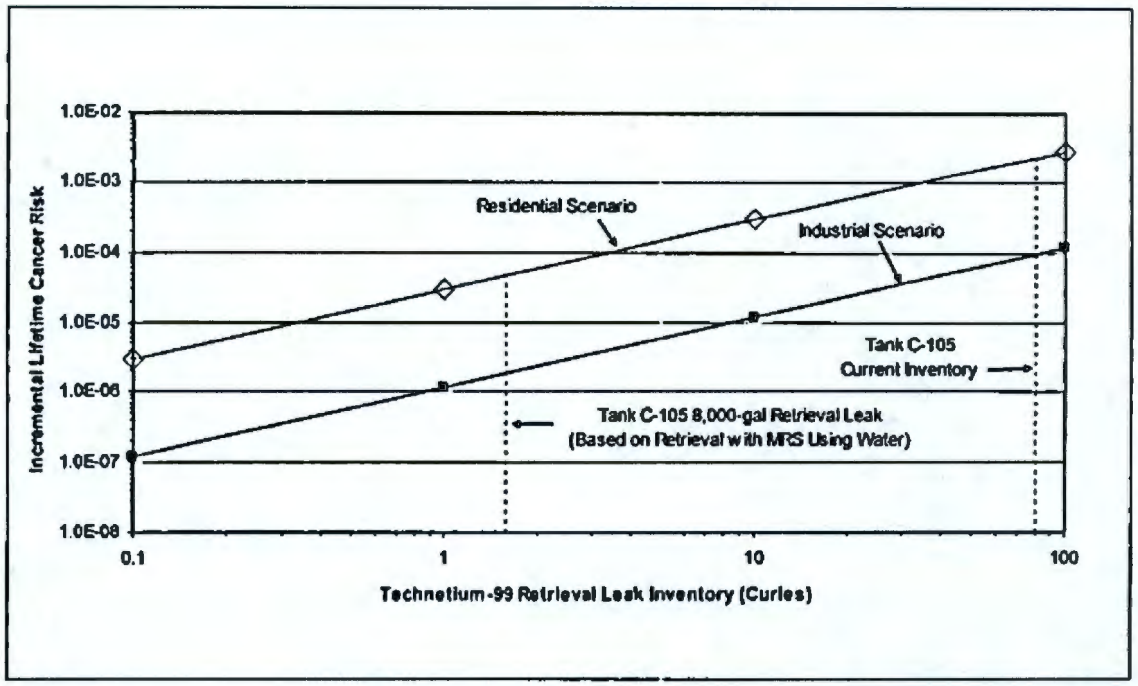

Figure B-2. Tank C-105 Hexavalent Chromium Hazard Quotient Plot.

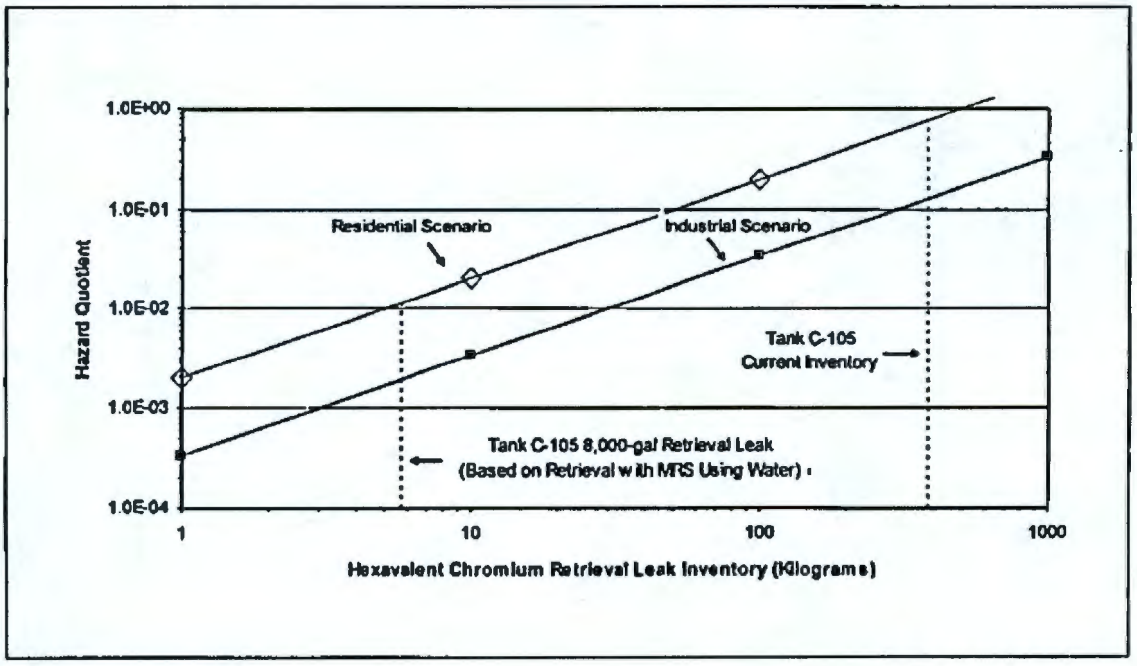

Figure B-3. Tank C-105 Nitrite Hazard Quotient Plot.

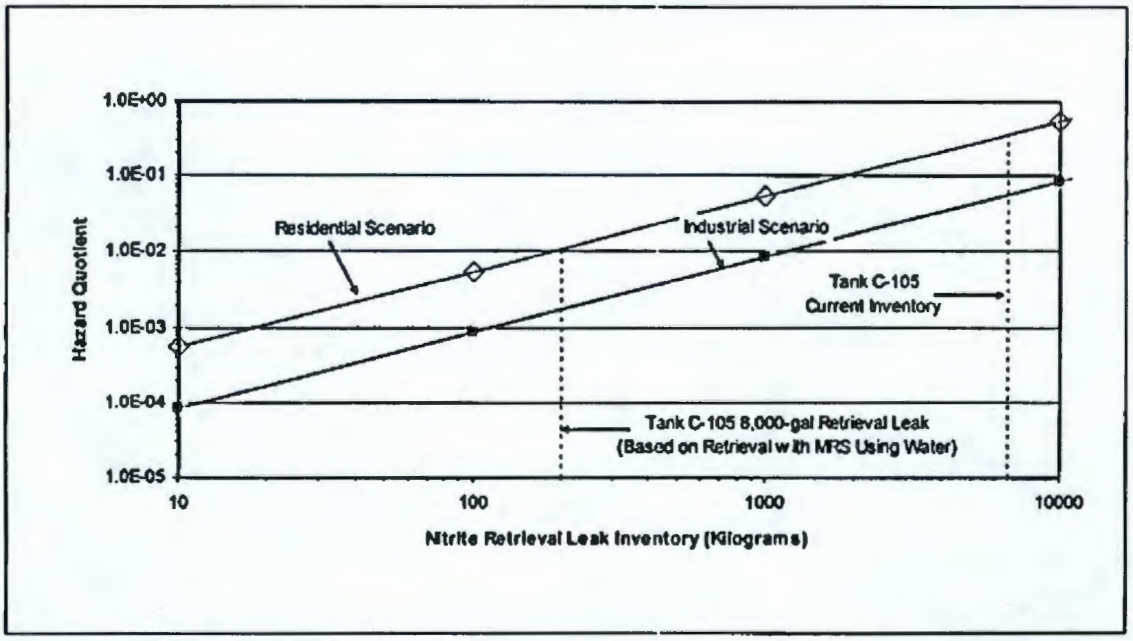

Figure B-1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-105 during waste retrieval. Figures B-2 and B-3 show the peak groundwater pathway hazard quotient (HQ) from hexavalent chromium and nitrite, respectively, as a function of the amount of hexavalent chromium and nitrite leaked from tank C-105 during waste retrieval.

The ILCR and HQ values shown on the graphs were based on the predicted peak groundwater concentrations at the waste management area (WMA) C downgradient fenceline. As discussed in Section 7.1.1.3, the projected arrival time of the peaks is approximately the year 2082 based on the supporting contaminant transport analysis in RPP-13774, *Single-Shell Tank System Closure Plan*. The graphs provide a retrieval leak risk picture for tank C-105 but do not include contributions from other WMA C sources. Projected impacts from other WMA C sources are discussed in Section 7.1.3.

Two sloped lines representing the industrial and residential scenarios were plotted on each graph. The datapoints for these lines were calculated as described in Section 7.1.1 over a range of technetium-99, hexavalent chromium, and nitrite values. Because potential retrieval leak volumes are uncertain, the inventory range was selected to encompass a small leak on the low end and a large leak on the high end.

Vertical dashed lines were added to each graph as points of reference to show the estimated current tank C-105 inventory and the inventory associated with a potential 8,000 gal. retrieval leak. The 8,000-gal. volume was a hypothetical volume used only as a point of reference and for consistency with previous analyses. It was not intended to represent anticipated retrieval leak volumes or leak detection limits for tank C-105.

In the event a leak is detected during waste retrieval, the leak monitoring system would be used to estimate the leak volume. The potential human health impacts from the leak could then be evaluated from the leak volume and estimated contaminant concentrations in the leak along with the graphs shown in Figures B-1 through B-3. Using the graphs, the impacts from leak inventories greater or lesser than those shown for the 8,000-gal. reference volume can be estimated rapidly by extrapolating from the impacts shown for the reference volume.

B2.2 INVENTORY

The reference lines shown in Figures B-1 through B-3 to indicate current inventory and retrieval leak inventory were developed from the best available data and information. Current inventories were taken from the best-basis inventory (BBI) by downloading from the Tank Waste Information Network System (TWINS) database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gal.) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-105 with the mobile retrieval system (MRS) using water. The retrieval leak fluid concentrations for this retrieval scenario were developed using data from RPP-21753, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*. The RPP-21753 flowsheet description provides representative contaminant concentrations for the fluids inside the SST, the MRS batch vessel, and the double-shell tank (DST) receiver tank during retrieval with the MRS. Retrieval leak inventories were developed for the representative SST fluid concentrations for RPP 21753 (Table B-1).

Table B-1. Tank C-105 Retrieval Leak Inventory Estimate.

Contaminant	Leak Fluid Concentration *	Inventory in 8,000-gal. Retrieval Leak
Technetium-99	5.25E-05 Ci/L	1.59E+00 Ci
Hexavalent Chromium	1.90E-04 kg/L	5.76E+00 kg
Nitrite	6.71E-03 kg/L	2.03E+02 kg

* Appendix D, Table D-3 from RPP-21753, 2005, *C Farm 100-Series Tanks, Retrieval Process Flowsheet Description*, CH2M HILL Hanford Group, Inc., Richland, Washington.

B2.3 SUMMARY OF IMPACTS FROM HYPOTHETICAL 8,000-GALLON RETRIEVAL LEAK

The technetium-99 inventory associated with a hypothetical 8,000 gal. retrieval leak from tank C-105 was estimated to be approximately 1.59 curies (RPP-22521). As shown in Figure B-1, this corresponds to an ILCR of approximately 1.84×10^{-6} for the industrial scenario and 4.49×10^{-5} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 134 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000 gal. retrieval leak from tank C-105 was estimated to be approximately 5.76 kg (RPP-22521). As shown in Figure B-2, this corresponds to an HQ of approximately 1.88×10^{-3} for the industrial scenario and 1.13×10^{-2} for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 4.84×10^{-4} mg/L.

The nitrite inventory associated with an 8,000 gal. retrieval leak from tank C-105 was estimated to be approximately 203 kg (RPP-22521). As shown in Figure B-3, this corresponds to an HQ of approximately 1.69×10^{-3} for the industrial scenario and 1.09×10^{-2} for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 1.71×10^{-2} mg/L.

B2.4 EXAMPLE CALCULATION

To illustrate the calculation method used for the retrieval leak impact graphs, the following example is provided. The example uses the industrial scenario ILCR result of 1.84×10^{-6}. Using Equation 7-1 from Section 7.1.1, the industrial scenario ILCR was calculated as the product of the technetium-99 inventory (Table B-1), the technetium-99 retrieval leak unit groundwater concentration factor (Table 7-2), and the technetium-99 industrial scenario unit risk factor (Table 7-3), as follows:

$$\text{ILCR} = (1.59\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 1.84 \times 10^{-6}$$

Complete calculation details are provided in RPP-22521.

B3.0 INADVERTENT INTRUDER IMPACTS

The starting inventories for the tank C-105 intruder calculation were the estimated radionuclide inventories remaining in the tank following retrieval to the Ecology et al. (1989), *Hanford Federal Facility Agreement and Consent Order* (HFFACO) interim retrieval goal of 360 ft^3 (2,700 gal.) of residual waste. These inventories were taken from RPP-15317, *241-C Waste Management Area Inventory Data Package* and are based on the selective phase removal inventory estimation method. Inventories for all 46 radionuclides reported in the BBI are provided in RPP-15317 and were used in the calculation (RPP-22521). Inventories for the subset of BBI radionuclides that were shown in DOE/ORP-2003-11, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* to dominate intruder doses at 500 years after closure are shown in Table B-2.

Table B-2. Tank C-105 Inventory of Dose-Driving Contaminants in 360 ft^3 of Residual Waste*.

Radionuclide	Units	Tank C-105
Strontium-90	Ci	9.70E+03
Technetium-99	Ci	1.66E+00
Tin-126	Ci	3.32E-04
Cesium-137	Ci	1.67E+03
Plutonium-239	Ci	4.19E+01
Plutonium-240	Ci	6.41E+00
Americium-241	Ci	2.42E+01

* Table 7-1 from RPP-15317, 2003, *241-C-Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington..

Table B-3 summarizes the intruder analysis results for tank C-105. These results were generated using the methodology described in Section 7.2. Complete calculation detail is provided in RPP-22521. Contaminant-specific doses are shown for the subset of radionuclides that dominate the total dose. The total dose shown represents the sum of the dose contributions from all radionuclides considered.

The dose values in Table B-3 are for intrusion at 500 years after closure assuming a grout-stabilized residual waste volume of 360 ft^3. Table B-3 indicates that tank C-105 would not exceed the performance objectives of 500 mrem effective dose equivalent for acute exposure and 100 mrem/yr effective dose equivalent for chronic exposure at 500 years after closure. The total doses at 500 years after closure would be dominated by plutonium-239, plutonium-240, and americium-241.

Table B-3. Tank C-105 Intruder Dose

Radionuclide	Well Driller (mrem EDE)	Suburban Resident with a Garden (mrem/yr EDE)	Rural Farmer with a Dairy Cow (mrem/yr EDE)
Strontium-90	0.000	0.008	0.001
Technetium-99	0.000	0.044	0.001
Tin-126	0.000	0.000	0.000
Cesium-137	0.002	0.003	0.000
Plutonium-239	0.268	1.513	0.068
Plutonium-240	0.039	0.223	0.010
Americium-241	0.107	0.431	0.021
Other Radionuclides	0.002	0.001	0.000
TOTAL	0.418	2.223	0.101

Note: The number of significant digits shown in Table B-3 is not intended to imply a level of accuracy greater than the input values.

EDE = effective dose equivalent.

B4.0 REFERENCES

DOE/ORP-2003-11, 2003, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-15317, 2003, *241-C Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-21753, 2005, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-22521, 2005, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX C

TANK C-110 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

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Table C-3. Tank C-110 Intruder Dose. 7

LIST OF TERMS

Terms

None required; terms are defined within the document text.

Abbreviations, Acronyms, and Initialisms

DST	double-shell tank
HQ	hazard quotient
ILCR	incremental lifetime cancer risk
WMA	waste management area

Units

Ci	curie
ft3	cubic feet
gal.	gallon
kg	kilogram
mg/L	milligrams per liter
mrem/yr	millirem per year
pCi/L	picocuries per liter

C1.0 TANK C-110 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

This appendix provides tank-specific pre-retrieval risk assessment results for 241-C-110 (tank C-110). The information presented was developed using the methodology described in Section 7.0. Groundwater pathway impacts are presented in Section C2.0. Inadvertent intruder impacts are presented in Section C3.0.

C2.0 GROUNDWATER PATHWAY IMPACTS

The groundwater pathway evaluation involved the development of a set of graphical tools to provide a basis for making informed decisions in the event a leak is detected or unexpected retrieval conditions arise during waste retrieval operations. This section provides and discusses the retrieval leak impact graphs generated for tank C-110. The methodology used to generate the graphs is described in Section 7.1.1. Calculation detail for the graphs is provided in RPP-22521, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan.*

C2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures C-1 through C-3 provide the tank C-110 waste retrieval leak impact graphs for the three indicator contaminants (technetium-99, hexavalent chromium, and nitrite) identified in Section 7.1.1.1.

Figure C-1. Tank C-110 Technetium-99 Risk Plot.

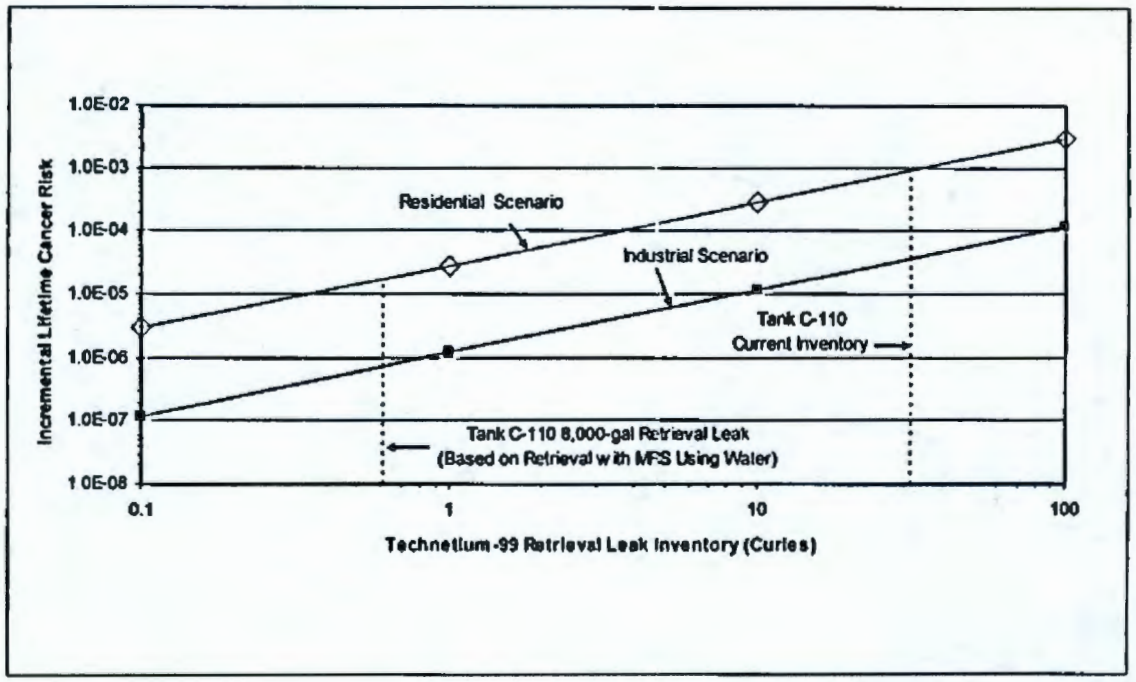

Figure C-2. Tank C-110 Hexavalent Chromium Hazard Quotient Plot.

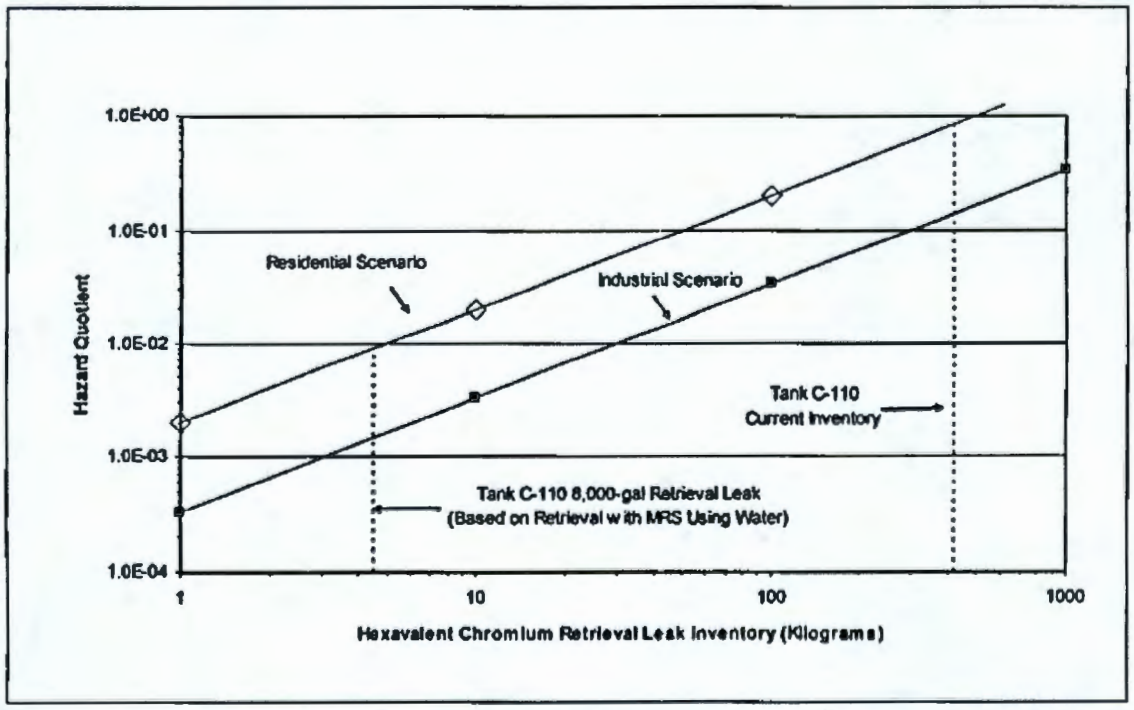

Figure C-3. Tank C-110 Nitrite Hazard Quotient Plot.

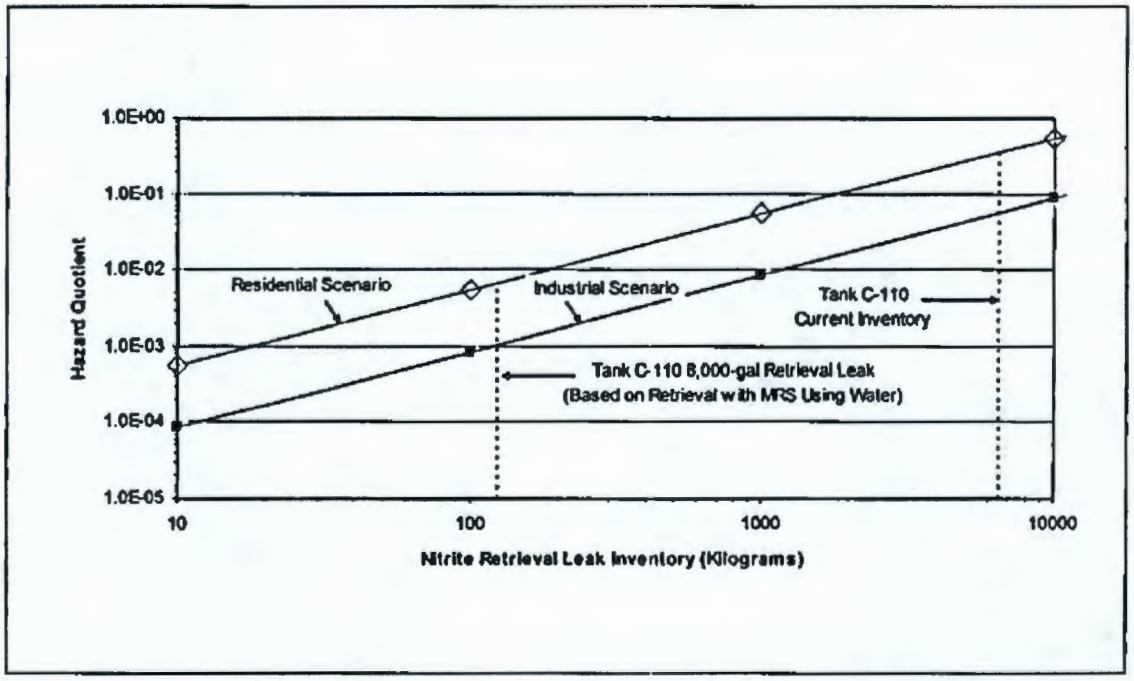

Figure C-1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-110 during waste retrieval. Figures C-2 and C-3 show the peak groundwater pathway hazard quotient (HQ) from hexavalent chromium and nitrite, respectively, as a function of the amount of hexavalent chromium and nitrite leaked from tank C-110 during waste retrieval.

The ILCR and HQ values shown on the graphs were based on the predicted peak groundwater concentrations at the waste management area (WMA) C downgradient fenceline. As discussed in Section 7.1.1.3, the projected arrival time of the peaks is approximately the year 2082 based on the supporting contaminant transport analysis in RPP-13774, *Single-Shell Tank System Closure Plan*. The graphs provide a retrieval leak risk picture for tank C-110 but do not include contributions from other WMA C sources. Projected impacts from other WMA C sources are discussed in Section 7.1.3.

Two sloped lines representing the industrial and residential scenarios were plotted on each graph. The datapoints for these lines were calculated as described in Section 7.1.1 over a range of technetium-99, hexavalent chromium, and nitrite values. Because potential retrieval leak volumes are uncertain, the inventory range was selected to encompass a small leak on the low end and a large leak on the high end.

Vertical dashed lines were added to each graph as points of reference to show the estimated current tank C-110 inventory and the inventory associated with a potential 8,000 gal. retrieval leak. The 8,000-gal. volume was a hypothetical volume used only as a point of reference and for consistency with previous analyses. It was not intended to represent anticipated retrieval leak volumes or leak detection limits for tank C-110.

In the event a leak is detected during waste retrieval, the leak monitoring system would be used to estimate the leak volume. The potential human health impacts from the leak could then be evaluated from the leak volume and estimated contaminant concentrations in the leak along with the graphs shown in Figures C-1 through C-3. Using the graphs, the impacts from leak inventories greater or lesser than those shown for the 8,000-gal. reference volume can be estimated rapidly by extrapolating from the impacts shown for the reference volume.

C2.2 INVENTORY

The reference lines shown in Figures C-1 through C-3 to indicate current inventory and retrieval leak inventory were developed from the best available data and information. Current inventories were taken from the best-basis inventory (BBI) by downloading from the Tank Waste Information Network System (TWINS) database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gal.) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-110 with the mobile retrieval system (MRS) using water. The retrieval leak fluid concentrations for this retrieval scenario were developed using data from *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description* (RPP-21753). The RPP-21753 flowsheet description provides representative contaminant concentrations for the fluids inside the SST, the MRS batch vessel, and the double-shell tank (DST) receiver tank during retrieval with the MRS. Retrieval leak inventories were developed for the representative SST fluid concentrations for RPP 21753 (Table C-1).

Table C-1. Tank C-110 Retrieval Leak Inventory Estimate.

Contaminant	Leak Fluid Concentration *	Inventory in 8,000-gal. Retrieval Leak
Technetium-99	2.01E-05 Ci/L	6.10E-01 Ci
Hexavalent Chromium	1.50E-04 kg/L	4.54E+00 kg
Nitrite	4.14E-03 kg/L	1.25E+02 kg

* Appendix D, Table D-3 from RPP-21753, 2005, *C Farm 100-Series Tanks, Retrieval Process Flowsheet Description*, CH2M HILL Hanford Group, Inc., Richland, Washington.

C2.3 SUMMARY OF IMPACTS FROM HYPOTHETICAL 8,000-GALLON RETRIEVAL LEAK

The technetium-99 inventory associated with a hypothetical 8,000 gal. retrieval leak from tank C-110 was estimated to be approximately 0.610 curie (RPP-22521). As shown in Figure C-1, this corresponds to an ILCR of approximately 7.07×10^{-7} for the industrial scenario and 1.72×10^{-5} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 51.2 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000 gal. retrieval leak from tank C-110 was estimated to be approximately 4.54 kg (RPP-22521). As shown in Figure C-2, this corresponds to an HQ of approximately 1.48×10^{-3} for the industrial scenario and 8.93×10^{-3} for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 3.82×10^{-4} mg/L.

The nitrite inventory associated with an 8,000 gal. retrieval leak from tank C-110 was estimated to be approximately 125 kg (RPP-22521). As shown in Figure C-3, this corresponds to an HQ of approximately 1.04×10^{-3} for the industrial scenario and 6.70×10^{-3} for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 1.05×10^{-2} mg/L.

C2.4 EXAMPLE CALCULATION

To illustrate the calculation method used for the retrieval leak impact graphs, the following example is provided. The example uses the industrial scenario ILCR result of 7.07×10^{-7}. Using Equation 7-1 from Section 7.1.1, the industrial scenario ILCR was calculated as the product of the technetium-99 inventory (Table C-1), the technetium-99 retrieval leak unit groundwater concentration factor (Table 7-2), and the technetium-99 industrial scenario unit risk factor (Table 7-3), as follows:

$$\text{ILCR} = (0.61\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 7.07 \times 10^{-7}$$

Complete calculation details are provided in RPP-22521.

C3.0 INADVERTENT INTRUDER IMPACTS

The starting inventories for the tank C-110 intruder calculation were the estimated radionuclide inventories remaining in the tank following retrieval to the Ecology et al. (1989), *Hanford Federal Facility Agreement and Consent Order* (HFFACO) interim retrieval goal of 360 ft^3 (2700 gal.) of residual waste. These inventories were taken from RPP-15317, *241-C Waste Management Area Inventory Data Package* and are based on the selective phase removal inventory estimation method. Inventories for all 46 radionuclides reported in the BBI are provided in RPP-15317 and were used in the calculation (RPP-22521). Inventories for the subset of BBI radionuclides that were shown in DOE/ORP-2003-11, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* to dominate intruder doses at 500 years after closure are shown in Table C-2.

Table C-2. Tank C-110 Inventory of Dose-Driving Contaminants in 360 ft^3 of Residual Waste*.

Radionuclide	Units	Tank C-110
Strontium-90	Ci	5.66E+01
Technetium-99	Ci	4.84E-01
Tin-126	Ci	1.61E-04
Cesium-137	Ci	2.19E+02
Plutonium-239	Ci	1.03E+00
Plutonium-240	Ci	6.09E-02
Americium-241	Ci	5.96E-01

* Table 7-1 from RPP-15317, 2003, *241-C-Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table C-3 summarizes the intruder analysis results for tank C-110. These results were generated using the methodology described in Section 7.2. Complete calculation detail is provided in RPP-22521. Contaminant-specific doses are shown for the subset of radionuclides that dominate the total dose. The total dose shown represents the sum of the dose contributions from all radionuclides considered.

The dose values in Table C-3 are for intrusion at 500 years after closure assuming a grout-stabilized residual waste volume of 360ft^3. Table C-3 indicates that tank C-110 would not exceed the performance objectives of 500 mrem effective dose equivalent for acute exposure and 100 mrem/yr effective dose equivalent for chronic exposure at 500 years after closure. The total doses at 500 years after closure would be dominated by plutonium-239, plutonium-240, and americium-241.

Table C-3. Tank C-110 Intruder Dose.

Radionuclide	Well Driller (mrem EDE)	Suburban Resident with a Garden (mrem/yr EDE)	Rural Farmer with a Dairy Cow (mrem/yr EDE)
Strontium-90	0.000	0.000	0.000
Technetium-99	0.000	0.013	0.000
Tin-126	0.000	0.000	0.000
Cesium-137	0.000	0.000	0.000
Plutonium-239	0.007	0.037	0.002
Plutonium-240	0.000	0.002	0.000
Americium-241	0.003	0.011	0.001
Other Radionuclides	0.000	0.000	0.000
TOTAL	0.010	0.063	0.003

Note: The number of significant digits shown in Table C-3 is not intended to imply a level of accuracy greater than the input values.
EDE = effective dose equivalent.

C4.0 REFERENCES

DOE/ORP-2003-11, 2003, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-15317, 2003, *241-C Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-21753, 2005, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-22521, 2005, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX D

TANK C-111 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

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Figure D-2. Tank C-111 Hexavalent Chromium Hazard Quotient Plot. 2

Figure D-3. Tank C-111 Nitrite Hazard Quotient Plot. 3

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Table D-1. Tank C-111 Retrieval Leak Inventory Estimate. 4

Table D-2. Tank C-111 Inventory of Dose-Driving Contaminants in 360 ft^3 of Residual Waste*. 6

Table D-3. Tank C-111 Intruder Dose. 7

LIST OF TERMS

Terms

None required; terms are defined within the document text.

Abbreviations, Acronyms, and Initialisms

DST	double-shell tank
HQ	hazard quotient
ILCR	incremental lifetime cancer risk
WMA	waste management area

Units

Ci	curie
ft3	cubic feet
gal.	gallon
kg	kilogram
mg/L	milligrams per liter
mrem/yr	millirem per year
pCi/L	picocuries per liter

D1.0 TANK C-111 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

This appendix provides tank-specific pre-retrieval risk assessment results for 241-C-111 (tank C-111). The information presented was developed using the methodology described in Section 7.0. Groundwater pathway impacts are presented in Section D2.0. Inadvertent intruder impacts are presented in Section D3.0.

D2.0 GROUNDWATER PATHWAY IMPACTS

The groundwater pathway evaluation involved the development of a set of graphical tools to provide a basis for making informed decisions in the event a leak is detected or unexpected retrieval conditions arise during waste retrieval operations. This section provides and discusses the retrieval leak impact graphs generated for tank C-111. The methodology used to generate the graphs is described in Section 7.1.1. Calculation detail for the graphs is provided in RPP-22521, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan.*

D2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures D-1 through D-3 provide the tank C-111 waste retrieval leak impact graphs for the three indicator contaminants (technetium-99, hexavalent chromium, and nitrite) identified in Section 7.1.1.1.

Figure D-1. Tank C-111 Technetium-99 Risk Plot.

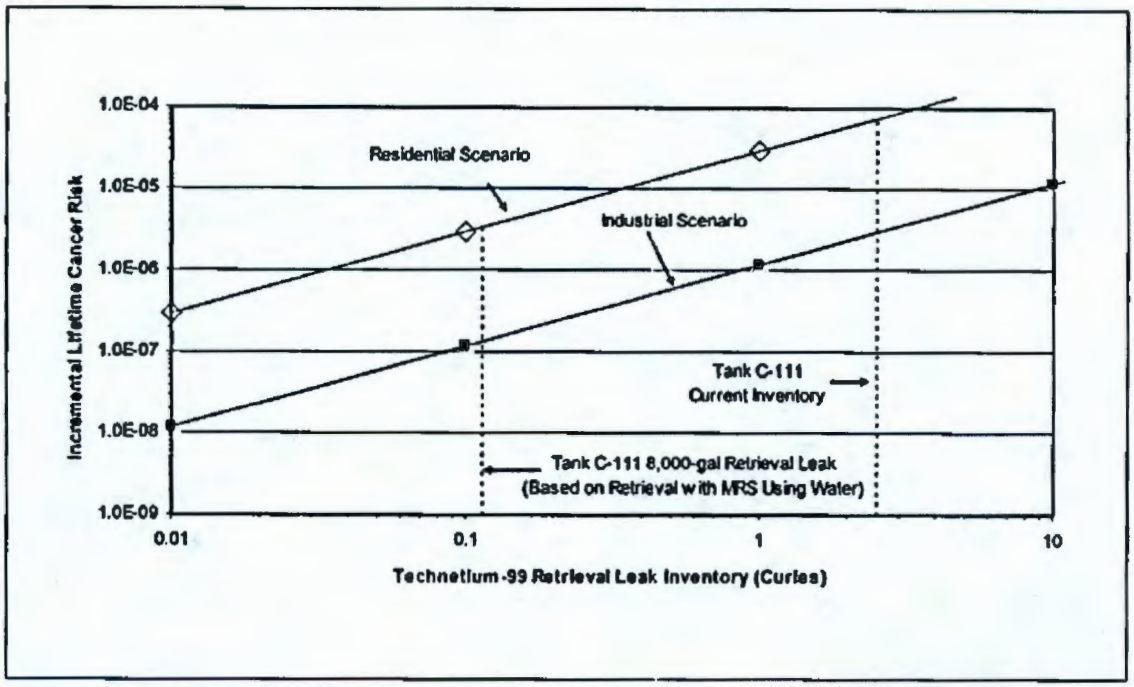

Figure D-2. Tank C-111 Hexavalent Chromium Hazard Quotient Plot.

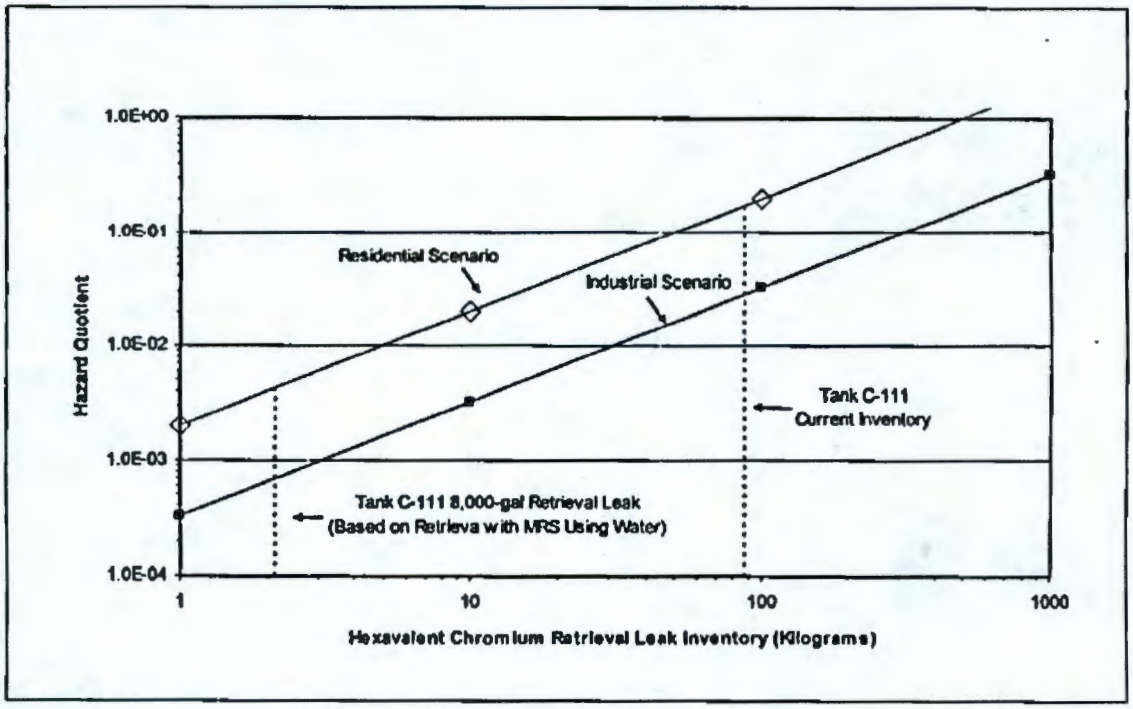

Figure D-3. Tank C-111 Nitrite Hazard Quotient Plot.

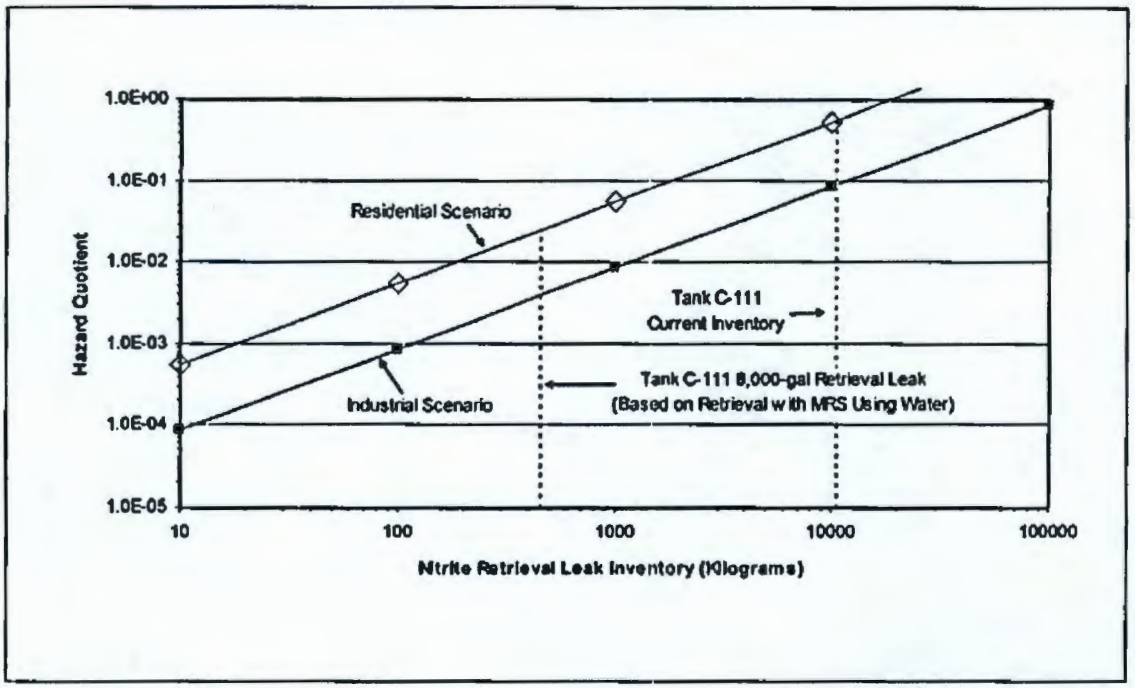

Figure D-1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-111 during waste retrieval. Figures D-2 and D-3 show the peak groundwater pathway hazard quotient (HQ) from hexavalent chromium and nitrite, respectively, as a function of the amount of hexavalent chromium and nitrite leaked from tank C-111 during waste retrieval.

The ILCR and HQ values shown on the graphs were based on the predicted peak groundwater concentrations at the waste management area (WMA) C downgradient fenceline. As discussed in Section 7.1.1.3, the projected arrival time of the peaks is approximately the year 2082 based on the supporting contaminant transport analysis in RPP-13774, *Single-Shell Tank System Closure Plan*. The graphs provide a retrieval leak risk picture for tank C-111 but do not include contributions from other WMA C sources. Projected impacts from other WMA C sources are discussed in Section 7.1.3.

Two sloped lines representing the industrial and residential scenarios were plotted on each graph. The datapoints for these lines were calculated as described in Section 7.1.1 over a range of technetium-99, hexavalent chromium, and nitrite values. Because potential retrieval leak volumes are uncertain, the inventory range was selected to encompass a small leak on the low end and a large leak on the high end.

Vertical dashed lines were added to each graph as points of reference to show the estimated current tank C-111 inventory and the inventory associated with a potential 8,000 gal. retrieval leak. The 8,000-gal. volume was a hypothetical volume used only as a point of reference and for

consistency with previous analyses. It was not intended to represent anticipated retrieval leak volumes or leak detection limits for tank C-111.

In the event a leak is detected during waste retrieval, the leak monitoring system would be used to estimate the leak volume. The potential human health impacts from the leak could then be evaluated from the leak volume and estimated contaminant concentrations in the leak along with the graphs shown in Figures D-1 through D-3. Using the graphs, the impacts from leak inventories greater or lesser than those shown for the 8,000-gal. reference volume can be estimated rapidly by extrapolating from the impacts shown for the reference volume.

D2.2 INVENTORY

The reference lines shown in Figures D-1 through D-3 to indicate current inventory and retrieval leak inventory were developed from the best available data and information. Current inventories were taken from the best-basis inventory (BBI) by downloading from the Tank Waste Information Network System (TWINS) database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gal.) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-111 with the mobile retrieval system (MRS) using water. The retrieval leak fluid concentrations for this retrieval scenario were developed using data from RPP-21753, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*. The RPP-21753 flowsheet description provides representative contaminant concentrations for the fluids inside the SST, the MRS batch vessel, and the double-shell tank (DST) receiver tank during retrieval with the MRS. Retrieval leak inventories were developed for the representative SST fluid concentrations for RPP 21753 (Table D-1).

Table D-1. Tank C-111 Retrieval Leak Inventory Estimate.

Contaminant	Leak Fluid Concentration *	Inventory in 8,000-gal. Retrieval Leak
Technetium-99	3.81E-6 Ci/L	1.15E-01 Ci
Hexavalent Chromium	7.05E-05 kg/L	2.13E+00 kg
Nitrite	1.53E-02 kg/L	4.64E+02 kg

* Appendix D, Table D-3 from RPP-21753, 2005, *C Farm 100-Series Tanks, Retrieval Process Flowsheet Description*, CH2M HILL Hanford Group, Inc., Richland, Washington.

D2.3 SUMMARY OF IMPACTS FROM HYPOTHETICAL 8,000-GALLON RETRIEVAL LEAK

The technetium-99 inventory associated with a hypothetical 8,000 gal. retrieval leak from tank C-111 was estimated to be approximately 0.115 curie (RPP-22521). As shown in Figure D-1, this corresponds to an ILCR of approximately 1.34×10^{-7} for the industrial scenario and 3.26

$\times 10^{-6}$ for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 9.69 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000 gal. retrieval leak from tank C-111 was estimated to be approximately 2.13 kg (RPP-22521). As shown in Figure D-2, this corresponds to an HQ of approximately 6.96×10^{-4} for the industrial scenario and 4.20×10^{-3} for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 1.79×10^{-4} mg/L.

The nitrite inventory associated with an 8,000 gal. retrieval leak from tank C-111 was estimated to be approximately 464 kg (RPP-22521). As shown in Figure D-3, this corresponds to an HQ of approximately 3.85×10^{-3} for the industrial scenario and 2.48×10^{-2} for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 3.89×10^{-2} mg/L.

D2.4 EXAMPLE CALCULATION

To illustrate the calculation method used for the retrieval leak impact graphs, the following example is provided. The example uses the industrial scenario ILCR result of 1.34×10^{-7}. Using Equation 7-1 from Section 7.1.1, the industrial scenario ILCR was calculated as the product of the technetium-99 inventory (Table D-1), the technetium-99 retrieval leak unit groundwater concentration factor (Table 7-2), and the technetium-99 industrial scenario unit risk factor (Table 7-3), as follows:

$$\text{ILCR} = (0.1153\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 1.34 \times 10^{-7}$$

Complete calculation details are provided in RPP-22521.

D3.0 INADVERTENT INTRUDER IMPACTS

The starting inventories for the tank C-111 intruder calculation were the estimated radionuclide inventories remaining in the tank following retrieval to the Ecology et al. (1989), *Hanford Federal Facility Agreement and Consent Order* (HFFACO) interim retrieval goal of 360 ft^3 (2700 gal.) of residual waste. These inventories were taken from RPP-15317, *241-C Waste Management Area Inventory Data Package* and are based on the selective phase removal inventory estimation method. Inventories for all 46 radionuclides reported in the BBI are provided in RPP-15317 and were used in the calculation (RPP-22521). Inventories for the subset of BBI radionuclides that were shown in DOE/ORP-2003-11, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* to dominate intruder doses at 500 years after closure are shown in Table D-2.

Table D-2. Tank C-111 Inventory of Dose-Driving Contaminants in 360 ft^3 of Residual Waste*.

Radionuclide	Units	Tank C-111
Strontium-90	Ci	4.18E+04
Technetium-99	Ci	1.27E-01
Tin-126	Ci	1.78E-03
Cesium-137	Ci	9.20E+02
Plutonium-239	Ci	6.14E+00
Plutonium-240	Ci	6.76E-01
Americium-241	Ci	1.00E+01

* Table 7-1 from RPP-15317, 2003, *241-C-Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table D-3 summarizes the intruder analysis results for tank C-111. These results were generated using the methodology described in Section 7.2. Complete calculation detail is provided in RPP-22521. Contaminant-specific doses are shown for the subset of radionuclides that dominate the total dose. The total dose shown represents the sum of the dose contributions from all radionuclides considered.

The dose values in Table D-3 are for intrusion at 500 years after closure assuming a grout-stabilized residual waste volume of 360ft^3. Table D-3 indicates that tank C-111 would not exceed the performance objectives of 500 mrem effective dose equivalent for acute exposure and 100 mrem/yr effective dose equivalent for chronic exposure at 500 years after closure. The total doses at 500 years after closure would be dominated by plutonium-239 and americium-241.

Table D-3. Tank C-111 Intruder Dose.

Radionuclide	Well Driller (mrem EDE)	Suburban Resident with a Garden (mrem/yr EDE)	Rural Farmer with a Dairy Cow (mrem/yr EDE)
Strontium-90	0.000	0.035	0.002
Technetium-99	0.000	0.003	0.000
Tin-126	0.001	0.001	0.000
Cesium-137	0.001	0.001	0.000
Plutonium-239	0.039	0.222	0.010
Plutonium-240	0.004	0.023	0.001
Americium-241	0.044	0.178	0.009
Other Radionuclides	0.002	0.003	0.001
TOTAL	0.091	0.466	0.023

Note: The number of significant digits shown in Table D-3 is not intended to imply a level of accuracy greater than the input values.
EDE = effective dose equivalent.

D4.0 REFERENCES

DOE/ORP-2003-11, 2003, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-15317, 2003, *241-C Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-21753, 2005, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-22521, 2005, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX E

AVAILABLE INVENTORY AND INVENTORY UNCERTAINTY DATA

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Table E-1. Tank C-101 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{106}Ru	Sludge	CWP1 (Solid)	2.03E-10	not reported	Ci
	Sludge	TBP (Solid)	3.75E-14	not reported	Ci
	Total		2.04E-10	--	Ci
^{113m}Cd	Sludge	CWP1 (Solid)	7.31E-01	not reported	Ci
	Sludge	TBP (Solid)	2.52E-02	not reported	Ci
	Total		7.56E-01	--	Ci
^{125}Sb	Sludge	CWP1 (Solid)	8.70E-04	not reported	Ci
	Sludge	TBP (Solid)	4.08E-04	not reported	Ci
	Total		1.28E-03	--	Ci
^{126}Sn	Sludge	CWP1 (Solid)	1.09E-03	not reported	Ci
	Sludge	TBP (Solid)	3.68E-03	not reported	Ci
	Total		4.77E-03	--	Ci
^{129}I	Sludge	CWP1 (Solid)	1.38E-01	not reported	Ci
	Sludge	TBP (Solid)	4.34E-04	not reported	Ci
	Total		1.39E-01	--	Ci
^{134}Cs	Sludge	CWP1 (Solid)	1.82E-05	not reported	Ci
	Sludge	TBP (Solid)	3.38E-06	not reported	Ci
	Total		2.16E-05	--	Ci
^{137}Cs	Sludge	CWP1 (Solid)	2.59E+04	3.98E+04	Ci
	Sludge	TBP (Solid)	4.08E+03	4.11E+03	Ci
	Total		3.00E+04	--	Ci
^{137m}Ba	Sludge	CWP1 (Solid)	2.45E+04	not reported	Ci
	Sludge	TBP (Solid)	3.85E+03	not reported	Ci
	Total		2.83E+04	--	Ci
^{14}C	Sludge	CWP1 (Solid)	6.39E-01	not reported	Ci
	Sludge	TBP (Solid)	2.16E-02	not reported	Ci
	Total		6.60E-01	--	Ci
^{151}Sm	Sludge	CWP1 (Solid)	1.09E+01	not reported	Ci
	Sludge	TBP (Solid)	3.53E+01	not reported	Ci
	Total		4.62E+01	--	Ci
^{152}Eu	Sludge	CWP1 (Solid)	1.31E-03	not reported	Ci
	Sludge	TBP (Solid)	1.13E-03	not reported	Ci
	Total		2.44E-03	--	Ci
^{154}Eu	Sludge	CWP1 (Solid)	8.69E-02	not reported	Ci
	Sludge	TBP (Solid)	7.87E-02	not reported	Ci
	Total		1.66E-01	--	Ci

Table E-1. Tank C-101 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{155}Eu	Sludge	CWP1 (Solid)	3.11E-02	not reported	Ci
	Sludge	TBP (Solid)	3.78E-02	not reported	Ci
	Total		6.88E-02	--	Ci
^{226}Ra	Sludge	CWP1 (Solid)	3.47E-07	not reported	Ci
	Sludge	TBP (Solid)	4.64E-06	not reported	Ci
	Total		4.99E-06	--	Ci
^{227}Ac	Sludge	CWP1 (Solid)	1.88E-06	not reported	Ci
	Sludge	TBP (Solid)	2.05E-05	not reported	Ci
	Total		2.23E-05	--	Ci
^{228}Ra	Sludge	CWP1 (Solid)	3.98E-12	not reported	Ci
	Sludge	TBP (Solid)	1.78E-11	not reported	Ci
	Total		2.18E-11	--	Ci
^{229}Th	Sludge	CWP1 (Solid)	5.83E-10	not reported	Ci
	Sludge	TBP (Solid)	1.04E-09	not reported	Ci
	Total		1.62E-09	--	Ci
^{231}Pa	Sludge	CWP1 (Solid)	3.72E-06	not reported	Ci
	Sludge	TBP (Solid)	1.94E-07	not reported	Ci
	Total		3.92E-06	--	Ci
^{232}Th	Sludge	CWP1 (Solid)	4.60E-12	not reported	Ci
	Sludge	TBP (Solid)	8.78E-12	not reported	Ci
	Total		1.34E-11	--	Ci
^{232}U	Sludge	CWP1 (Solid)	1.07E-04	not reported	Ci
	Sludge	TBP (Solid)	1.60E-05	not reported	Ci
	Total		1.23E-04	--	Ci
^{233}U	Sludge	CWP1 (Solid)	5.24E-06	not reported	Ci
	Sludge	TBP (Solid)	1.34E-06	not reported	Ci
	Total		6.58E-06	--	Ci
^{234}U	Sludge	CWP1 (Solid)	2.35E+00	not reported	Ci
	Sludge	TBP (Solid)	1.32E+00	not reported	Ci
	Total		3.67E+00	--	Ci
^{235}U	Sludge	CWP1 (Solid)	1.00E-01	not reported	Ci
	Sludge	TBP (Solid)	5.89E-02	not reported	Ci
	Total		1.59E-01	--	Ci
^{236}U	Sludge	CWP1 (Solid)	5.37E-02	not reported	Ci
	Sludge	TBP (Solid)	1.51E-02	not reported	Ci
	Total		6.87E-02	--	Ci

Table E-1. Tank C-101 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{237}Np	Sludge	CWP1 (Solid)	7.71E-04	not reported	Ci
	Sludge	TBP (Solid)	2.69E-03	not reported	Ci
	Total		3.46E-03	--	Ci
^{238}Pu	Sludge	CWP1 (Solid)	5.58E+00	not reported	Ci
	Sludge	TBP (Solid)	9.98E-01	not reported	Ci
	Total		6.57E+00	--	Ci
^{238}U	Sludge	CWP1 (Solid)	2.41E+00	not reported	Ci
	Sludge	TBP (Solid)	1.34E+00	not reported	Ci
	Total		3.76E+00	--	Ci
^{239}Pu	Sludge	CWP1 (Solid)	3.23E+02	not reported	Ci
	Sludge	TBP (Solid)	1.43E+02	not reported	Ci
	Total		4.67E+02	--	Ci
^{240}Pu	Sludge	CWP1 (Solid)	6.73E+01	not reported	Ci
	Sludge	TBP (Solid)	1.54E+01	not reported	Ci
	Total		8.26E+01	--	Ci
^{241}Am	Sludge	CWP1 (Solid)	6.11E+00	not reported	Ci
	Sludge	TBP (Solid)	7.89E+01	not reported	Ci
	Total		8.50E+01	--	Ci
^{241}Pu	Sludge	CWP1 (Solid)	2.52E+02	not reported	Ci
	Sludge	TBP (Solid)	2.60E+01	not reported	Ci
	Total		2.78E+02	--	Ci
^{242}Cm	Sludge	CWP1 (Solid)	8.98E-05	not reported	Ci
	Sludge	TBP (Solid)	1.89E-02	not reported	Ci
	Total		1.90E-02	--	Ci
^{242}Pu	Sludge	CWP1 (Solid)	2.10E-03	not reported	Ci
	Sludge	TBP (Solid)	2.11E-04	not reported	Ci
	Total		2.31E-03	--	Ci
^{243}Am	Sludge	CWP1 (Solid)	5.36E-05	not reported	Ci
	Sludge	TBP (Solid)	1.12E-02	not reported	Ci
	Total		1.12E-02	--	Ci
^{243}Cm	Sludge	CWP1 (Solid)	1.59E-06	not reported	Ci
	Sludge	TBP (Solid)	2.12E-04	not reported	Ci
	Total		2.14E-04	--	Ci
^{244}Cm	Sludge	CWP1 (Solid)	3.97E-05	not reported	Ci
	Sludge	TBP (Solid)	4.78E-03	not reported	Ci
	Total		4.82E-03	--	Ci

Table E-1. Tank C-101 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{3}H	Sludge	CWP1 (Solid)	5.72E+01	not reported	Ci
	Sludge	TBP (Solid)	4.71E-01	not reported	Ci
	Total		5.77E+01	--	Ci
^{59}Ni	Sludge	CWP1 (Solid)	2.51E+00	not reported	Ci
	Sludge	TBP (Solid)	5.65E-03	not reported	Ci
	Total		2.51E+00	--	Ci
^{60}Co	Sludge	CWP1 (Solid)	3.36E+00	not reported	Ci
	Sludge	TBP (Solid)	1.13E-02	not reported	Ci
	Total		3.37E+00	--	Ci
^{63}Ni	Sludge	CWP1 (Solid)	2.30E+02	not reported	Ci
	Sludge	TBP (Solid)	4.82E-01	not reported	Ci
	Total		2.30E+02	--	Ci
^{79}Se	Sludge	CWP1 (Solid)	2.64E-04	not reported	Ci
	Sludge	TBP (Solid)	9.75E-04	not reported	Ci
	Total		1.24E-03	--	Ci
^{90}Sr	Sludge	CWP1 (Solid)	2.40E+02	not reported	Ci
	Sludge	TBP (Solid)	3.78E+04	2.72E+04	Ci
	Total		3.80E+04	--	Ci
^{90}Y	Sludge	CWP1 (Solid)	2.40E+02	not reported	Ci
	Sludge	TBP (Solid)	3.78E+04	not reported	Ci
	Total		3.80E+04	--	Ci
^{93m}Nb	Sludge	CWP1 (Solid)	1.35E-02	not reported	Ci
	Sludge	TBP (Solid)	2.35E-04	not reported	Ci
	Total		1.37E-02	--	Ci
^{93}Zr	Sludge	CWP1 (Solid)	1.58E-02	not reported	Ci
	Sludge	TBP (Solid)	2.62E-04	not reported	Ci
	Total		1.60E-02	--	Ci
^{99}Tc *	Sludge	CWP1 (Solid)	1.15E-01	not reported	Ci
	Sludge	TBP (Solid)	3.39E-01	not reported	Ci
	Total		4.54E-01	--	Ci
Al	Sludge	CWP1 (Solid)	7.88E+04	2.00E+04	kg
	Sludge	TBP (Solid)	6.20E+02	2.30E+02	kg
	Total		7.94E+04	--	kg
Bi	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Sludge	TBP (Solid)	1.74E+02	5.14E+01	kg
	Total		1.74E+02	--	kg

Table E-1. Tank C-101 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
Ca	Sludge	CWP1 (Solid)	1.15E+03	1.16E+03	kg
	Sludge	TBP (Solid)	9.02E+02	3.76E+02	kg
	Total		2.06E+03	--	kg
Cl	Sludge	CWP1 (Solid)	1.11E+02	2.01E+02	kg
	Sludge	TBP (Solid)	4.82E+02	3.19E+02	kg
	Total		5.93E+02	--	kg
CN	not reported				
Cr *	Sludge	CWP1 (Solid)	1.92E+02	5.36E+02	kg
	Sludge	TBP (Solid)	5.65E+01	3.09E+01	kg
	Total		2.49E+02	--	kg
F	Sludge	CWP1 (Solid)	4.18E+02	3.13E+03	kg
	Sludge	TBP (Solid)	2.70E+02	4.39E+02	kg
	Total		6.88E+02	--	kg
Fe	Sludge	CWP1 (Solid)	3.07E+03	3.32E+03	kg
	Sludge	TBP (Solid)	6.85E+03	1.42E+03	kg
	Total		9.92E+03	--	kg
Hg	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Sludge	TBP (Solid)	2.32E+01	not reported	kg
	Total		2.32E+01	--	kg
K	Sludge	CWP1 (Solid)	2.40E+01	not reported	kg
	Sludge	TBP (Solid)	6.78E+01	3.64E+01	kg
	Total		9.18E+01	--	kg
La	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Sludge	TBP (Solid)	1.22E+01	1.23E+01	kg
	Total		1.22E+01	--	kg
Mn	Sludge	CWP1 (Solid)	1.29E+02	1.20E+02	kg
	Sludge	TBP (Solid)	5.58E+01	2.11E+01	kg
	Total		1.85E+02	--	kg
Na	Sludge	CWP1 (Solid)	1.75E+04	1.56E+04	kg
	Sludge	TBP (Solid)	3.75E+04	8.72E+03	kg
	Total		5.50E+04	--	kg
Ni	Sludge	CWP1 (Solid)	3.67E+01	not reported	kg
	Sludge	TBP (Solid)	2.55E+01	5.27E+00	kg
	Total		6.22E+01	--	kg
NO_2 *	Sludge	CWP1 (Solid)	3.15E+03	6.59E+03	kg
	Sludge	TBP (Solid)	4.41E+03	3.26E+03	kg
	Total		7.55E+03	--	kg

Table E-1. Tank C-101 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
NO_3	Sludge	CWP1 (Solid)	2.30E+03	9.09E+03	kg
	Sludge	TBP (Solid)	6.40E+04	2.18E+04	kg
	Total		6.63E+04	--	kg
Oxalate	Sludge	CWP1 (Solid)	4.44E+02	not reported	kg
	Sludge	TBP (Solid)	1.41E+02	not reported	kg
	Total		5.85E+02	--	kg
Pb	Sludge	CWP1 (Solid)	1.62E+03	4.77E+03	kg
	Sludge	TBP (Solid)	1.61E+02	1.03E+02	kg
	Total		1.78E+03	--	kg
PO_4	Sludge	CWP1 (Solid)	1.07E+03	5.69E+03	kg
	Sludge	TBP (Solid)	2.96E+04	1.16E+04	kg
	Total		3.07E+04	--	kg
Si	Sludge	CWP1 (Solid)	3.56E+03	2.59E+03	kg
	Sludge	TBP (Solid)	1.88E+02	9.61E+01	kg
	Total		3.75E+03	--	kg
SO_4	Sludge	CWP1 (Solid)	8.60E+02	5.55E+02	kg
	Sludge	TBP (Solid)	6.03E+03	6.97E+03	kg
	Total		6.89E+03	--	kg
Sr	Sludge	CWP1 (Solid)	8.73E+01	9.07E+01	kg
	Sludge	TBP (Solid)	1.83E+02	6.62E+01	kg
	Total		2.70E+02	--	kg
TIC as CO_3	Sludge	CWP1 (Solid)	7.11E+03	4.94E+03	kg
	Sludge	TBP (Solid)	5.13E+02	2.66E+02	kg
	Total		7.62E+03	--	kg
TOC	Sludge	CWP1 (Solid)	1.43E+03	2.40E+03	kg
	Sludge	TBP (Solid)	2.34E+02	8.48E+01	kg
	Total		1.66E+03	--	kg
U_{TOTAL}	Sludge	CWP1 (Solid)	7.24E+03	1.26E+05	kg
	Sludge	TBP (Solid)	4.03E+03	1.68E+03	kg
	Total		1.13E+04	--	kg
Zr	Sludge	CWP1 (Solid)	2.04E+02	3.23E+02	kg
	Sludge	TBP (Solid)	2.96E+00	1.46E+00	kg
	Total		2.07E+02	--	kg

[a] Indicator constituents as identified in Section 7.1.1.1.

CWP1 = aluminum cladding waste.
TBP = tributyl phosphate.
TIC = total inorganic carbon.
TOC = total organic carbon.

[a] Reference download from http://twinsweb.pnl.gov/data dated 6/10/05.

Table E-2. Tank C-105 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{106}Ru	Sludge	CWP1 (Solid)	3.71E-10	not reported	Ci
	Sludge	TBP (Solid)	8.44E-15	not reported	Ci
	Total		3.71E-10	--	Ci
^{113m}Cd	Sludge	CWP1 (Solid)	1.33E+00	not reported	Ci
	Sludge	TBP (Solid)	5.68E-03	not reported	Ci
	Total		1.34E+00	--	Ci
^{125}Sb	Sludge	CWP1 (Solid)	1.59E-03	not reported	Ci
	Sludge	TBP (Solid)	9.19E-05	not reported	Ci
	Total		1.68E-03	--	Ci
^{126}Sn	Sludge	CWP1 (Solid)	1.98E-03	not reported	Ci
	Sludge	TBP (Solid)	8.29E-04	not reported	Ci
	Total		2.81E-03	--	Ci
^{129}I	Sludge	CWP1 (Solid)	8.37E-02	not reported	Ci
	Sludge	TBP (Solid)	9.30E-03	not reported	Ci
	Total		9.30E-02	--	Ci
^{134}Cs	Sludge	CWP1 (Solid)	3.32E-05	not reported	Ci
	Sludge	TBP (Solid)	7.61E-07	not reported	Ci
	Total		3.40E-05	--	Ci
^{137}Cs	Sludge	CWP1 (Solid)	6.87E+04	not reported	Ci
	Sludge	TBP (Solid)	7.64E+03	not reported	Ci
	Total		7.64E+04	--	Ci
^{137m}Ba	Sludge	CWP1 (Solid)	6.49E+04	not reported	Ci
	Sludge	TBP (Solid)	7.21E+03	not reported	Ci
	Total		7.21E+04	--	Ci
^{14}C	Sludge	CWP1 (Solid)	4.56E-01	not reported	Ci
	Sludge	TBP (Solid)	5.07E-02	not reported	Ci
	Total		5.07E-01	--	Ci
^{151}Sm	Sludge	CWP1 (Solid)	1.99E+01	not reported	Ci
	Sludge	TBP (Solid)	7.95E+00	not reported	Ci
	Total		2.78E+01	--	Ci
^{152}Eu	Sludge	CWP1 (Solid)	2.38E-03	not reported	Ci
	Sludge	TBP (Solid)	2.54E-04	not reported	Ci
	Total		2.64E-03	--	Ci
^{154}Eu	Sludge	CWP1 (Solid)	1.59E-01	not reported	Ci
	Sludge	TBP (Solid)	1.77E-02	not reported	Ci
	Total		1.76E-01	--	Ci

Table E-2. Tank C-105 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{155}Eu	Sludge	CWP1 (Solid)	5.67E-02	not reported	Ci
	Sludge	TBP (Solid)	8.50E-03	not reported	Ci
	Total		6.52E-02	--	Ci
^{226}Ra	Sludge	CWP1 (Solid)	6.33E-07	not reported	Ci
	Sludge	TBP (Solid)	1.04E-06	not reported	Ci
	Total		1.68E-06	--	Ci
^{227}Ac	Sludge	CWP1 (Solid)	3.42E-06	not reported	Ci
	Sludge	TBP (Solid)	4.60E-06	not reported	Ci
	Total		8.02E-06	--	Ci
^{228}Ra	Sludge	CWP1 (Solid)	7.27E-12	not reported	Ci
	Sludge	TBP (Solid)	4.01E-12	not reported	Ci
	Total		1.13E-11	--	Ci
^{229}Th	Sludge	CWP1 (Solid)	1.06E-09	not reported	Ci
	Sludge	TBP (Solid)	2.33E-10	not reported	Ci
	Total		1.30E-09	--	Ci
^{231}Pa	Sludge	CWP1 (Solid)	6.79E-06	not reported	Ci
	Sludge	TBP (Solid)	4.35E-08	not reported	Ci
	Total		6.83E-06	--	Ci
^{233}Th	Sludge	CWP1 (Solid)	8.39E-12	not reported	Ci
	Sludge	TBP (Solid)	1.98E-12	not reported	Ci
	Total		1.04E-11	--	Ci
^{232}U	Sludge	CWP1 (Solid)	1.32E-04	not reported	Ci
	Sludge	TBP (Solid)	3.90E-06	not reported	Ci
	Total		1.35E-04	--	Ci
^{233}U	Sludge	CWP1 (Solid)	6.41E-06	not reported	Ci
	Sludge	TBP (Solid)	3.27E-07	not reported	Ci
	Total		6.74E-06	--	Ci
^{234}U	Sludge	CWP1 (Solid)	2.88E+00	not reported	Ci
	Sludge	TBP (Solid)	3.22E-01	not reported	Ci
	Total		3.20E+00	--	Ci
^{235}U	Sludge	CWP1 (Solid)	1.23E-01	not reported	Ci
	Sludge	TBP (Solid)	1.44E-02	not reported	Ci
	Total		1.37E-01	--	Ci
^{236}U	Sludge	CWP1 (Solid)	6.57E-02	not reported	Ci
	Sludge	TBP (Solid)	3.68E-03	not reported	Ci
	Total		6.93E-02	--	Ci

Table E-2. Tank C-105 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{237}Np	Sludge	CWP1 (Solid)	1.41E-03	not reported	Ci
	Sludge	TBP (Solid)	6.06E-04	not reported	Ci
	Total		2.01E-03	--	Ci
^{238}Pu	Sludge	CWP1 (Solid)	3.04E+01	not reported	Ci
	Sludge	TBP (Solid)	1.49E+00	not reported	Ci
	Total		3.19E+01	--	Ci
^{238}U	Sludge	CWP1 (Solid)	2.95E+00	not reported	Ci
	Sludge	TBP (Solid)	3.28E-01	not reported	Ci
	Total		3.28E+00	--	Ci
^{239}Pu	Sludge	CWP1 (Solid)	1.77E+03	not reported	Ci
	Sludge	TBP (Solid)	2.14E+02	not reported	Ci
	Total		1.98E+03	--	Ci
^{240}Pu	Sludge	CWP1 (Solid)	3.67E+02	not reported	Ci
	Sludge	TBP (Solid)	2.29E+01	not reported	Ci
	Total		3.90E+02	--	Ci
^{241}Am	Sludge	CWP1 (Solid)	1.08E+03	not reported	Ci
	Sludge	TBP (Solid)	1.15E+02	not reported	Ci
	Total		1.19E+03	--	Ci
^{241}Pu	Sludge	CWP1 (Solid)	1.38E+03	not reported	Ci
	Sludge	TBP (Solid)	3.89E+01	not reported	Ci
	Total		1.42E+03	--	Ci
^{242}Cm	Sludge	CWP1 (Solid)	1.66E-02	not reported	Ci
	Sludge	TBP (Solid)	2.75E-02	not reported	Ci
	Total		4.42E-02	--	Ci
^{242}Pu	Sludge	CWP1 (Solid)	1.15E-02	not reported	Ci
	Sludge	TBP (Solid)	3.15E-04	not reported	Ci
	Total		1.18E-02	--	Ci
^{243}Am	Sludge	CWP1 (Solid)	1.16E-02	not reported	Ci
	Sludge	TBP (Solid)	1.62E-02	not reported	Ci
	Total		2.78E-02	--	Ci
^{243}Cm	Sludge	CWP1 (Solid)	1.62E-04	not reported	Ci
	Sludge	TBP (Solid)	3.08E-04	not reported	Ci
	Total		4.70E-04	--	Ci
^{244}Cm	Sludge	CWP1 (Solid)	2.55E-03	not reported	Ci
	Sludge	TBP (Solid)	6.95E-03	not reported	Ci
	Total		9.51E-03	--	Ci

Table E-2. Tank C-105 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{3}H	Sludge	CWP1 (Solid)	1.04E+02	not reported	Ci
	Sludge	TBP (Solid)	1.06E-01	not reported	Ci
	Total		1.04E+02	--	Ci
^{59}Ni	Sludge	CWP1 (Solid)	4.58E+00	not reported	Ci
	Sludge	TBP (Solid)	1.27E-03	not reported	Ci
	Total		4.58E+00	--	Ci
^{60}Co	Sludge	CWP1 (Solid)	5.23E+01	not reported	Ci
	Sludge	TBP (Solid)	5.81E+00	not reported	Ci
	Total		5.81E+01	--	Ci
^{63}Ni	Sludge	CWP1 (Solid)	4.19E+02	not reported	Ci
	Sludge	TBP (Solid)	1.09E-01	not reported	Ci
	Total		4.19E+02	--	Ci
^{79}Se	Sludge	CWP1 (Solid)	4.82E-04	not reported	Ci
	Sludge	TBP (Solid)	2.19E-04	not reported	Ci
	Total		7.01E-04	--	Ci
^{90}Sr	Sludge	CWP1 (Solid)	3.97E+05	not reported	Ci
	Sludge	TBP (Solid)	4.41E+04	not reported	Ci
	Total		4.41E+05	--	Ci
^{90}Y	Sludge	CWP1 (Solid)	3.97E+05	not reported	Ci
	Sludge	TBP (Solid)	4.41E+04	not reported	Ci
	Total		4.41E+05	--	Ci
^{93m}Nb	Sludge	CWP1 (Solid)	2.46E-02	not reported	Ci
	Sludge	TBP (Solid)	5.29E-05	not reported	Ci
	Total		2.47E-02	--	Ci
^{93}Zr	Sludge	CWP1 (Solid)	2.87E-02	not reported	Ci
	Sludge	TBP (Solid)	5.89E-05	not reported	Ci
	Total		2.88E-02	--	Ci
^{99}Tc *	Sludge	CWP1 (Solid)	7.32E+01	not reported	Ci
	Sludge	TBP (Solid)	8.14E+00	not reported	Ci
	Total		8.14E+01	--	Ci
Al	Sludge	CWP1 (Solid)	1.55E+05	1.82E+04	kg
	Sludge	TBP (Solid)	1.39E+02	4.97E+01	kg
	Total		1.55E+05	--	kg
Bi	Sludge	CWP1 (Solid)	3.35E+02	not reported	kg
	Sludge	TBP (Solid)	3.72E+01	not reported	kg
	Total		3.72E+02	--	kg

Table E-2. Tank C-105 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
Ca	Sludge	CWP1 (Solid)	1.78E+03	5.86E+02	kg
	Sludge	TBP (Solid)	2.03E+02	8.21E+01	kg
	Total		1.98E+03	--	kg
Cl	Sludge	CWP1 (Solid)	2.02E+02	3.65E+02	kg
	Sludge	TBP (Solid)	1.08E+02	7.06E+01	kg
	Total		3.10E+02	--	kg
CN	not reported				
Cr *	Sludge	CWP1 (Solid)	3.72E+02	4.97E+01	kg
	Sludge	TBP (Solid)	1.27E+01	6.82E+00	kg
	Total		3.85E+02	--	kg
F	Sludge	CWP1 (Solid)	7.62E+02	5.70E+03	kg
	Sludge	TBP (Solid)	6.08E+01	9.86E+01	kg
	Total		8.23E+02	--	kg
Fe	Sludge	CWP1 (Solid)	2.54E+03	3.06E+02	kg
	Sludge	TBP (Solid)	1.54E+03	2.80E+02	kg
	Total		4.08E+03	--	kg
Hg	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Sludge	TBP (Solid)	5.23E+00	not reported	kg
	Total		5.23E+00	--	kg
K	Sludge	CWP1 (Solid)	7.74E+02	not reported	kg
	Sludge	TBP (Solid)	8.60E+01	not reported	kg
	Total		8.60E+02	--	kg
La	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Sludge	TBP (Solid)	2.73E+00	2.75E+00	kg
	Total		2.73E+00	--	kg
Mn	Sludge	CWP1 (Solid)	1.71E+03	not reported	kg
	Sludge	TBP (Solid)	1.90E+02	not reported	kg
	Total		1.90E+03	--	kg
Na	Sludge	CWP1 (Solid)	2.97E+04	3.74E+03	kg
	Sludge	TBP (Solid)	8.44E+03	1.77E+03	kg
	Total		3.81E+04	--	kg
Ni	Sludge	CWP1 (Solid)	1.49E+03	not reported	kg
	Sludge	TBP (Solid)	1.66E+02	not reported	kg
	Total		1.66E+03	--	kg
NO_2 *	Sludge	CWP1 (Solid)	5.74E+03	1.20E+04	kg
	Sludge	TBP (Solid)	9.92E+02	7.25E+02	kg
	Total		6.73E+03	--	kg

Table E-2. Tank C-105 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
NO_3	Sludge	CWP1 (Solid)	7.32E+03	not reported	kg
	Sludge	TBP (Solid)	8.14E+02	not reported	kg
	Total		8.14E+03	--	kg
Oxalate	Sludge	CWP1 (Solid)	1.33E+03	not reported	kg
	Sludge	TBP (Solid)	3.16E+01	not reported	kg
	Total		1.36E+03	--	kg
Pb	Sludge	CWP1 (Solid)	3.23E+02	not reported	kg
	Sludge	TBP (Solid)	3.59E+01	not reported	kg
	Total		3.59E+02	--	kg
PO_4	Sludge	CWP1 (Solid)	5.41E+03	not reported	kg
	Sludge	TBP (Solid)	6.01E+02	not reported	kg
	Total		6.01E+03	--	kg
Si	Sludge	CWP1 (Solid)	2.78E+04	not reported	kg
	Sludge	TBP (Solid)	3.09E+03	not reported	kg
	Total		3.09E+04	--	kg
SO_4	Sludge	CWP1 (Solid)	1.57E+03	1.00E+03	kg
	Sludge	TBP (Solid)	1.36E+03	1.57E+03	kg
	Total		2.92E+03	--	kg
Sr	Sludge	CWP1 (Solid)	1.28E+02	not reported	kg
	Sludge	TBP (Solid)	1.43E+01	not reported	kg
	Total		1.43E+02	--	kg
TIC as CO_3	Sludge	CWP1 (Solid)	1.30E+04	8.93E+03	kg
	Sludge	TBP (Solid)	1.15E+02	5.85E+01	kg
	Total		1.31E+04	--	kg
TOC	Sludge	CWP1 (Solid)	4.26E+03	6.75E+02	kg
	Sludge	TBP (Solid)	5.27E+01	1.83E+01	kg
	Total		4.31E+03	--	kg
U_{TOTAL}	Sludge	CWP1 (Solid)	8.86E+03	not reported	kg
	Sludge	TBP (Solid)	9.84E+02	not reported	kg
	Total		9.84E+03	--	kg
Zr	Sludge	CWP1 (Solid)	1.62E+02	2.40E+01	kg
	Sludge	TBP (Solid)	6.66E-01	3.22E-01	kg
	Total		1.62E+02	--	kg

[a] Indicator constituents as identified in Section 7.1.1.1.

CWP1 = aluminum cladding waste.
TBP = tributyl phosphate.
TIC = total inorganic carbon.
TOC = total organic carbon.

[b] Reference download from http://twinsweb.pnl.gov/data dated 6/10/05.

Table E-3. Tank C-110 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{106}Ru	Sludge	1C (Solid)	3.85E-11	not reported	Ci
	Supernatant	1C1 (Liquid)	2.20E-14	not reported	Ci
	Total		3.86E-11	--	Ci
^{113m}Cd	Sludge	1C (Solid)	4.53E-02	not reported	Ci
	Supernatant	1C1 (Liquid)	2.87E-04	not reported	Ci
	Total		4.56E-02	--	Ci
^{125}Sb	Sludge	1C (Solid)	6.05E-04	not reported	Ci
	Supernatant	1C1 (Liquid)	2.50E-06	not reported	Ci
	Total		6.07E-04	--	Ci
^{126}Sn	Sludge	1C (Solid)	3.76E-03	not reported	Ci
	Supernatant	1C1 (Liquid)	2.87E-05	not reported	Ci
	Total		3.79E-03	--	Ci
^{129}I	Sludge	1C (Solid)	4.00E-04	not reported	Ci
	Supernatant	1C1 (Liquid)	2.95E-07	not reported	Ci
	Total		4.00E-04	--	Ci
^{134}Cs	Sludge	1C (Solid)	4.61E-07	not reported	Ci
	Supernatant	1C1 (Liquid)	6.00E-10	not reported	Ci
	Total		4.62E-07	--	Ci
^{137}Cs	Sludge	1C (Solid)	1.35E+04	2.26E+03	Ci
	Supernatant	1C1 (Liquid)	1.50E+01	2.54E+02	Ci
	Total		1.35E+04	--	Ci
^{137m}Ba	Sludge	1C (Solid)	1.27E+04	not reported	Ci
	Supernatant	1C1 (Liquid)	1.41E+01	not reported	Ci
	Total		1.27E+04	--	Ci
^{14}C	Sludge	1C (Solid)	3.32E-01	1.10E-01	Ci
	Supernatant	1C1 (Liquid)	7.95E-04	1.34E-02	Ci
	Total		3.33E-01	--	Ci
^{151}Sm	Sludge	1C (Solid)	7.92E+01	not reported	Ci
	Supernatant	1C1 (Liquid)	6.49E-01	not reported	Ci
	Total		7.98E+01	--	Ci
^{152}Eu	Sludge	1C (Solid)	2.54E-03	not reported	Ci
	Supernatant	1C1 (Liquid)	7.07E-06	not reported	Ci
	Total		2.55E-03	--	Ci
^{154}Eu	Sludge	1C (Solid)	1.71E-01	not reported	Ci
	Supernatant	1C1 (Liquid)	6.26E-04	not reported	Ci
	Total		1.72E-01	--	Ci

Table E-3. Tank C-110 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{155}Eu	Sludge	1C (Solid)	7.39E-02	not reported	Ci
	Supernatant	1C1 (Liquid)	4.19E-04	not reported	Ci
	Total		7.43E-02	--	Ci
^{226}Ra	Sludge	1C (Solid)	4.96E-06	not reported	Ci
	Supernatant	1C1 (Liquid)	5.82E-08	not reported	Ci
	Total		5.01E-06	--	Ci
^{227}Ac	Sludge	1C (Solid)	4.23E-05	not reported	Ci
	Supernatant	1C1 (Liquid)	4.88E-07	not reported	Ci
	Total		4.28E-05	--	Ci
^{228}Ra	Sludge	1C (Solid)	5.56E-11	not reported	Ci
	Supernatant	1C1 (Liquid)	4.77E-13	not reported	Ci
	Total		5.61E-11	--	Ci
^{229}Th	Sludge	1C (Solid)	1.57E-08	not reported	Ci
	Supernatant	1C1 (Liquid)	1.34E-10	not reported	Ci
	Total		1.58E-08	--	Ci
^{231}Pa	Sludge	1C (Solid)	3.16E-04	not reported	Ci
	Supernatant	1C1 (Liquid)	3.62E-06	not reported	Ci
	Total		3.20E-04	--	Ci
^{232}Th	Sludge	1C (Solid)	1.32E-10	not reported	Ci
	Supernatant	1C1 (Liquid)	1.13E-12	not reported	Ci
	Total		1.33E-10	--	Ci
^{232}U	Sludge	1C (Solid)	8.04E-06	not reported	Ci
	Supernatant	1C1 (Liquid)	3.70E-09	not reported	Ci
	Total		8.05E-06	--	Ci
^{233}U	Sludge	1C (Solid)	6.69E-07	not reported	Ci
	Supernatant	1C1 (Liquid)	3.37E-10	not reported	Ci
	Total		6.70E-07	--	Ci
^{234}U	Sludge	1C (Solid)	6.46E-01	not reported	Ci
	Supernatant	1C1 (Liquid)	4.23E-04	not reported	Ci
	Total		6.46E-01	--	Ci
^{235}U	Sludge	1C (Solid)	2.89E-02	not reported	Ci
	Supernatant	1C1 (Liquid)	1.90E-05	not reported	Ci
	Total		2.89E-02	--	Ci
^{236}U	Sludge	1C (Solid)	7.21E-03	not reported	Ci
	Supernatant	1C1 (Liquid)	3.60E-06	not reported	Ci
	Total		7.22E-03	--	Ci

Table E-3. Tank C-110 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{237}Np	Sludge	1C (Solid)	1.72E-03	not reported	Ci
	Supernatant	1C1 (Liquid)	1.36E-05	not reported	Ci
	Total		1.74E-03	--	Ci
^{238}Pu	Sludge	1C (Solid)	4.56E-01	not reported	Ci
	Supernatant	1C1 (Liquid)	2.23E-05	not reported	Ci
	Total		4.56E-01	--	Ci
^{238}U	Sludge	1C (Solid)	6.59E-01	not reported	Ci
	Supernatant	1C1 (Liquid)	4.27E-04	not reported	Ci
	Total		6.59E-01	--	Ci
^{239}Pu	Sludge	1C (Solid)	6.48E+01	not reported	Ci
	Supernatant	1C1 (Liquid)	6.59E-03	not reported	Ci
	Total		6.48E+01	--	Ci
^{240}Pu	Sludge	1C (Solid)	7.05E+00	not reported	Ci
	Supernatant	1C1 (Liquid)	4.44E-04	not reported	Ci
	Total		7.05E+00	--	Ci
^{241}Am	Sludge	1C (Solid)	3.86E+01	not reported	Ci
	Supernatant	1C1 (Liquid)	7.58E-05	1.28E-03	Ci
	Total		3.86E+01	--	Ci
^{241}Pu	Sludge	1C (Solid)	1.18E+01	not reported	Ci
	Supernatant	1C1 (Liquid)	3.73E-04	not reported	Ci
	Total		1.18E+01	--	Ci
^{242}Cm	Sludge	1C (Solid)	6.79E-03	not reported	Ci
	Supernatant	1C1 (Liquid)	3.84E-09	not reported	Ci
	Total		6.79E-03	--	Ci
^{242}Pu	Sludge	1C (Solid)	9.80E-05	not reported	Ci
	Supernatant	1C1 (Liquid)	2.01E-09	not reported	Ci
	Total		9.80E-05	--	Ci
^{243}Am	Sludge	1C (Solid)	3.98E-03	not reported	Ci
	Supernatant	1C1 (Liquid)	2.22E-09	not reported	Ci
	Total		3.98E-03	--	Ci
^{243}Cm	Sludge	1C (Solid)	7.58E-05	not reported	Ci
	Supernatant	1C1 (Liquid)	2.15E-11	not reported	Ci
	Total		7.58E-05	--	Ci
^{244}Cm	Sludge	1C (Solid)	1.70E-03	not reported	Ci
	Supernatant	1C1 (Liquid)	4.82E-10	not reported	Ci
	Total		1.70E-03	--	Ci

Table E-3. Tank C-110 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{3}H	Sludge	1C (Solid)	5.68E-01	1.03E-01	Ci
	Supernatant	1C1 (Liquid)	1.53E-03	2.59E-02	Ci
	Total		5.70E-01	--	Ci
^{59}Ni	Sludge	1C (Solid)	9.74E-03	not reported	Ci
	Supernatant	1C1 (Liquid)	7.50E-05	not reported	Ci
	Total		9.81E-03	--	Ci
^{60}Co	Sludge	1C (Solid)	6.20E-02	not reported	Ci
	Supernatant	1C1 (Liquid)	2.92E-04	not reported	Ci
	Total		6.22E-02	--	Ci
^{63}Ni	Sludge	1C (Solid)	1.35E+00	not reported	Ci
	Supernatant	1C1 (Liquid)	1.08E-02	not reported	Ci
	Total		1.36E+00	--	Ci
^{79}Se	Sludge	1C (Solid)	9.97E-04	not reported	Ci
	Supernatant	1C1 (Liquid)	2.47E-04	4.18E-03	Ci
	Total		1.24E-03	--	Ci
^{90}Sr	Sludge	1C (Solid)	3.45E+03	7.10E+02	Ci
	Supernatant	1C1 (Liquid)	8.46E-02	1.43E+00	Ci
	Total		3.45E+03	--	Ci
^{90}Y	Sludge	1C (Solid)	3.45E+03	not reported	Ci
	Supernatant	1C1 (Liquid)	8.46E-02	not reported	Ci
	Total		3.45E+03	--	Ci
^{93m}Nb	Sludge	1C (Solid)	1.15E+00	not reported	Ci
	Supernatant	1C1 (Liquid)	3.41E-03	not reported	Ci
	Total		1.16E+00	--	Ci
^{93}Zr	Sludge	1C (Solid)	1.28E+00	not reported	Ci
	Supernatant	1C1 (Liquid)	3.74E-03	not reported	Ci
	Total		1.28E+00	--	Ci
^{99}Tc *	Sludge	1C (Solid)	3.18E+01	5.61E+00	Ci
	Supernatant	1C1 (Liquid)	7.11E-02	1.20E+00	Ci
	Total		3.18E+01	--	Ci
Al	Sludge	1C (Solid)	1.31E+04	1.67E+03	kg
	Supernatant	1C1 (Liquid)	8.34E-01	1.41E+01	kg
	Total		1.31E+04	--	kg
Bi	Sludge	1C (Solid)	1.48E+04	2.02E+03	kg
	Supernatant	1C1 (Liquid)	7.66E-01	1.30E+01	kg
	Total		1.48E+04	--	kg

Table E-3. Tank C-110 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
Ca	Sludge	1C (Solid)	1.05E+03	3.94E+02	kg
	Supernatant	1C1 (Liquid)	5.52E-02	9.35E-01	kg
	Total		1.05E+03	--	kg
Cl	Sludge	1C (Solid)	9.88E+02	2.48E+02	kg
	Supernatant	1C1 (Liquid)	2.92E+00	4.94E+01	kg
	Total		9.91E+02	--	kg
CN	Sludge	1C (Solid)	2.86E+00	2.88E+00	kg
	Supernatant	1C1 (Liquid)	1.05E-02	1.78E-01	kg
	Total		2.87E+00	--	kg
Cr *	Sludge	1C (Solid)	4.19E+02	5.45E+01	kg
	Supernatant	1C1 (Liquid)	4.76E-01	8.06E+00	kg
	Total		4.20E+02	--	kg
F	Sludge	1C (Solid)	6.75E+03	1.13E+03	kg
	Supernatant	1C1 (Liquid)	3.23E+00	5.46E+01	kg
	Total		6.75E+03	--	kg
Fe	Sludge	1C (Solid)	9.84E+03	1.35E+03	kg
	Supernatant	1C1 (Liquid)	5.60E-01	9.47E+00	kg
	Total		9.84E+03	--	kg
Hg	Sludge	1C (Solid)	3.98E-01	6.95E-02	kg
	Supernatant	1C1 (Liquid)	4.24E-04	7.17E-03	kg
	Total		3.98E-01	--	kg
K	Sludge	1C (Solid)	5.10E+02	6.67E+01	kg
	Supernatant	1C1 (Liquid)	1.16E+00	1.96E+01	kg
	Total		5.11E+02	--	kg
La	Sludge	1C (Solid)	1.32E+00	1.33E+00	kg
	Supernatant	1C1 (Liquid)	6.48E-03	1.10E-01	kg
	Total		1.33E+00	--	kg
Mn	Sludge	1C (Solid)	4.76E+01	8.52E+00	kg
	Supernatant	1C1 (Liquid)	2.13E-03	3.60E-02	kg
	Total		4.76E+01	--	kg
Na	Sludge	1C (Solid)	7.51E+04	9.65E+03	kg
	Supernatant	1C1 (Liquid)	1.22E+02	2.06E+03	kg
	Total		7.53E+04	--	kg
Ni	Sludge	1C (Solid)	2.17E+01	5.02E+00	kg
	Supernatant	1C1 (Liquid)	4.28E-03	7.25E-02	kg
	Total		2.17E+01	--	kg
NO_2 *	Sludge	1C (Solid)	6.51E+03	2.23E+03	kg
	Supernatant	1C1 (Liquid)	1.84E+01	3.11E+02	kg
	Total		6.53E+03	--	kg

Table E-3. Tank C-110 Inventory.[a] (6 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
NO_3	Sludge	1C (Solid)	9.77E+04	1.33E+04	kg
	Supernatant	1C1 (Liquid)	2.41E+02	4.08E+03	kg
	Total		9.80E+04	--	kg
Oxalate	Sludge	1C (Solid)	7.89E+02	not reported	kg
	Supernatant	1C1 (Liquid)	4.25E+00	not reported	kg
	Total		7.94E+02	--	kg
Pb	Sludge	1C (Solid)	2.20E+02	7.20E+01	kg
	Supernatant	1C1 (Liquid)	0.00E+00	not reported	kg
	Total		2.20E+02	--	kg
PO_4	Sludge	1C (Solid)	5.67E+04	1.32E+04	kg
	Supernatant	1C1 (Liquid)	2.04E+01	3.45E+02	kg
	Total		5.68E+04	--	kg
Si	Sludge	1C (Solid)	6.33E+03	8.42E+02	kg
	Supernatant	1C1 (Liquid)	5.78E-01	9.78E+00	kg
	Total		6.33E+03	--	kg
SO_4	Sludge	1C (Solid)	1.11E+04	2.19E+03	kg
	Supernatant	1C1 (Liquid)	2.33E+01	3.94E+02	kg
	Total		1.11E+04	--	kg
Sr	Sludge	1C (Solid)	1.12E+02	2.02E+01	kg
	Supernatant	1C1 (Liquid)	6.34E-03	1.07E-01	kg
	Total		1.12E+02	--	kg
TIC as CO_3	Sludge	1C (Solid)	9.41E+03	1.78E+03	kg
	Supernatant	1C1 (Liquid)	1.09E+01	1.84E+02	kg
	Total		9.42E+03	--	kg
TOC	Sludge	1C (Solid)	4.10E+02	2.85E+02	kg
	Supernatant	1C1 (Liquid)	2.32E+00	3.92E+01	kg
	Total		4.12E+02	--	kg
U_{TOTAL}	Sludge	1C (Solid)	1.97E+03	6.34E+02	kg
	Supernatant	1C1 (Liquid)	1.29E+00	2.18E+01	kg
	Total		1.97E+03	--	kg
Zr	Sludge	1C (Solid)	1.50E+02	2.13E+01	kg
	Supernatant	1C1 (Liquid)	7.30E-03	1.23E-01	kg
	Total		1.50E+02	--	kg

* Indicator constituents as identified in Section 7.1.1.1.

1C = first-cycle bismuth phosphate waste.
1C1 = first-cycle bismuth phosphate waste.
TIC = total inorganic carbon.
TOC = total organic carbon.

[a] Reference download from http://twinsweb.pnl.gov/data dated 6/10/05.

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{106}Ru	Sludge	1C (Solid)	3.47E-12	not reported	Ci
	Sludge	CWP1 (Solid)	4.55E-11	not reported	Ci
	Sludge	HS (Solid)	3.75E-05	not reported	Ci
	Sludge	TFeCN (Solid)	6.68E-12	not reported	Ci
	Total		3.75E-05	--	Ci
^{113m}Cd	Sludge	1C (Solid)	4.08E-03	not reported	Ci
	Sludge	CWP1 (Solid)	1.63E-01	not reported	Ci
	Sludge	HS (Solid)	3.20E-02	not reported	Ci
	Sludge	TFeCN (Solid)	5.52E-02	not reported	Ci
	Total		2.55E-01	--	Ci
^{125}Sb	Sludge	1C (Solid)	5.44E-05	not reported	Ci
	Sludge	CWP1 (Solid)	1.94E-04	not reported	Ci
	Sludge	HS (Solid)	7.60E-02	not reported	Ci
	Sludge	TFeCN (Solid)	8.15E-04	not reported	Ci
	Total		7.71E-02	--	Ci
^{126}Sn	Sludge	1C (Solid)	3.38E-04	not reported	Ci
	Sludge	CWP1 (Solid)	2.43E-04	not reported	Ci
	Sludge	HS (Solid)	2.57E-03	not reported	Ci
	Sludge	TFeCN (Solid)	7.21E-03	not reported	Ci
	Total		1.04E-02	--	Ci
^{129}I	Sludge	1C (Solid)	3.59E-05	not reported	Ci
	Sludge	CWP1 (Solid)	3.09E-02	not reported	Ci
	Sludge	HS (Solid)	1.16E-05	not reported	Ci
	Sludge	TFeCN (Solid)	1.40E-03	not reported	Ci
	Total		3.24E-02	--	Ci
^{134}Cs	Sludge	1C (Solid)	4.15E-08	not reported	Ci
	Sludge	CWP1 (Solid)	4.07E-06	not reported	Ci
	Sludge	HS (Solid)	2.25E-04	not reported	Ci
	Sludge	TFeCN (Solid)	1.82E-04	not reported	Ci
	Total		4.10E-04	--	Ci
^{137}Cs	Sludge	1C (Solid)	1.11E+03	1.01E+03	Ci
	Sludge	CWP1 (Solid)	6.66E+03	not reported	Ci
	Sludge	HS (Solid)	1.89E+03	not reported	Ci
	Sludge	TFeCN (Solid)	1.01E+04	not reported	Ci
	Total		1.98E+04	--	Ci

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{137m}Ba	Sludge	1C (Solid)	1.05E+03	not reported	Ci
	Sludge	CWP1 (Solid)	6.28E+03	not reported	Ci
	Sludge	HS (Solid)	1.78E+03	not reported	Ci
	Sludge	TFeCN (Solid)	9.53E+03	not reported	Ci
	Total		1.86E+04	--	Ci
^{14}C	Sludge	1C (Solid)	1.61E-02	1.67E-02	Ci
	Sludge	CWP1 (Solid)	1.43E-01	not reported	Ci
	Sludge	HS (Solid)	5.02E-03	not reported	Ci
	Sludge	TFeCN (Solid)	4.80E-02	not reported	Ci
	Total		2.12E-01	--	Ci
^{151}Sm	Sludge	1C (Solid)	7.12E+00	not reported	Ci
	Sludge	CWP1 (Solid)	2.44E+00	not reported	Ci
	Sludge	HS (Solid)	6.82E+02	not reported	Ci
	Sludge	TFeCN (Solid)	7.57E+01	not reported	Ci
	Total		7.67E+02	--	Ci
^{152}Eu	Sludge	1C (Solid)	2.28E-04	not reported	Ci
	Sludge	CWP1 (Solid)	2.92E-04	not reported	Ci
	Sludge	HS (Solid)	1.21E-01	not reported	Ci
	Sludge	TFeCN (Solid)	2.36E-03	not reported	Ci
	Total		1.23E-01	--	Ci
^{154}Eu	Sludge	1C (Solid)	1.54E-02	not reported	Ci
	Sludge	CWP1 (Solid)	1.94E-02	not reported	Ci
	Sludge	HS (Solid)	8.66E+00	not reported	Ci
	Sludge	TFeCN (Solid)	1.65E-01	not reported	Ci
	Total		8.86E+00	--	Ci
^{155}Eu	Sludge	1C (Solid)	6.65E-03	not reported	Ci
	Sludge	CWP1 (Solid)	6.94E-03	not reported	Ci
	Sludge	HS (Solid)	3.78E+00	not reported	Ci
	Sludge	TFeCN (Solid)	7.91E-02	not reported	Ci
	Total		3.87E+00	--	Ci
^{226}Ra	Sludge	1C (Solid)	4.46E-07	not reported	Ci
	Sludge	CWP1 (Solid)	7.75E-08	not reported	Ci
	Sludge	HS (Solid)	2.56E-08	not reported	Ci
	Sludge	TFeCN (Solid)	9.19E-06	not reported	Ci
	Total		9.73E-06	--	Ci

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{227}Ac	Sludge	1C (Solid)	3.81E-06	not reported	Ci
	Sludge	CWP1 (Solid)	4.19E-07	not reported	Ci
	Sludge	HS (Solid)	1.22E-07	not reported	Ci
	Sludge	TFeCN (Solid)	4.39E-05	not reported	Ci
	Total		4.83E-05	--	Ci
^{228}Ra	Sludge	1C (Solid)	5.00E-12	not reported	Ci
	Sludge	CWP1 (Solid)	8.90E-13	not reported	Ci
	Sludge	HS (Solid)	1.85E-13	not reported	Ci
	Sludge	TFeCN (Solid)	4.01E-11	not reported	Ci
	Total		4.62E-11	--	Ci
^{229}Th	Sludge	1C (Solid)	1.41E-09	not reported	Ci
	Sludge	CWP1 (Solid)	1.30E-10	not reported	Ci
	Sludge	HS (Solid)	2.98E-10	not reported	Ci
	Sludge	TFeCN (Solid)	4.10E-09	not reported	Ci
	Total		5.94E-09	--	Ci
^{231}Pa	Sludge	1C (Solid)	2.84E-05	not reported	Ci
	Sludge	CWP1 (Solid)	8.32E-07	not reported	Ci
	Sludge	HS (Solid)	1.72E-07	not reported	Ci
	Sludge	TFeCN (Solid)	4.77E-05	not reported	Ci
	Total		7.71E-05	--	Ci
^{232}Th	Sludge	1C (Solid)	1.18E-11	not reported	Ci
	Sludge	CWP1 (Solid)	1.03E-12	not reported	Ci
	Sludge	HS (Solid)	1.89E-13	not reported	Ci
	Sludge	TFeCN (Solid)	3.47E-11	not reported	Ci
	Total		4.78E-11	--	Ci
^{232}U	Sludge	1C (Solid)	5.31E-07	not reported	Ci
	Sludge	CWP1 (Solid)	2.33E-05	not reported	Ci
	Sludge	HS (Solid)	1.08E-05	not reported	Ci
	Sludge	TFeCN (Solid)	9.74E-06	not reported	Ci
	Total		4.44E-05	--	Ci
^{233}U	Sludge	1C (Solid)	4.42E-08	not reported	Ci
	Sludge	CWP1 (Solid)	1.14E-06	not reported	Ci
	Sludge	HS (Solid)	4.71E-05	not reported	Ci
	Sludge	TFeCN (Solid)	8.08E-07	not reported	Ci
	Total		4.91E-05	--	Ci

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{234}U	Sludge	1C (Solid)	4.27E-02	not reported	Ci
	Sludge	CWP1 (Solid)	5.11E-01	not reported	Ci
	Sludge	HS (Solid)	1.53E-01	not reported	Ci
	Sludge	TFeCN (Solid)	8.00E-01	not reported	Ci
	Total		1.51E+00	--	Ci
^{235}U	Sludge	1C (Solid)	1.91E-03	not reported	Ci
	Sludge	CWP1 (Solid)	2.18E-02	not reported	Ci
	Sludge	HS (Solid)	6.43E-03	not reported	Ci
	Sludge	TFeCN (Solid)	3.57E-02	not reported	Ci
	Total		6.59E-02	--	Ci
^{236}U	Sludge	1C (Solid)	4.76E-04	not reported	Ci
	Sludge	CWP1 (Solid)	1.16E-02	not reported	Ci
	Sludge	HS (Solid)	3.64E-03	not reported	Ci
	Sludge	TFeCN (Solid)	8.98E-03	not reported	Ci
	Total		2.47E-02	--	Ci
^{237}Np	Sludge	1C (Solid)	1.55E-04	not reported	Ci
	Sludge	CWP1 (Solid)	1.72E-04	not reported	Ci
	Sludge	HS (Solid)	8.20E-04	not reported	Ci
	Sludge	TFeCN (Solid)	5.17E-03	not reported	Ci
	Total		6.31E-03	--	Ci
^{238}Pu	Sludge	1C (Solid)	4.11E-02	not reported	Ci
	Sludge	CWP1 (Solid)	1.90E+00	not reported	Ci
	Sludge	HS (Solid)	9.83E-01	not reported	Ci
	Sludge	TFeCN (Solid)	1.47E-01	not reported	Ci
	Total		3.07E+00	--	Ci
^{238}U	Sludge	1C (Solid)	4.35E-02	not reported	Ci
	Sludge	CWP1 (Solid)	5.24E-01	not reported	Ci
	Sludge	HS (Solid)	1.53E-01	not reported	Ci
	Sludge	TFeCN (Solid)	8.16E-01	not reported	Ci
	Total		1.54E+00	--	Ci
^{239}Pu	Sludge	1C (Solid)	5.84E+00	not reported	Ci
	Sludge	CWP1 (Solid)	1.10E+02	not reported	Ci
	Sludge	HS (Solid)	3.09E+01	not reported	Ci
	Sludge	TFeCN (Solid)	2.01E+01	not reported	Ci
	Total		1.67E+02	--	Ci

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{240}Pu	Sludge	1C (Solid)	6.35E-01	not reported	Ci
	Sludge	CWP1 (Solid)	2.29E+01	not reported	Ci
	Sludge	HS (Solid)	6.68E+00	not reported	Ci
	Sludge	TFeCN (Solid)	2.24E+00	not reported	Ci
	Total		3.25E+01	--	Ci
^{241}Am	Sludge	1C (Solid)	9.68E-01	not reported	Ci
	Sludge	CWP1 (Solid)	2.08E+00	not reported	Ci
	Sludge	HS (Solid)	1.24E+00	not reported	Ci
	Sludge	TFeCN (Solid)	1.86E+02	not reported	Ci
	Total		1.90E+02	--	Ci
^{241}Pu	Sludge	1C (Solid)	1.07E+00	not reported	Ci
	Sludge	CWP1 (Solid)	8.58E+01	not reported	Ci
	Sludge	HS (Solid)	3.54E+01	not reported	Ci
	Sludge	TFeCN (Solid)	3.95E+00	not reported	Ci
	Total		1.26E+02	--	Ci
^{242}Cm	Sludge	1C (Solid)	1.67E-04	not reported	Ci
	Sludge	CWP1 (Solid)	3.06E-05	not reported	Ci
	Sludge	HS (Solid)	4.85E-02	not reported	Ci
	Sludge	TFeCN (Solid)	4.20E-02	not reported	Ci
	Total		9.07E-02	--	Ci
^{242}Pu	Sludge	1C (Solid)	8.83E-06	not reported	Ci
	Sludge	CWP1 (Solid)	7.14E-04	not reported	Ci
	Sludge	HS (Solid)	3.14E-04	not reported	Ci
	Sludge	TFeCN (Solid)	3.25E-05	not reported	Ci
	Total		1.07E-03	--	Ci
^{243}Am	Sludge	1C (Solid)	9.81E-05	not reported	Ci
	Sludge	CWP1 (Solid)	1.82E-05	not reported	Ci
	Sludge	HS (Solid)	5.29E-04	not reported	Ci
	Sludge	TFeCN (Solid)	2.47E-02	not reported	Ci
	Total		2.54E-02	--	Ci
^{243}Cm	Sludge	1C (Solid)	1.87E-06	not reported	Ci
	Sludge	CWP1 (Solid)	5.40E-07	not reported	Ci
	Sludge	HS (Solid)	2.45E-03	not reported	Ci
	Sludge	TFeCN (Solid)	4.70E-04	not reported	Ci
	Total		2.93E-03	--	Ci

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{244}Cm	Sludge	1C (Solid)	4.20E-05	not reported	Ci
	Sludge	CWP1 (Solid)	1.35E-05	not reported	Ci
	Sludge	HS (Solid)	5.54E-02	not reported	Ci
	Sludge	TFeCN (Solid)	1.06E-02	not reported	Ci
	Total		6.61E-02	--	Ci
^{3}H	Sludge	1C (Solid)	2.64E-02	1.93E-02	Ci
	Sludge	CWP1 (Solid)	1.28E+01	not reported	Ci
	Sludge	HS (Solid)	9.77E-03	not reported	Ci
	Sludge	TFeCN (Solid)	1.76E+00	1.80E+00	Ci
	Total		1.46E+01	--	Ci
^{59}Ni	Sludge	1C (Solid)	8.76E-04	not reported	Ci
	Sludge	CWP1 (Solid)	5.60E-01	not reported	Ci
	Sludge	HS (Solid)	1.03E-01	not reported	Ci
	Sludge	TFeCN (Solid)	2.40E+00	2.46E+00	Ci
	Total		3.07E+00	--	Ci
^{60}Co	Sludge	1C (Solid)	5.57E-03	not reported	Ci
	Sludge	CWP1 (Solid)	7.50E-01	not reported	Ci
	Sludge	HS (Solid)	4.93E-01	not reported	Ci
	Sludge	TFeCN (Solid)	4.46E-02	not reported	Ci
	Total		1.29E+00	--	Ci
^{63}Ni	Sludge	1C (Solid)	1.21E-01	not reported	Ci
	Sludge	CWP1 (Solid)	5.14E+01	not reported	Ci
	Sludge	HS (Solid)	9.51E+00	not reported	Ci
	Sludge	TFeCN (Solid)	2.14E+02	2.19E+02	Ci
	Total		2.75E+02	--	Ci
^{79}Se	Sludge	1C (Solid)	8.97E-05	not reported	Ci
	Sludge	CWP1 (Solid)	5.90E-05	not reported	Ci
	Sludge	HS (Solid)	6.20E-04	not reported	Ci
	Sludge	TFeCN (Solid)	1.92E-03	not reported	Ci
	Total		2.68E-03	--	Ci
^{90}Sr	Sludge	1C (Solid)	3.38E+02	2.46E+02	Ci
	Sludge	CWP1 (Solid)	3.24E+05	not reported	Ci
	Sludge	HS (Solid)	9.17E+04	not reported	Ci
	Sludge	TFeCN (Solid)	4.91E+05	not reported	Ci
	Total		9.07E+05	--	Ci

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{90}Y	Sludge	1C (Solid)	3.38E+02	not reported	Ci
	Sludge	CWP1 (Solid)	3.24E+05	not reported	Ci
	Sludge	HS (Solid)	9.17E+04	not reported	Ci
	Sludge	TFeCN (Solid)	4.91E+05	not reported	Ci
	Total		9.07E+05	--	Ci
^{93m}Nb	Sludge	1C (Solid)	1.04E-01	not reported	Ci
	Sludge	CWP1 (Solid)	3.02E-03	not reported	Ci
	Sludge	HS (Solid)	3.08E-02	not reported	Ci
	Sludge	TFeCN (Solid)	5.72E-02	not reported	Ci
	Total		1.95E-01	--	Ci
^{93}Zr	Sludge	1C (Solid)	1.15E-01	not reported	Ci
	Sludge	CWP1 (Solid)	3.52E-03	not reported	Ci
	Sludge	HS (Solid)	3.68E-02	not reported	Ci
	Sludge	TFeCN (Solid)	6.34E-02	not reported	Ci
	Total		2.19E-01	--	Ci
^{99}Tc *	Sludge	1C (Solid)	1.70E+00	6.49E+00	Ci
	Sludge	CWP1 (Solid)	2.57E-02	not reported	Ci
	Sludge	HS (Solid)	1.94E-01	not reported	Ci
	Sludge	TFeCN (Solid)	6.36E-01	not reported	Ci
	Total		2.56E+00	--	Ci
Al	Sludge	1C (Solid)	1.04E+03	7.34E+02	kg
	Sludge	CWP1 (Solid)	1.08E+04	not reported	kg
	Sludge	HS (Solid)	3.06E+03	not reported	kg
	Sludge	TFeCN (Solid)	1.64E+04	not reported	kg
	Total		3.13E+04	--	kg
Bi	Sludge	1C (Solid)	1.33E+03	4.08E+02	kg
	Sludge	CWP1 (Solid)	1.56E+02	not reported	kg
	Sludge	HS (Solid)	4.43E+01	not reported	kg
	Sludge	TFeCN (Solid)	2.37E+02	not reported	kg
	Total		1.77E+03	--	kg
Ca	Sludge	1C (Solid)	6.49E+01	4.12E+01	kg
	Sludge	CWP1 (Solid)	1.55E+03	not reported	kg
	Sludge	HS (Solid)	4.38E+02	not reported	kg
	Sludge	TFeCN (Solid)	2.34E+03	not reported	kg
	Total		4.39E+03	--	kg

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
Cl	Sludge	IC (Solid)	7.92E+01	3.56E+01	kg
	Sludge	CWP1 (Solid)	2.47E+01	4.49E+01	kg
	Sludge	HS (Solid)	6.15E+01	not reported	kg
	Sludge	TFeCN (Solid)	1.59E+02	1.08E+02	kg
	Total		3.24E+02	--	kg
CN	not reported				
Cr*	Sludge	IC (Solid)	5.82E+01	2.61E+01	kg
	Sludge	CWP1 (Solid)	1.09E+01	not reported	kg
	Sludge	HS (Solid)	3.09E+00	not reported	kg
	Sludge	TFeCN (Solid)	1.65E+01	not reported	kg
	Total		8.88E+01	--	kg
F	Sludge	IC (Solid)	7.15E+02	5.76E+02	kg
	Sludge	CWP1 (Solid)	9.34E+01	6.99E+02	kg
	Sludge	HS (Solid)	0.00E+00	not reported	kg
	Sludge	TFeCN (Solid)	1.19E+02	1.94E+02	kg
	Total		9.27E+02	--	kg
Fe	Sludge	IC (Solid)	7.08E+02	2.08E+02	kg
	Sludge	CWP1 (Solid)	4.93E+03	not reported	kg
	Sludge	HS (Solid)	1.40E+03	not reported	kg
	Sludge	TFeCN (Solid)	7.48E+03	not reported	kg
	Total		1.45E+04	--	kg
Hg	Sludge	IC (Solid)	2.65E-02	3.55E-02	kg
	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Sludge	HS (Solid)	4.64E+01	not reported	kg
	Sludge	TFeCN (Solid)	1.06E+00	4.61E-01	kg
	Total		4.75E+01	--	kg
K	Sludge	IC (Solid)	2.23E+01	1.75E+01	kg
	Sludge	CWP1 (Solid)	5.36E+00	not reported	kg
	Sludge	HS (Solid)	1.22E+02	not reported	kg
	Sludge	TFeCN (Solid)	9.18E+01	5.13E+01	kg
	Total		2.42E+02	--	kg
La	Sludge	IC (Solid)	1.19E-01	1.22E-01	kg
	Sludge	CWP1 (Solid)	4.10E+01	not reported	kg
	Sludge	HS (Solid)	1.16E+01	not reported	kg
	Sludge	TFeCN (Solid)	6.21E+01	not reported	kg
	Total		1.15E+02	--	kg

Table E-4. Tank C-111 Inventory.* (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
Mn	Sludge	1C (Solid)	6.57E+00	6.05E+00	kg
	Sludge	CWP1 (Solid)	2.91E+01	not reported	kg
	Sludge	HS (Solid)	8.25E+00	not reported	kg
	Sludge	TFeCN (Solid)	4.41E+01	not reported	kg
	Total		8.81E+01	--	kg
Na	Sludge	1C (Solid)	6.96E+03	3.02E+03	kg
	Sludge	CWP1 (Solid)	2.43E+03	not reported	kg
	Sludge	HS (Solid)	6.88E+02	not reported	kg
	Sludge	TFeCN (Solid)	3.68E+03	not reported	kg
	Total		1.38E+04	--	kg
Ni	Sludge	1C (Solid)	1.47E+00	1.07E+00	kg
	Sludge	CWP1 (Solid)	1.91E+03	not reported	kg
	Sludge	HS (Solid)	5.43E+02	not reported	kg
	Sludge	TFeCN (Solid)	2.90E+03	not reported	kg
	Total		5.36E+03	--	kg
NO_2 *	Sludge	1C (Solid)	6.80E+02	1.06E+03	kg
	Sludge	CWP1 (Solid)	7.03E+02	1.48E+03	kg
	Sludge	HS (Solid)	7.95E+02	not reported	kg
	Sludge	TFeCN (Solid)	8.46E+03	6.39E+03	kg
	Total		1.06E+04	--	kg
NO_3	Sludge	1C (Solid)	8.83E+03	6.86E+03	kg
	Sludge	CWP1 (Solid)	5.14E+02	2.03E+03	kg
	Sludge	HS (Solid)	1.32E+03	not reported	kg
	Sludge	TFeCN (Solid)	9.87E+03	3.70E+03	kg
	Total		2.05E+04	--	kg
Oxalate	Sludge	1C (Solid)	7.10E+01	not reported	kg
	Sludge	CWP1 (Solid)	2.46E+01	not reported	kg
	Sludge	HS (Solid)	3.43E+01	not reported	kg
	Sludge	TFeCN (Solid)	7.20E+01	not reported	kg
	Total		2.02E+02	--	kg
Pb	Sludge	1C (Solid)	1.37E+01	1.28E+01	kg
	Sludge	CWP1 (Solid)	5.43E+02	not reported	kg
	Sludge	HS (Solid)	1.54E+02	not reported	kg
	Sludge	TFeCN (Solid)	8.24E+02	not reported	kg
	Total		1.53E+03	--	kg

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
PO_4	Sludge	1C (Solid)	4.86E+03	2.80E+03	kg
	Sludge	CWP1 (Solid)	5.14E+03	not reported	kg
	Sludge	HS (Solid)	1.46E+03	not reported	kg
	Sludge	TFeCN (Solid)	7.80E+03	not reported	kg
	Total		1.93E+04	--	kg
Si	Sludge	1C (Solid)	4.31E+02	4.08E+02	kg
	Sludge	CWP1 (Solid)	7.16E+02	not reported	kg
	Sludge	HS (Solid)	2.03E+02	not reported	kg
	Sludge	TFeCN (Solid)	1.09E+03	not reported	kg
	Total		2.44E+03	--	kg
SO_4	Sludge	1C (Solid)	9.39E+02	6.53E+02	kg
	Sludge	CWP1 (Solid)	1.92E+02	1.28E+02	kg
	Sludge	HS (Solid)	7.03E+01	not reported	kg
	Sludge	TFeCN (Solid)	3.77E+02	not reported	kg
	Total		1.58E+03	--	kg
Sr	Sludge	1C (Solid)	1.01E+01	3.26E+00	kg
	Sludge	CWP1 (Solid)	1.86E+01	not reported	kg
	Sludge	HS (Solid)	5.26E+00	not reported	kg
	Sludge	TFeCN (Solid)	2.82E+01	not reported	kg
	Total		6.21E+01	--	kg
TIC as CO_3	Sludge	1C (Solid)	4.16E+02	4.85E+02	kg
	Sludge	CWP1 (Solid)	1.59E+03	1.13E+03	kg
	Sludge	HS (Solid)	1.04E+01	not reported	kg
	Sludge	TFeCN (Solid)	5.35E+03	2.90E+03	kg
	Total		7.36E+03	--	kg
TOC	Sludge	1C (Solid)	3.69E+01	2.65E+01	kg
	Sludge	CWP1 (Solid)	7.91E+01	not reported	kg
	Sludge	HS (Solid)	2.24E+01	not reported	kg
	Sludge	TFeCN (Solid)	1.20E+02	not reported	kg
	Total		2.58E+02	--	kg
U_{TOTAL}	Sludge	1C (Solid)	1.30E+02	1.42E+02	kg
	Sludge	CWP1 (Solid)	1.61E+03	not reported	kg
	Sludge	HS (Solid)	4.57E+02	not reported	kg
	Sludge	TFeCN (Solid)	2.44E+03	not reported	kg
	Total		4.64E+03	--	kg

Table E-4. Tank C-111 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
Zr	Sludge	1C (Solid)	9.60E+00	9.47E+00	kg
	Sludge	CWP1 (Solid)	4.56E+01	7.26E+01	kg
	Sludge	HS (Solid)	0.00E+00	not reported	kg
	Sludge	TFeCN (Solid)	2.04E+00	1.06E+00	kg
	Total		5.72E+01	--	kg

[a] Indicator constituents as identified in Section 7.1.1.1.

1C = first-cycle bismuth phosphate waste.
CWP1 = cladding waste.
HS = hot semiworks waste.
TFeCN = ferrocyanide scavenging waste.
TIC = total inorganic carbon.
TOC = total organic carbon.

[a] Reference download from http://twinsweb.pnl.gov/data dated 6/10/05.