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RPP-22520, Rev. 1

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

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CH2M HILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

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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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21. Revisions Planned (include a brief description of the contents of each revision)
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Note: All revisions shall have the approvals of the affected organizations as identified in block 11 "Approval Designator," on page 1 of this ECN.

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LIST OF TERMS

ALARA	as low as reasonably achievable
AMS	articulated mast system
BBI	best-basis inventory
CH2M HILL	CH2M HILL Hanford Group, Inc.
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HI	hazard index
HPGe	high purity germanium
HRR	high-resolution resistivity
IH	Industrial Hygiene
ITV	in-tank vehicle
ILCR	incremental lifetime cancer risk
LDM	leak detection and monitoring
MRS	mobile retrieval system
PCB	polychlorinated biphenyls
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
WMA	waste management area
WRS	waste retrieval system

1.0 INTRODUCTION

The 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 U.S. Department of Energy (DOE) Hanford Site. Single-shell tanks (SSTs) 241-C-101 (C-101), 241-C-105 (C-105), 241-C-110 (C-110), and 241-C-111 (C-111), located in the 200 East Area (Figure 1.1), represent the C farm 100-series tanks identified 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 *Waste Tank Summary Report for Month Ending October 31, 2004* (HNF-EP-0182). The MRS provides for waste retrieval in a batch mode where limited volumes of water are introduced into the tank and retrieved for each batch. This technology represents the best available waste retrieval technology for tanks with suspect integrity.

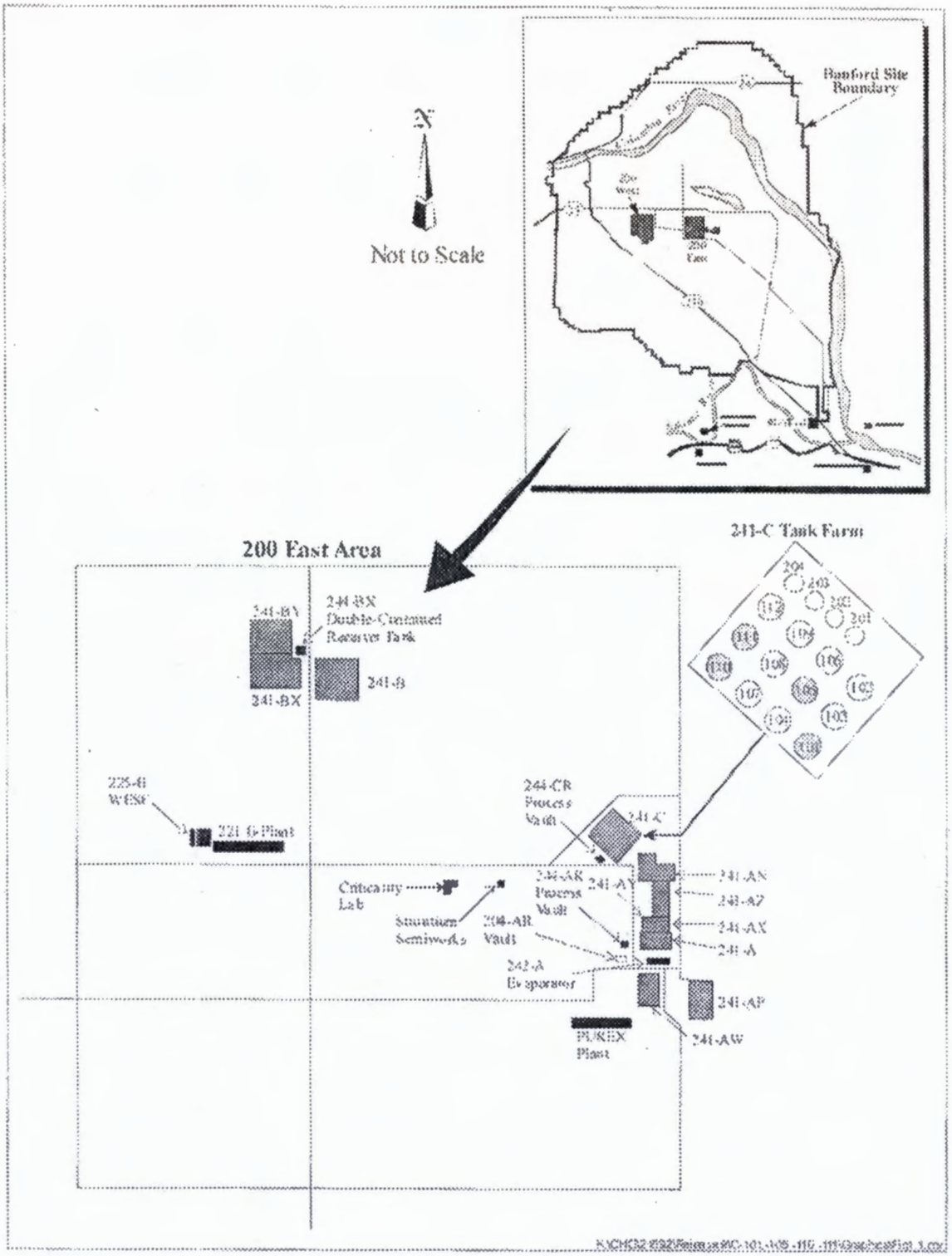
- Tank C-105 is classified as a sound tank; however, vadose zone characterization data collected around tank C-105 indicates that an unplanned release occurred near tank C-105. Because the cause or source of this unplanned release cannot be confirmed, the MRS was selected for retrieving the waste from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

This is a primary document developed to meet the requirements identified in the *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989). 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. 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 *241-C-103 and 241-C-109 Tanks Waste Retrieval Work Plan* (RPP-21895); *241-C-102, 241-C-104, 241-C-107, 241-C-108, and 241-C-112 Tanks Waste Retrieval Work Plan* (RPP-22393). A similar document was also prepared for the C-200-series tanks, *C-200-Series Tanks Retrieval Functions and Requirements* (RPP-16525). 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*, as amended) has been incorporated, 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 the "Hazardous Waste Management Act" (70.105 RCW), but is only presented for general knowledge in support of project discussion.

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 WASTE RETRIEVAL START DATES

A summary of the current schedule baseline for waste retrieval from the four tanks addressed in this document is provided in Figure 2.1. Current plans include initiating waste retrieval from tank C-101 in February 2006, tank C-111 in April 2006, tank C-105 in July 2006, and tank C-110 in July 2006. The schedule information provided in this document is current as of the time of document preparation and is subject to change. Schedule changes will not require modification of this document. As shown in Figure 2.1, waste retrieval is planned to be completed within 12 months of the waste retrieval start date for each tank in accordance with HFFACO, Appendix I requirements. The waste retrieval durations are estimated based on planning assumptions for operating efficiency and performance of the waste retrieval system (WRS).

2.2 TANK HISTORY

This work plan addresses waste retrieval from four C tank farm 100-series tanks: C-101, C-105, C-110, and C-111 (Figure 2.2). Summary-level historical data related to the configuration and operating history for those tanks are provided in Table 2.1.

Table 2.1. Summary Data for Tanks C-101, C-105, C-110, and C-111.

Tank	C-101	C-105	C-110	C-111
Constructed[a]	1943-44	1943-44	1943-44	1943-44
In service[a]	1946	1947	1946	1946
Diameter (ft)[a]	75	75	75	75
Operating depth (ft)[a]	16	16	16	16
Design capacity (gal)[a]	530,000	530,000	530,000	530,000
Bottom shape[a]	Dish	Dish	Dish	Dish
Ventilation[b]	Passive with plans to actively ventilate in the near future	Passive with plans to actively ventilate in the near future	Passive with plans to actively ventilate in the near future	Passive with plans to actively ventilate in the near future
Nominal burial depth (ft)[a]	6	6	6	6
Declared inactive[a]	1977	1980	1977	1978
Integrity[a]	Assumed leaker	Sound	Assumed leaker	Assumed leaker
Interim stabilized[b]	11/83	10/95	5/95	3/84

[a] Source: RPP-10435.
[b] As reported in HNF-EP-0182.

Figure 2.1. Waste Retrieval Schedule.

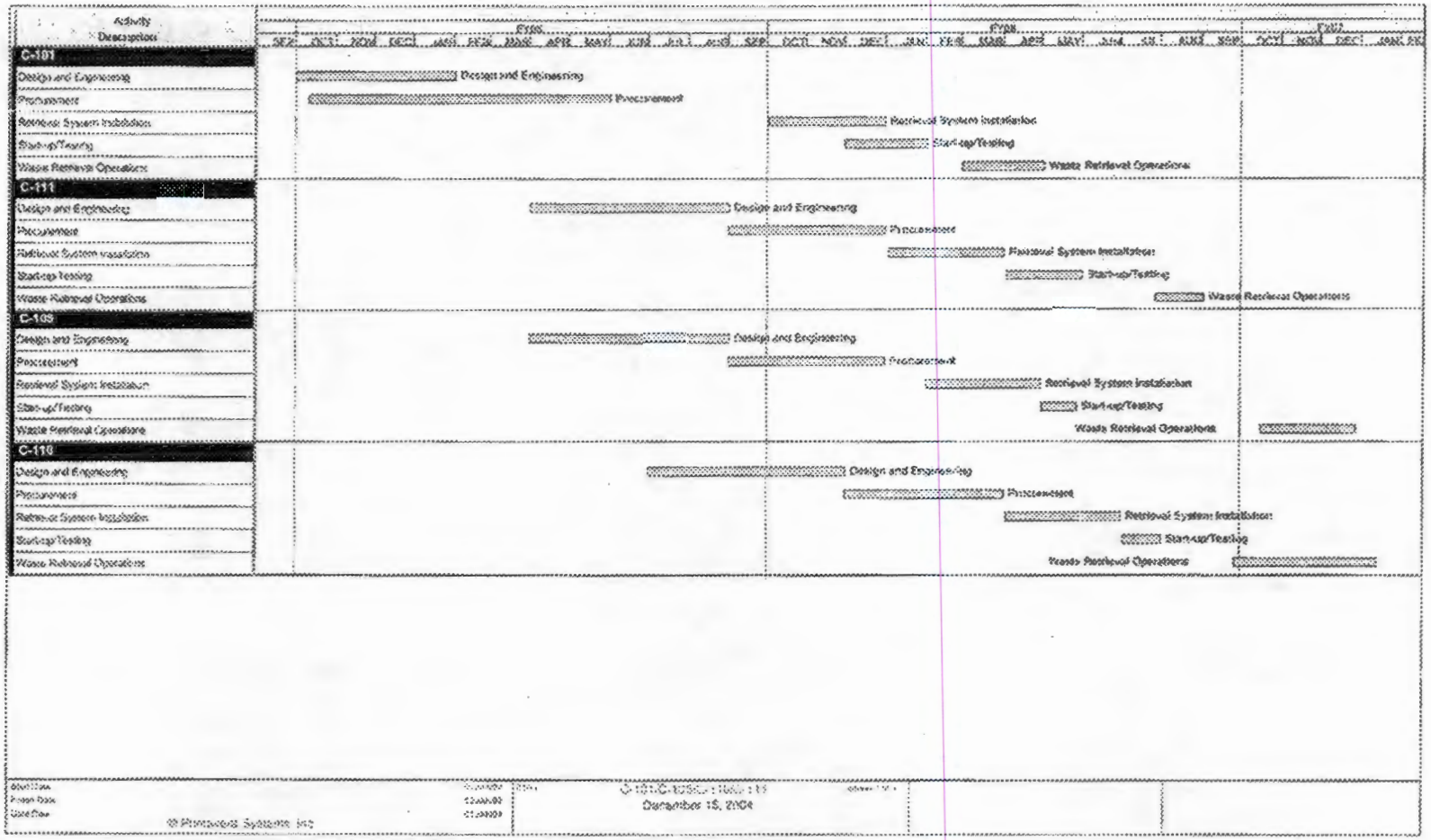
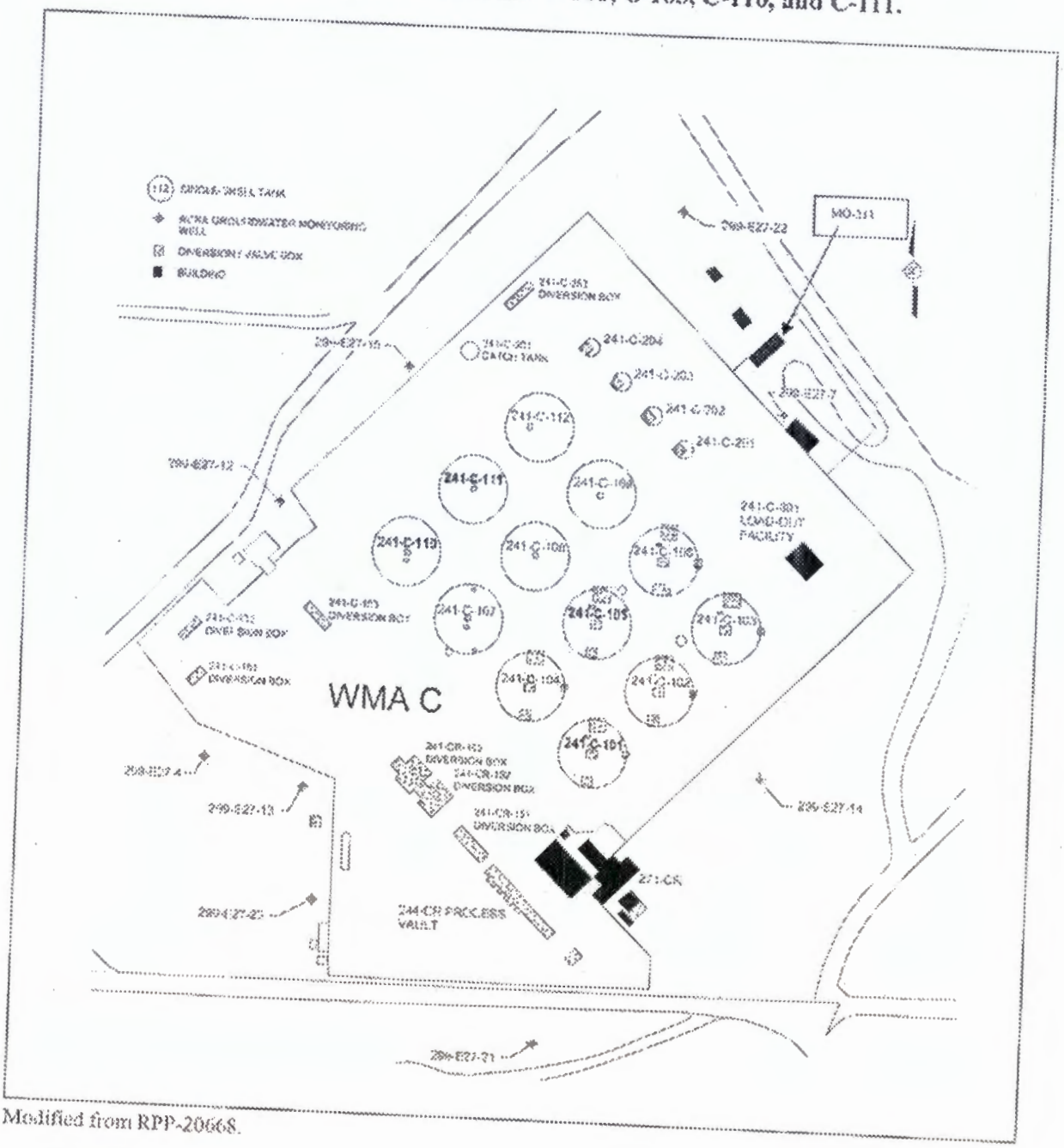


Figure 2.2. Location of Tanks C-101, C-105, C-110, and C-111.



Modified from RPP-20668.

The C farm 100-series SSTs are 75 feet in diameter and 32 feet tall. The tanks have a 16-foot operating depth and an operating capacity of 530,000 gallons each. The tanks sit below grade with at least 6 feet of soil cover to provide shielding from radiation exposure to operating personnel.

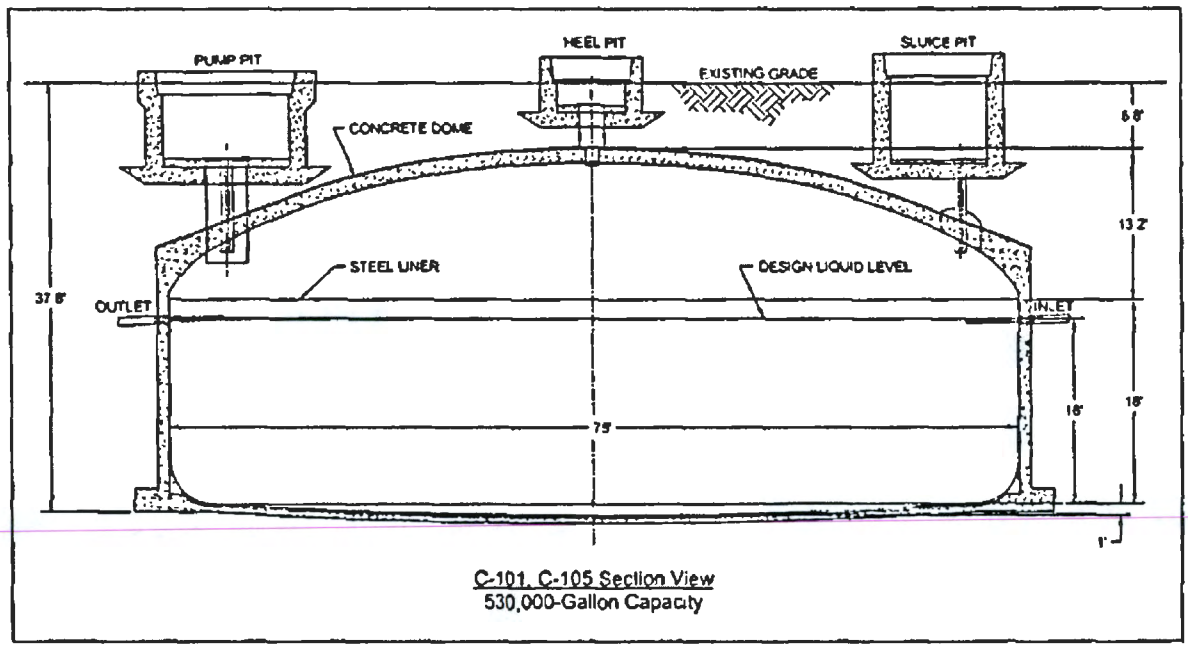
The SSTs were constructed in-place with a carbon steel lining on the bottom and sides, and a reinforced-concrete shell. The welded liners are independent of the reinforced-concrete tanks and were designed to provide leak-tight containment of the liquid radioactive wastes and to protect the reinforced-concrete 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 dished 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 and are shown in Figure 2.3 as a cross-section view.

Figure 2.3. Tanks C-101 and C-105 Cross-Section View.



Source: RPP-20658.

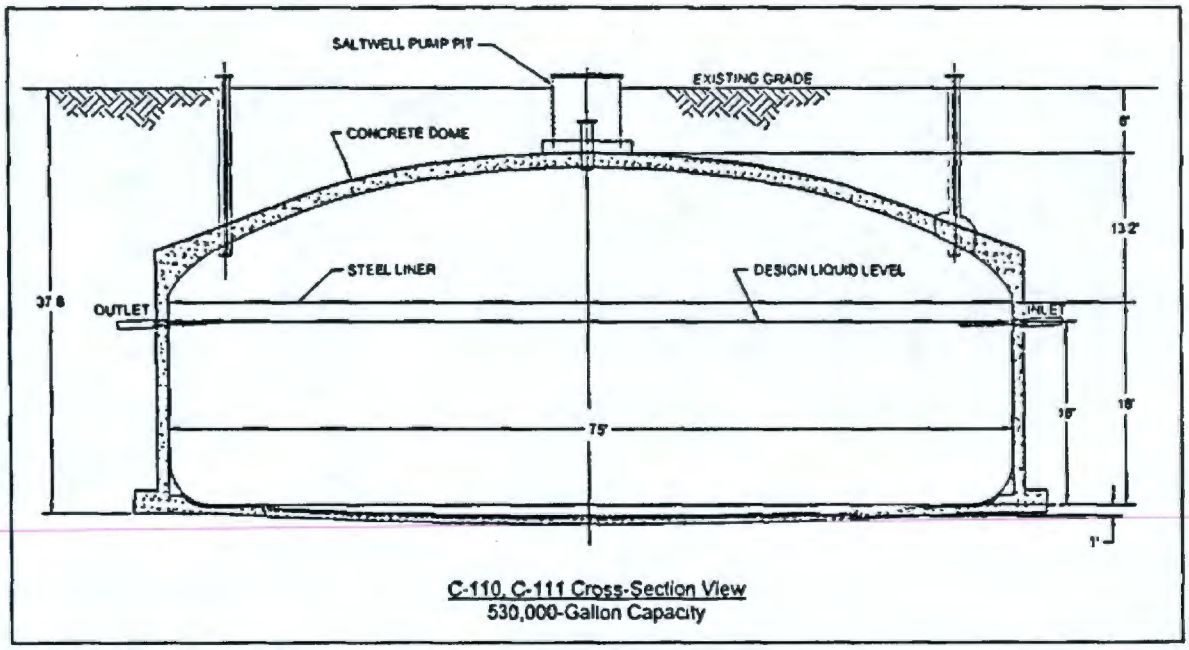
Note: The cascade line configuration in tanks C-101 and C-105 is different. Tank C-101 has only an outlet line and tank C-105 has both an inlet and outlet line.

Tanks C-101 and C-105 both have three process pits that were installed after initial tank construction to facilitate uranium recovery 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 2.5) located above the outside edge of the tank provided an indirect access path into the tank for ventilation.

2.2.2 Tank C-110 and C-111 Configuration

The configuration of tanks C-110 and C-111 is shown in Figure 2.4 as a cross-section view.

Figure 2.4. Tanks C-110 and C-111 Cross-Section View.



Modified from RPP-21616.

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 caissons that were installed over the center riser after initial tank construction to facilitate waste retrieval. The caissons were 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. These caissons extend above grade and are closed off on the top with a cover plate.

2.3 TANK RISER, FILL/CASCADE LINE INFORMATION

This section identifies the 'as is' configuration of the risers and fill/cascade lines. Use of the risers for waste retrieval is described in Section 3.0. Table 2.2 provides the size and current use/contents of tanks C-101 and C-105 risers and fill/cascade lines. Figure 2.5 provides the tanks C-101 and C-105 riser plan view. Table 2.3 provides the size and current use/contents of tanks C-110 and C-111 risers and fill/cascade lines. Figure 2.6 provides the tanks C-110 and C-111 riser plan view.

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
001	4	Abandoned temperature probe, benchmark	Temperature probe (multi-function instrument tree)
002	12	Temperature probe/manual tape	Ventilation line – air inlet filter
003	12	Sluicing access riser in weather covered pit (01-C pit)	Spare, weather covered (05-C pit)
004	4	Drain in weather covered pit (01-C pit)	Recirculating dip leg in weather covered pit (05-C pit)
005	4	Drain in weather covered pit (01-A pit)	Recirculating dip leg in weather covered pit (05-A pit)
006	12	Pump in riser in weather covered pit (01-A pit)	Sluicing access riser in weather covered pit (05-A pit)
007	12	Observation port through pitwall (01-A pit)	Pump
008	4	ENRAF/breather filter in offset adapter	Level instrument (ENRAF)
009	36	Pump in riser in weather covered pit (01-B pit)	Pump in riser in weather covered pit (05-A pit)
011	12	NA	Exhaust port in condenser hatchway cover
013	12	Pump in riser in weather covered pit	Future transfer pump
A*		NA	Cascade overflow outlet to tank C-106
B*		NA	Cascade overflow inlet from tank C-104
N1/C1*	3	Spare, plugged	Line V103, sealed in diversion box 241-C151
N2/C2*	3	Spare, plugged	Spare inlet, capped
N3/C3*	3	Line V102, sealed in diversion box 241-C151	Spare inlet, capped
N4/C4*	3	Line V104, sealed in diversion box 241-C151	Spare inlet, capped
N5*	3	Cascade outlet overflow to tank C-102	NA

* Cascade and/or fill line, not a riser. N1 through N4 are located in tank C-101. C-1 through C-4 are in tank C-105. Tank C-101 information is from RPP-8144. Tank C-105 information is from RPP-18633.

NA = not applicable.

Figure 2.5. Tanks C-101 and C-105 Riser and Fill/Cascade Line Plan View.

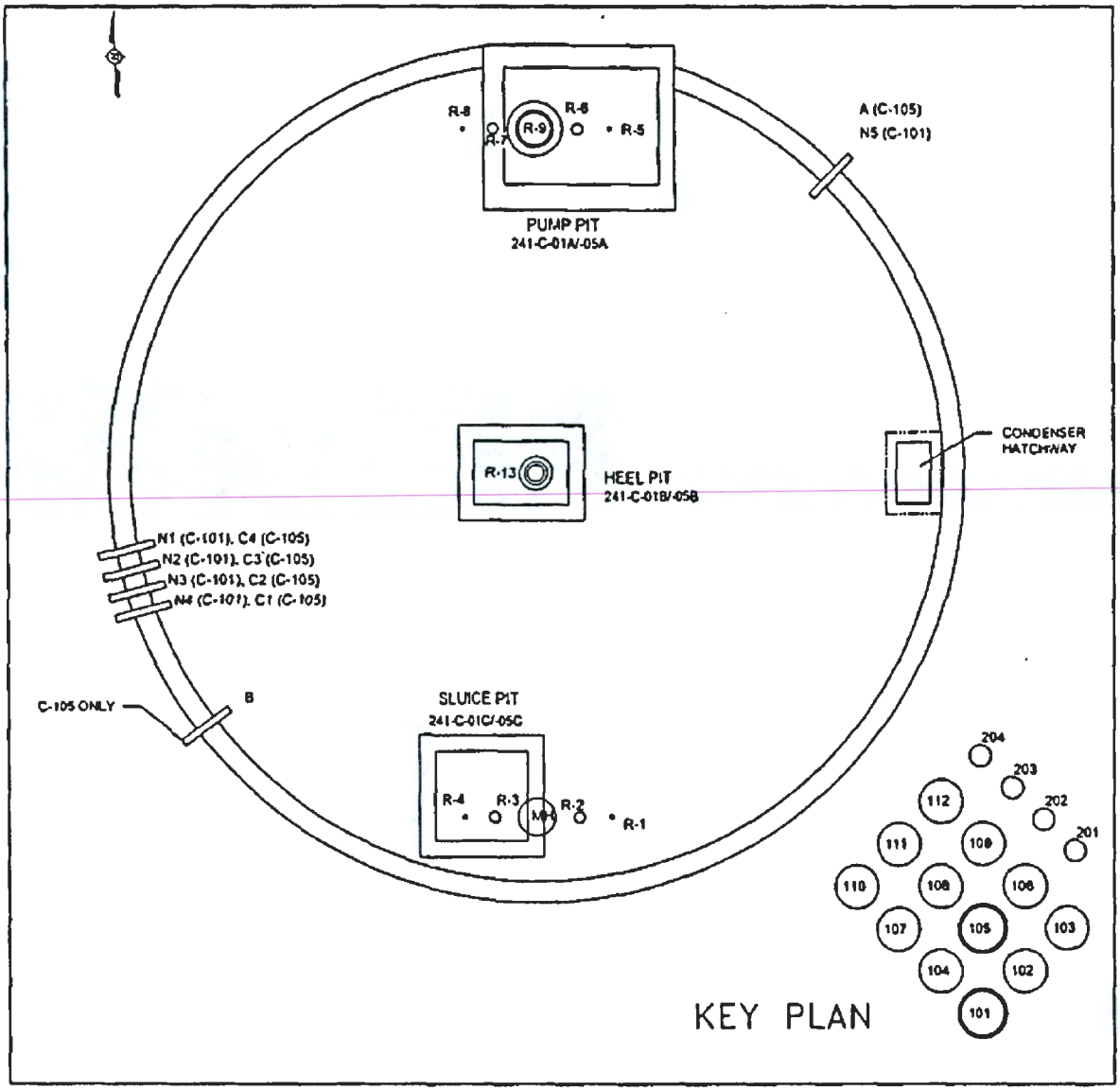


Table 2.3. Tanks C-110 and C-111 Riser and Fill/Cascade Line Descriptions.

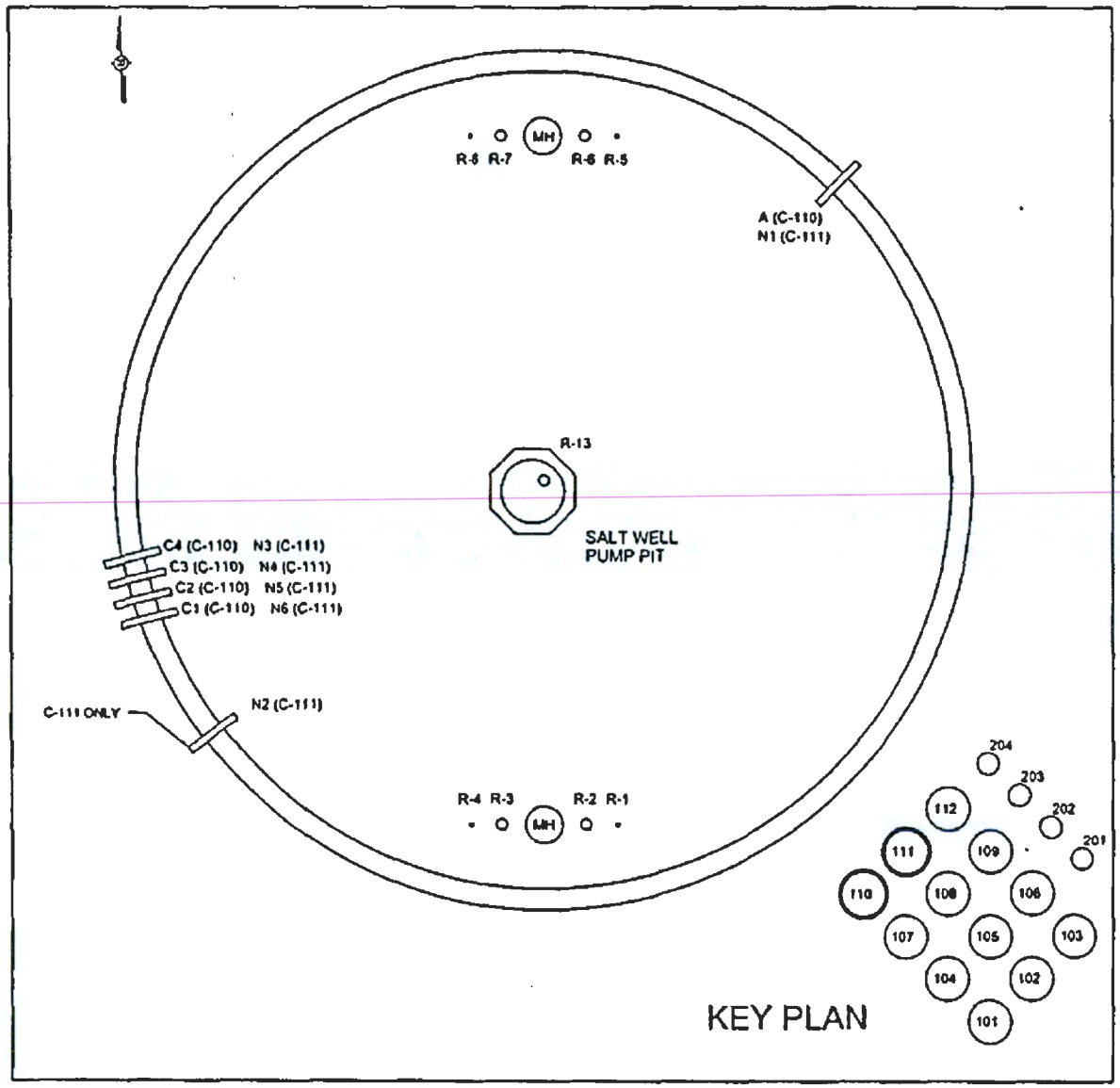
Component Identification Number	Diameter (in.)	Use Descriptions and Comments	
		Tank C-110	Tank C-111
R1	4	Spare, blind flange	Spare, blind flange
R2	12	Spare, blind flange with BM	Spare, blind flange with BM
R3	12	Breather filter	Spare, breather filter with offset adapter
R4	4	ENRAF	Spare, blind flange
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	ENRAF
R13	12	Saltwell pump in weather covered pit	Saltwell pump in weather covered pit
A*	3	Cascade line overflow to tank C-111	NA
B*	3	NA for this tank	NA
C1*	3	Fill line, sealed in diversion box 241-C-153	NA
C2*	3	Fill line, sealed in diversion box 241-C-153	NA
C3*	3	Fill line, sealed in diversion box 241-C-153	NA
C4*	3	Spare, capped	NA
N1*	3	NA	Cascade overflow outlet line
N2*	3	NA	Cascade inlet line from tank C-110
N3*	3	NA	Spare, capped
N4*	3	NA	Spare, capped
N5*	3	NA	Spare, capped
N6*	3	NA	Fill line V137, sealed in diversion box 241-C-153

* Cascade and/or fill line, not a riser.

BM = benchmark.

NA = not applicable.

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 C-105 is classified as 'sound' (HNF-EP-0182). Tank C-101 was designated as a 'confirmed or assumed leaker' in 1980 with an estimated leak volume of 20,000 gallons (HNF-EP-0182). A liquid level decrease was experienced in the late 1960s and the tank was taken out of service and pumped in 1969. Liquid level data showed continued decreases in the liquid level throughout the 1970s. The tank was saltwell pumped in the late 1970s. The tank contained aged plutonium-uranium extraction (PUREX) high-level supernate at the time the liquid level decreases were observed. However, the spectral gamma logging data from drywells around tank C-101 show little evidence of any leakage indicating that the liquid level decreases may have been associated with evaporation (*241-C Waste Management Area Inventory Data Package* [RPP-15317]).

Tank C-110 was designated as a 'confirmed or assumed leaker' in 1984 and has an estimated leak volume of 2,000 gallons (HNF-EP-0182). The spectral gamma logging data and historical waste transfer records provide no definitive evidence of leaks from this tank (RPP-15317).

Tank C-111 was designated as a 'confirmed or assumed leaker' in 1968 and has an estimated leak volume of 5,500 gallons (HNF-EP-0182). The integrity of the tank, and subsequently the leak volume estimate, are based on a reported liquid level drop. However, there are no spectral gamma data that suggest that the tank leaked (RPP-15317).

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 and could be associated with tank C-105.

2.5 TANK WASTE VOLUME/CHARACTERISTICS

The waste volume and select constituent inventories currently stored in tanks C-101, C-105, C-110, and C-111 awaiting retrieval are summarized in Table 2.4.

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 available inventory uncertainty data for tanks C-101, C-105, C-110, and C-111 is presented in Tables 2.5 through 2.8. 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 best-basis inventory (BBI) are provided in *Best Basis Inventory Process Requirements* (RPP-7625). The inventory uncertainty data associated with contaminants that drive long-term risk (e.g., technetium-99) can be used to provide insight to the uncertainty in long-term human health risks presented in Section 7.0.

Table 2.4. Waste Volume/Inventory Summary.

Waste Property	Units	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
Cesium-137[b]	Ci	3.00E+04	7.64E+04	1.35E+04	1.98E+04
Strontium-90[b]	Ci	3.80E+04	4.41E+05	3.45E+03	9.07E+05
Technetium-99[b]	Ci	4.54E-01	8.14E+01	3.18E+01	2.56E+00
Carbon-14[b]	Ci	6.60E-01	5.07E-01	3.33E-01	2.12E-01
Iodine-129[b]	Ci	1.39E-01	9.30E-02	4.00E-04	3.24E-02
Plutonium-238, -239, -240, -241[b]	Ci	8.34E+02	3.82E+03	8.41E+01	3.29E+02
Sodium[b]	kg	5.48E+04	3.80E+04	7.53E+04	1.38E+04
Nitrate/nitrite[b]	kg	7.35E+04	1.48E+04	1.04E+05	3.10E+04
Chromium[b]	kg	2.48E+02	3.84E+02	4.19E+02	8.85E+01

[a] Source: HNF-EP-0182.

[b] Source: Best-basis inventory download from http://twinsweb.pnl.gov/twins.htm dated August 24, 2004.

Note: Totals are rounded.

Table 2.5. Tank C-101 Inventory Uncertainty (2 Sheets).

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Inventory & Standard Deviation Units
^{137}Cs	Sludge	CWP1 (solid)	2.59E+04	3.98E+04	Ci
	Sludge	TBP (solid)	4.08E+03	4.11E+03	Ci
^{90}Sr	Sludge	TBP (solid)	3.78E+04	2.72E+04	Ci
Al	Sludge	CWP1 (solid)	7.88E+04	2.00E+04	kg
	Sludge	TBP (solid)	6.20E+02	2.30E+02	kg
Bi	Sludge	TBP (solid)	1.74E+02	5.14E+01	kg
Ca	Sludge	CWP1 (solid)	1.15E+03	1.16E+03	kg
	Sludge	TBP (solid)	9.02E+02	3.76E+02	kg
Cl	Sludge	CWP1 (solid)	1.11E+02	2.01E+02	kg
	Sludge	TBP (solid)	4.82E+02	3.19E+02	kg
Cr *	Sludge	CWP1 (solid)	1.92E+02	5.36E+02	kg
	Sludge	TBP (solid)	5.65E+01	3.09E+01	kg
F	Sludge	CWP1 (solid)	4.18E+02	3.13E+03	kg
	Sludge	TBP (solid)	2.70E+02	4.39E+02	kg
Fe	Sludge	CWP1 (solid)	3.07E+03	3.32E+03	kg
	Sludge	TBP (solid)	6.85E+03	1.42E+03	kg
K	Sludge	TBP (solid)	6.78E+01	3.64E+01	kg
La	Sludge	TBP (solid)	1.22E+01	1.23E+01	kg
Mn	Sludge	CWP1 (solid)	1.29E+02	1.20E+02	kg
	Sludge	TBP (solid)	5.58E+01	2.11E+01	kg
Na	Sludge	TBP (solid)	3.75E+04	8.72E+03	kg
	Sludge	CWP1 (solid)	1.75E+04	1.56E+04	kg
Ni	Sludge	TBP (solid)	2.55E+01	5.27E+00	kg
NO_2 *	Sludge	CWP1 (solid)	3.15E+03	6.59E+03	kg
	Sludge	TBP (solid)	4.41E+03	3.26E+03	kg
NO_3	Sludge	CWP1 (solid)	2.30E+03	9.09E+03	kg
	Sludge	TBP (solid)	6.40E+04	2.18E+04	kg
Pb	Sludge	CWP1 (solid)	1.62E+03	4.77E+03	kg
	Sludge	TBP (solid)	1.61E+02	1.03E+02	kg
PO_4	Sludge	CWP1 (solid)	1.07E+03	5.69E+03	kg
	Sludge	TBP (solid)	2.96E+04	1.16E+04	kg
Si	Sludge	CWP1 (solid)	3.56E+03	2.59E+03	kg
	Sludge	TBP (solid)	1.88E+02	9.61E+01	kg
SO_4	Sludge	CWP1 (solid)	8.60E+02	5.55E+02	kg
	Sludge	TBP (solid)	6.03E+03	6.97E+03	kg

Table 2.5. Tank C-101 Inventory Uncertainty (2 Sheets).

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Inventory & Standard Deviation Units
Sr	Sludge	CWP1 (solid)	8.73E+01	9.07E+01	kg
	Sludge	TBP (solid)	1.83E+02	6.62E+01	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
TOC	Sludge	CWP1 (solid)	1.43E+03	2.40E+03	kg
	Sludge	TBP (solid)	2.34E+02	8.48E+01	kg
U_{TOTAL}	Sludge	CWP1 (solid)	7.24E+03	1.26E+05	kg
	Sludge	TBP (solid)	4.03E+03	1.68E+03	kg
Zr	Sludge	TBP (solid)	2.96E+00	1.46E+00	kg
	Sludge	CWP1 (solid)	2.04E+02	3.23E+02	kg

Source: Best-basis inventory download from http://twinsweb.pnl.gov/data dated December 13, 2004.

* 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.

Table 2.6. Tank C-105 Inventory Uncertainty.

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Inventory & Standard Deviation Units
Al	Sludge	CWP1 (solid)	1.55E+05	1.82E+04	kg
	Sludge	TBP (solid)	1.39E+02	4.97E+01	kg
Ca	Sludge	CWP1 (solid)	1.78E+03	5.86E+02	kg
	Sludge	TBP (solid)	2.03E+02	8.21E+01	kg
Cl	Sludge	CWP1 (solid)	2.02E+02	3.65E+02	kg
	Sludge	TBP (solid)	1.08E+02	7.06E+01	kg
Cr *	Sludge	CWP1 (solid)	3.72E+02	4.97E+01	kg
	Sludge	TBP (solid)	1.27E+01	6.82E+00	kg
F	Sludge	CWP1 (solid)	7.62E+02	5.70E+03	kg
	Sludge	TBP (solid)	6.08E+01	9.86E+01	kg
Fe	Sludge	CWP1 (solid)	2.54E+03	3.06E+02	kg
	Sludge	TBP (solid)	1.54E+03	2.80E+02	kg
La	Sludge	TBP (solid)	2.73E+00	2.75E+00	kg
Na	Sludge	CWP1 (solid)	2.97E+04	3.74E+03	kg
	Sludge	TBP (solid)	8.44E+03	1.77E+03	kg
NO_2 *	Sludge	CWP1 (solid)	5.74E+03	1.20E+04	kg
	Sludge	TBP (solid)	9.92E+02	7.25E+02	kg
SO_4	Sludge	CWP1 (solid)	1.57E+03	1.00E+03	kg
	Sludge	TBP (solid)	1.36E+03	1.57E+03	kg
TIC as CO_3	Sludge	TBP (solid)	1.15E+02	5.85E+01	kg
	Sludge	CWP1 (solid)	1.30E+04	8.93E+03	kg
TOC	Sludge	CWP1 (solid)	4.26E+03	6.75E+02	kg
	Sludge	TBP (solid)	5.27E+01	1.83E+01	kg
Zr	Sludge	CWP1 (solid)	1.62E+02	2.40E+01	kg
	Sludge	TBP (solid)	6.66E-01	3.22E-01	kg

Source: Best-basis inventory download from http://twinsweb.pnl.gov/data dated December 13, 2004.

* 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.

Table 2.7. Tank C-110 Inventory Uncertainty (2 Sheets).

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Inventory & Standard Deviation Units
^{137}Cs	Sludge	1C (solid)	1.35E+04	2.26E+03	Ci
	Supernate	1C1 (liquid)	1.50E+01	2.54E+02	Ci
^{14}C	Sludge	1C (solid)	3.32E-01	1.10E-01	Ci
	Supernate	1C1 (liquid)	7.95E-04	1.34E-02	Ci
^{241}Am	Supernate	1C1 (liquid)	7.58E-05	1.28E-03	Ci
^{3}H	Sludge	1C (solid)	5.68E-01	1.03E-01	Ci
	Supernate	1C1 (liquid)	1.53E-03	2.59E-02	Ci
^{79}Se	Supernate	1C1 (liquid)	2.47E-04	4.18E-03	Ci
^{90}Sr	Sludge	1C (solid)	3.45E+03	7.10E+02	Ci
	Supernate	1C1 (liquid)	8.46E-02	1.43E+00	Ci
^{99}Tc *	Sludge	1C (solid)	3.18E+01	5.61E+00	Ci
	Supernate	1C1 (liquid)	7.11E-02	1.20E+00	Ci
Al	Sludge	1C (solid)	1.31E+04	1.67E+03	kg
	Supernate	1C1 (liquid)	8.34E-01	1.41E+01	kg
Bi	Sludge	1C (solid)	1.48E+04	2.02E+03	kg
	Supernate	1C1 (liquid)	7.66E-01	1.30E+01	kg
Ca	Supernate	1C1 (liquid)	5.52E-02	9.35E-01	kg
	Sludge	1C (solid)	1.05E+03	3.94E+02	kg
Cl	Sludge	1C (solid)	9.88E+02	2.48E+02	kg
	Supernate	1C1 (liquid)	2.92E+00	4.94E+01	kg
Cr *	Sludge	1C (solid)	4.19E+02	5.45E+01	kg
	Supernate	1C1 (liquid)	4.76E-01	8.06E+00	kg
F	Supernate	1C1 (liquid)	3.23E+00	5.46E+01	kg
	Sludge	1C (solid)	6.75E+03	1.13E+03	kg
Fe	Sludge	1C (solid)	9.84E+03	1.35E+03	kg
	Supernate	1C1 (liquid)	5.60E-01	9.47E+00	kg
Hg	Sludge	1C (solid)	3.98E-01	6.95E-02	kg
	Supernate	1C1 (liquid)	4.24E-04	7.17E-03	kg
K	Sludge	1C (solid)	5.10E+02	6.67E+01	kg
	Supernate	1C1 (liquid)	1.16E+00	1.96E+01	kg
La	Sludge	1C (solid)	1.32E+00	1.33E+00	kg
	Supernate	1C1 (liquid)	6.48E-03	1.10E-01	kg
Mn	Sludge	1C (solid)	4.76E+01	8.52E+00	kg
	Supernate	1C1 (liquid)	2.13E-03	3.60E-02	kg
Na	Sludge	1C (solid)	7.51E+04	9.65E+03	kg
	Supernate	1C1 (liquid)	1.22E+02	2.06E+03	kg

Table 2.7. Tank C-110 Inventory Uncertainty (2 Sheets).

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Inventory & Standard Deviation Units
Ni	Sludge	1C (solid)	2.17E+01	5.02E+00	kg
	Supernate	1C1 (liquid)	4.28E-03	7.25E-02	kg
NO_2 *	Sludge	1C (solid)	6.51E+03	2.23E+03	kg
	Supernate	1C1 (liquid)	1.84E+01	3.11E+02	kg
NO_3	Sludge	1C (solid)	9.77E+04	1.33E+04	kg
	Supernate	1C1 (liquid)	2.41E+02	4.08E+03	kg
Pb	Sludge	1C (solid)	2.20E+02	7.20E+01	kg
PO_4	Sludge	1C (solid)	5.67E+04	1.32E+04	kg
	Supernate	1C1 (liquid)	2.04E+01	3.45E+02	kg
Si	Sludge	1C (solid)	6.33E+03	8.42E+02	kg
	Supernate	1C1 (liquid)	5.78E-01	9.78E+00	kg
SO_4	Sludge	1C (solid)	1.11E+04	2.19E+03	kg
	Supernate	1C1 (liquid)	2.33E+01	3.94E+02	kg
Sr	Supernate	1C1 (liquid)	6.34E-03	1.07E-01	kg
	Sludge	1C (solid)	1.12E+02	2.02E+01	kg
TIC as CO_3	Sludge	1C (solid)	9.41E+03	1.78E+03	kg
	Supernate	1C1 (liquid)	1.09E+01	1.84E+02	kg
TOC	Sludge	1C (solid)	4.10E+02	2.85E+02	kg
	Supernate	1C1 (liquid)	2.32E+00	3.92E+01	kg
U_{TOTAL}	Sludge	1C (solid)	1.97E+03	6.34E+02	kg
	Supernate	1C1 (liquid)	1.29E+00	2.18E+01	kg
Zr	Sludge	1C (solid)	1.50E+02	2.13E+01	kg
	Supernate	1C1 (liquid)	7.30E-03	1.23E-01	kg

Source: Best-basis inventory download from http://twinsweb.pnl.gov/data dated December 13, 2004.

* Indicator constituents as identified in Section 7.1.1.1.

1C = first cycle decontamination.
TIC = total inorganic carbon.
TOC = total organic carbon.

Table 2.8. Tank C-111 Inventory Uncertainty (2 Sheets).

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Inventory & Standard Deviation Units
^{137}Cs	Sludge	1C (solid)	1.11E+03	1.01E+03	Ci
^{14}C	Sludge	1C (solid)	1.61E-02	1.67E-02	Ci
^{3}H	Sludge	TFeCN (solid)	1.76E+00	1.80E+00	Ci
	Sludge	1C (solid)	2.64E-02	1.93E-02	Ci
^{59}Ni	Sludge	TFeCN (solid)	2.40E+00	2.46E+00	Ci
^{63}Ni	Sludge	TFeCN (solid)	2.14E+02	2.19E+02	Ci
^{90}Sr	Sludge	1C (solid)	3.38E+02	2.46E+02	Ci
^{99}Tc *	Sludge	1C (solid)	1.70E+00	6.49E+00	Ci
Al	Sludge	1C (solid)	1.04E+03	7.34E+02	kg
Bi	Sludge	1C (solid)	1.33E+03	4.08E+02	kg
Ca	Sludge	1C (solid)	6.49E+01	4.12E+01	kg
Cl	Sludge	1C (solid)	7.92E+01	3.56E+01	kg
	Sludge	CWP1 (solid)	2.47E+01	4.49E+01	kg
	Sludge	TFeCN (solid)	1.59E+02	1.08E+02	kg
Cr *	Sludge	1C (solid)	5.82E+01	2.61E+01	kg
F	Sludge	1C (solid)	7.15E+02	5.76E+02	kg
	Sludge	CWP1 (solid)	9.34E+01	6.99E+02	kg
	Sludge	TFeCN (solid)	1.19E+02	1.94E+02	kg
Fe	Sludge	1C (solid)	7.08E+02	2.08E+02	kg
Hg	Sludge	1C (solid)	2.65E-02	3.55E-02	kg
	Sludge	TFeCN (solid)	1.06E+00	4.61E-01	kg
K	Sludge	1C (solid)	2.23E+01	1.75E+01	kg
	Sludge	TFeCN (solid)	9.18E+01	5.13E+01	kg
La	Sludge	1C (solid)	1.19E-01	1.22E-01	kg
Mn	Sludge	1C (solid)	6.57E+00	6.05E+00	kg
Na	Sludge	1C (solid)	6.96E+03	3.02E+03	kg
Ni	Sludge	1C (solid)	1.47E+00	1.07E+00	kg
NO_2 *	Sludge	TFeCN (solid)	8.46E+03	6.39E+03	kg
	Sludge	1C (solid)	6.80E+02	1.06E+03	kg
	Sludge	CWP1 (solid)	7.03E+02	1.48E+03	kg
NO_3	Sludge	1C (solid)	8.83E+03	6.86E+03	kg
	Sludge	CWP1 (solid)	5.14E+02	2.03E+03	kg
	Sludge	TFeCN (solid)	9.87E+03	3.70E+03	kg
Pb	Sludge	1C (solid)	1.37E+01	1.28E+01	kg
PO_4	Sludge	1C (solid)	4.86E+03	2.80E+03	kg
Si	Sludge	1C (solid)	4.31E+02	4.08E+02	kg

Table 2.8. Tank C-111 Inventory Uncertainty (2 Sheets).

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Inventory & Standard Deviation Units
SO_4	Sludge	CWP1 (solid)	1.92E+02	1.28E+02	kg
	Sludge	1C (solid)	9.39E+02	6.53E+02	kg
Sr	Sludge	1C (solid)	1.01E+01	3.26E+00	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	TFeCN (solid)	5.35E+03	2.90E+03	kg
TOC	Sludge	1C (solid)	3.69E+01	2.65E+01	kg
U_{TOTAL}	Sludge	1C (solid)	1.30E+02	1.42E+02	kg
Zr	Sludge	1C (solid)	9.60E+00	9.47E+00	kg
	Sludge	CWP1 (solid)	4.56E+01	7.26E+01	kg
	Sludge	TFeCN (solid)	2.04E+00	1.06E+00	kg

Source: Best-basis inventory download from http://twinsweb.pnl.gov/data dated December 13, 2004.

* Indicator constituents as identified in Section 7.1.1.1.

1C = first cycle decontamination.
CWP1 = aluminum cladding waste.
TFeCN = ferrocyanide scavenging.
TIC = total inorganic carbon.
TOC = total organic carbon.

Although there are uncertainties associated with contaminant inventories in the tanks, 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.

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. Additional sampling and analysis may be required to establish dilution and flushing requirements for waste transfers to avoid transfer line plugging in accordance with *Dilution and Flushing Requirements* (TFC-ENG-STD-26). TFC-ENG-STD-26 provides guidance for assessing the risks of line plugging due to either precipitation of solids from solution or deposition of insoluble solids. Sampling and analyses of the waste from each of the tanks will be performed at or near the end of waste retrieval activities in support of component closure activity actions. Sampling and analysis activities associated with component closure actions will be defined through the planned component closure data quality objective process and described in the associated waste sampling and analysis plans yet to be developed.

2.5.1 Tank C-101 Operating History

The following information is taken from *Tank Characterization Report for Single-Shell Tank 241-C-101* (WHC-SD-WM-ER-473). The purpose of WHC-SD-WM-ER-473 was to summarize the information on the historical uses, current status, and sampling and analysis results of waste stored in tank C-101. WHC-SD-WM-ER-473 supports requirements of HFFACO Milestone M-44-09. Milestone M-44-00 was designed to support characterization of the tank waste that would support retrieval of the tank waste for each SST. This information indirectly supports WAC 173-303-300.

Tank C-101 began receiving metal waste from the bismuth phosphate process in March 1946. In May 1946, the tank was declared full. During 1946, additions of metal 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 gallons. 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 *Tank Characterization Report for Single-Shell Tank 241-C-105* (WHC-SD-WM-ER-489). The purpose of WHC-SD-WM-ER-489 was to summarize the information on the historical uses, current status, and sampling and analysis results of waste stored in tank C-101. WHC-SD-WM-ER-489 supported requirements of HFFACO Milestone M-44-09. Milestone M-44-00 was designed to support characterization of the tank waste that would support retrieval of the tank waste for each SST. This information indirectly supports "General Waste Analysis" (WAC 173-303-300).

Tank C-105 began receiving metal waste from the bismuth phosphate process in 1947. The metal 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 metal waste to recover uranium. In 1956, the tank was pumped to a 79,000-gallon heel.

In August 1956, tank C-105 received PUREX coating 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-gallon 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 inches was recorded during the static period between the time of fill and late 1967. Although 'steaming' was indicated as the cause of this waste loss, no documentation of other decrease studies or temperature data are available. A 109,000-gallon 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 *Tank Characterization Report for Single-Shell Tank 241-C-110* (HNF-SD-WM-ER-367). The purpose of HNF-SD-WM-ER-367 was to summarize the information on the historical uses, current status, and sampling and analysis results of waste stored in tank C-101. HNF-SD-WM-ER-367 supported requirements of HFFACO Milestone M-44-09. Milestone M-44-00 was designed to support characterization of the tank waste that would support retrieval of the tank waste for each SST. This information indirectly supports WAC 173-303-300.

Tank C-110 began receiving waste in May 1946, and by April 1947 was filled with first-cycle 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 (*A History of the 200 Area Tank Farms* [WHC-MR-0132]). 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 *Tank Characterization Report for Single-Shell Tank 241-C-111* (WHC-SD-WM-ER-475). The purpose of WHC-SD-WM-ER-475 was to summarize the information on the historical uses, current status, and sampling and analysis results of waste stored in tank C-101. WHC-SD-WM-ER-475 supported requirements of HFFACO Milestone M-44-09. Milestone M-44-00 was designed to support characterization of the tank waste that would support retrieval of the tank waste for each SST. This information indirectly supports WAC 173-303-300.

Tank C-111 entered service in 1946 when first-cycle 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 waste resulting from in-farm scavenging of cesium-137 (TFeCN) (*An Assessment of the Inventories of the Ferrocyanide Watchlist Tanks* [WHC-SD-WM-ER-133]). 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 2 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 tank farms 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 below ground, reinforced-concrete boxes that were designed to contain any waste that leaked from the waste transfer line connections. Diversion boxes are generally drained by gravity to nearby catch tanks where any waste that accumulated from leaky jumper connections was stored and then pumped to SSTs. Some diversion boxes drain directly to SSTs.

One valve pit, 241-C (a corrugated structure with a concrete floor), also serves 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 salt wells to pump to the CR vault receiver tank, 003, through a single transfer line, SN-275.

Table 2.9 provides a summary of the C tank farm ancillary equipment connected to tanks C-101, C-105, C-110, and C-111.

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), a residual waste volume equal to 25% of the piping components is assumed. Additional details on the methodology used to estimate the inventory associated with the ancillary equipment is described in Section 7.0.

2.6.1 Tank C-101 Ancillary Equipment

Tank C-101 is connected to tank C-102 by a 3-inch-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 five 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, nozzles, conduits, and pit drains. Twenty pathways into tank C-101 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.

2.6.2 Tank C-105 Ancillary Equipment

Tank C-105 is connected to tanks C-104 and C-106 by 3-inch-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. Figure 2.8 illustrates the line and riser locations into and around tank C-105 along with their current uses. A cross-section view of tank C-105 is shown in Figure 2.3.

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 2.12. 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.

2.6.3 Tank C-110 Ancillary Equipment

Tank C-110 is connected to tank C-111 by a 3-inch-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-105 is shown in Figure 2.4, and 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, nozzles, and risers. Eight pathways into tank C-110 have already been isolated, as shown in Table 2.14. Current plans for isolation of all remaining pathways are shown in Table 2.15. This work will be accomplished in accordance with the tank closure plan.

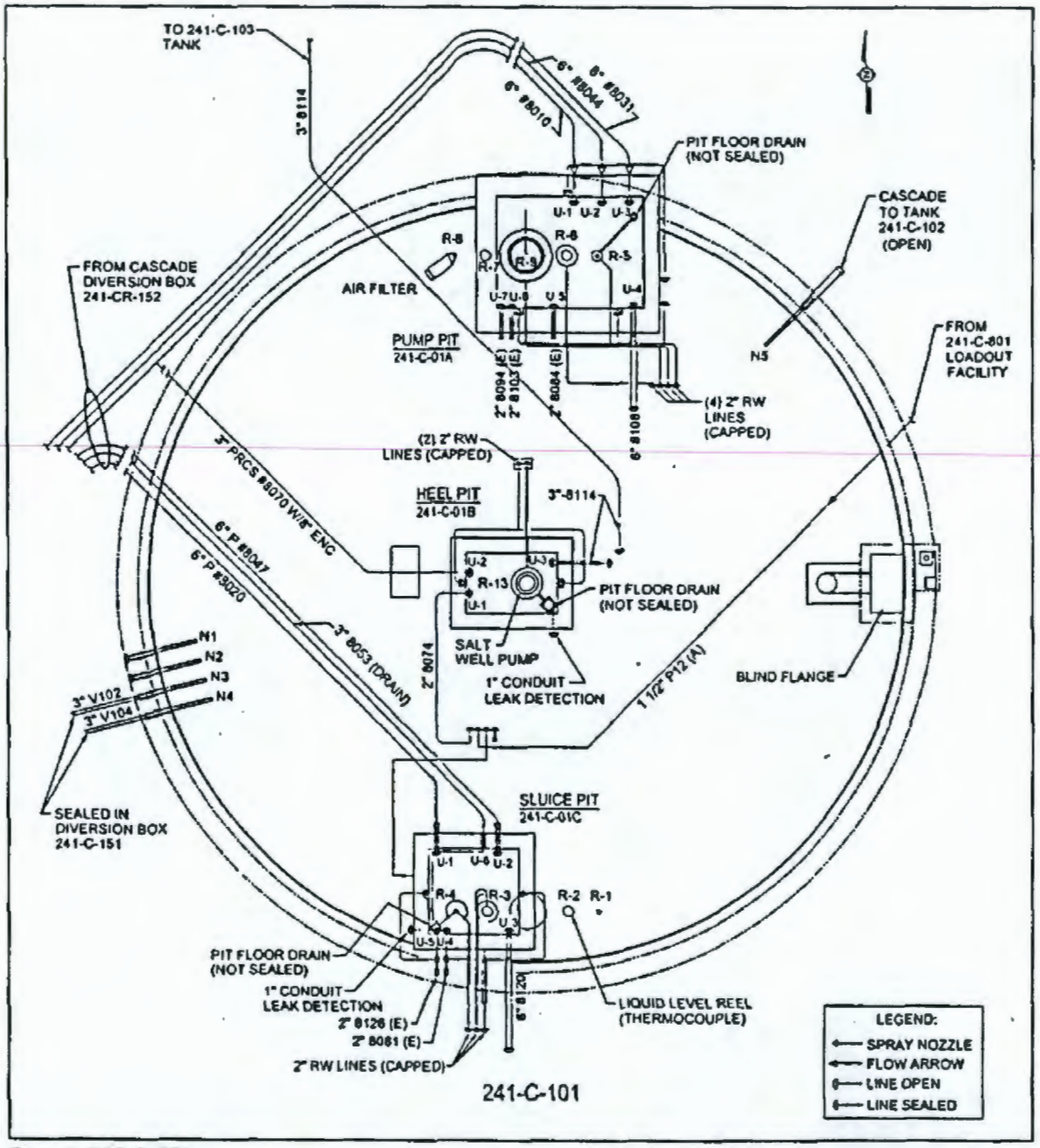
Table 2.9. C Tank Farm Components Associated with Tanks C-101, C-105, C-110, and C-111 (2 Sheets).

Single-Shell Tanks			
Tank	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	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 salt well caisson pit	
241-C-11		Covered salt well caisson pit	
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	8010	
8114	241-C-101-01B-U3	241-C-103	
SN250/8070	241-C-101-01B-U2	241-CR-152	
8047	241-C-101-01C-U2	241-CR-152-U1	
8053	241-C-101-01C-U6	241-CR-152-L11	

Table 2.9. C Tank Farm Components Associated with Tanks C-101, C-105, C-110, and C-111 (2 Sheets).

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

Figure 2.7. Tank C-101 Plan View.



Source: RPP-21571.

Table 2.10. Tank C-101 Previously Isolated Lines (2 Sheets).

Line	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 2.10. Tank C-101 Previously Isolated Lines (2 Sheets).

Line	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, L5	H-14-104175

Source: RPP-21571.

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

Table 2.11. 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

Source: RPP-21571.

Figure 2.8. Tank C-105 Plan View.

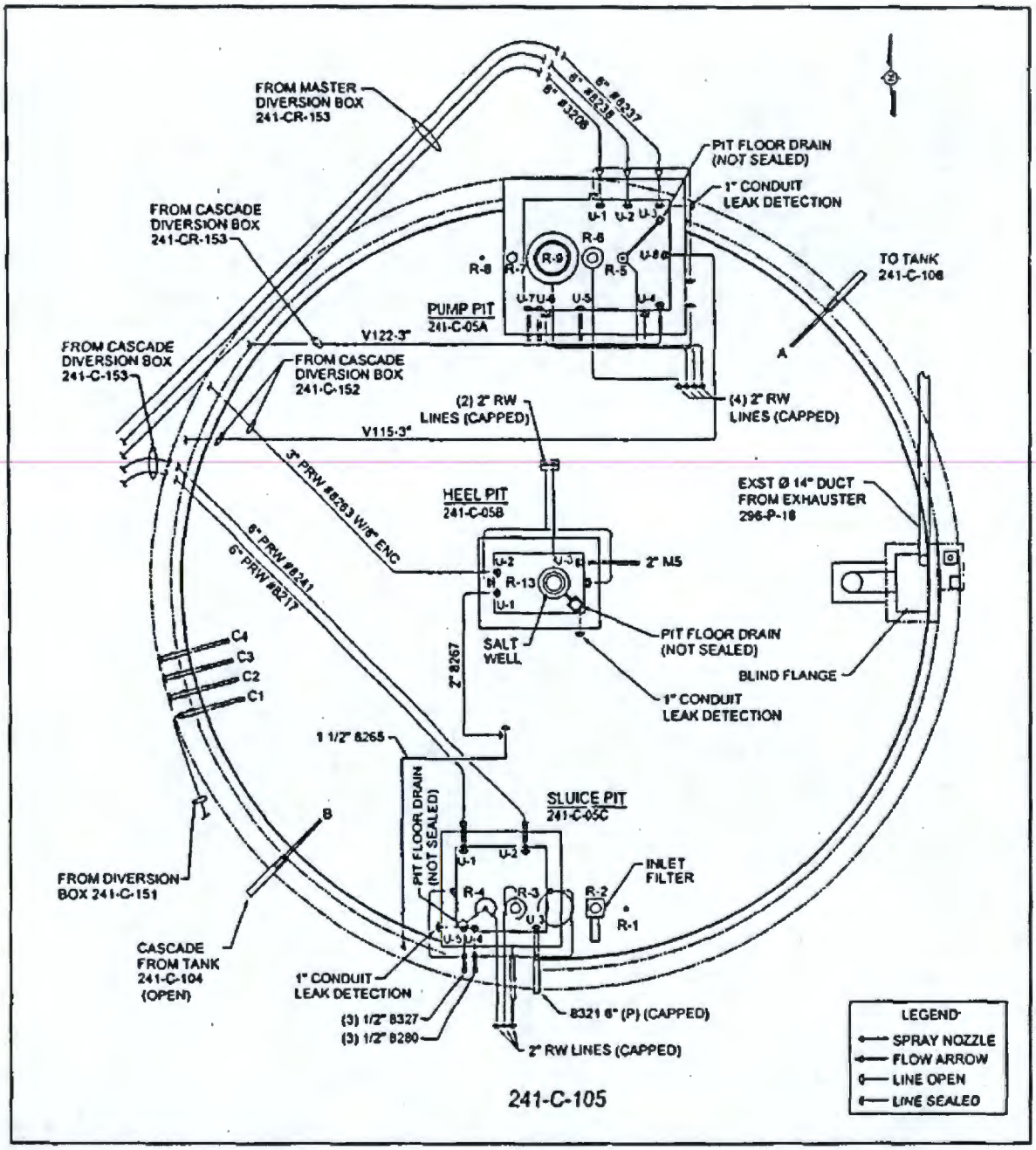


Table 2.12. Tank C-105 Previously Isolated Lines (2 Sheets).

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 2.12. 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

Source: RPP-20668

Table 2.13. 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.

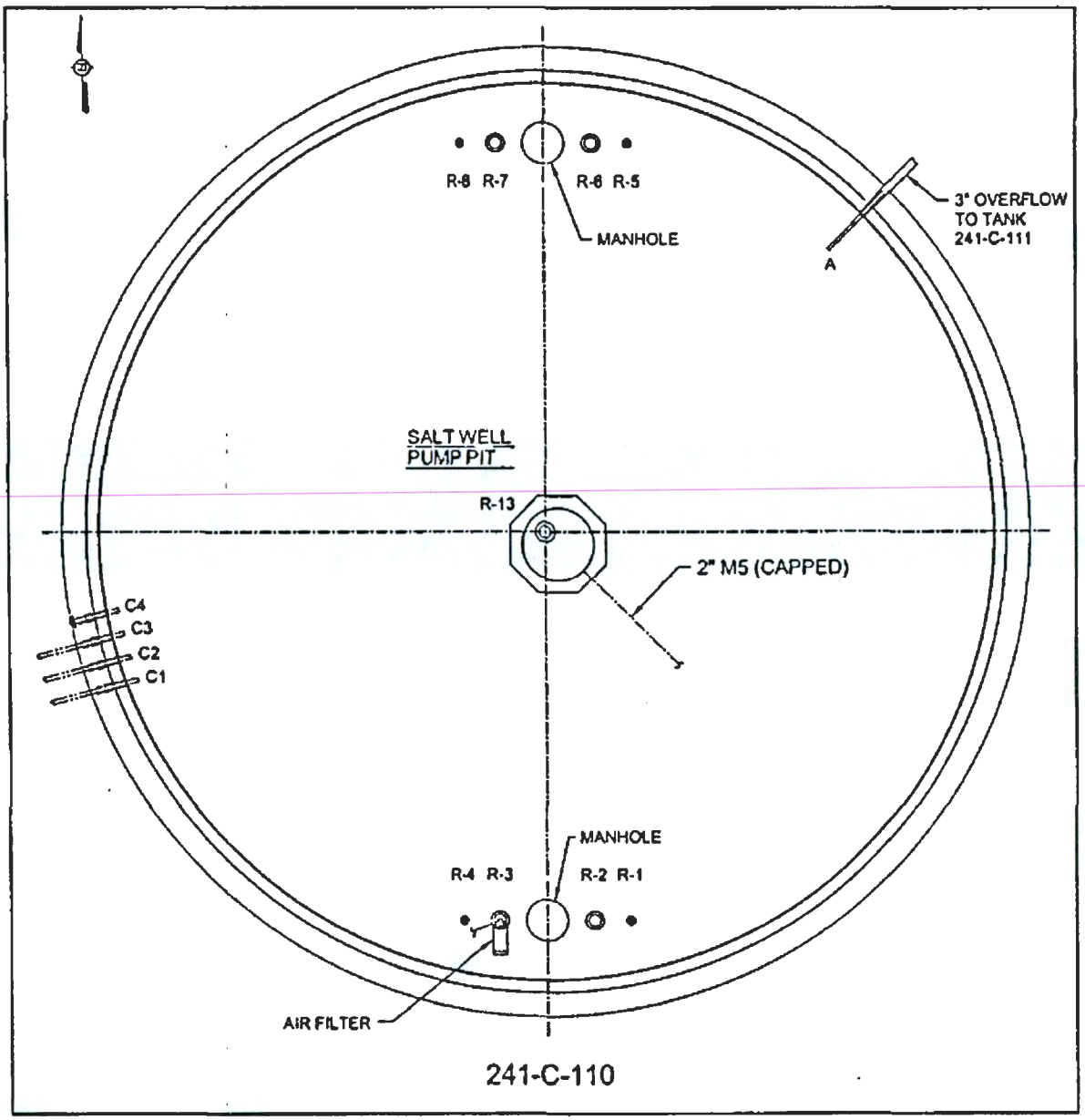


Table 2.14. Tank C-110 Previously Isolated Lines.

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	Salt well 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

Table 2.15. 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-inch-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, and 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, nozzles, and risers. Five pathways into tank C-111 have already been isolated, as shown in Table 2.16. Current plans for isolation of all remaining pathways are shown in Table 2.17. This work will be accomplished in accordance with the tank closure plan.

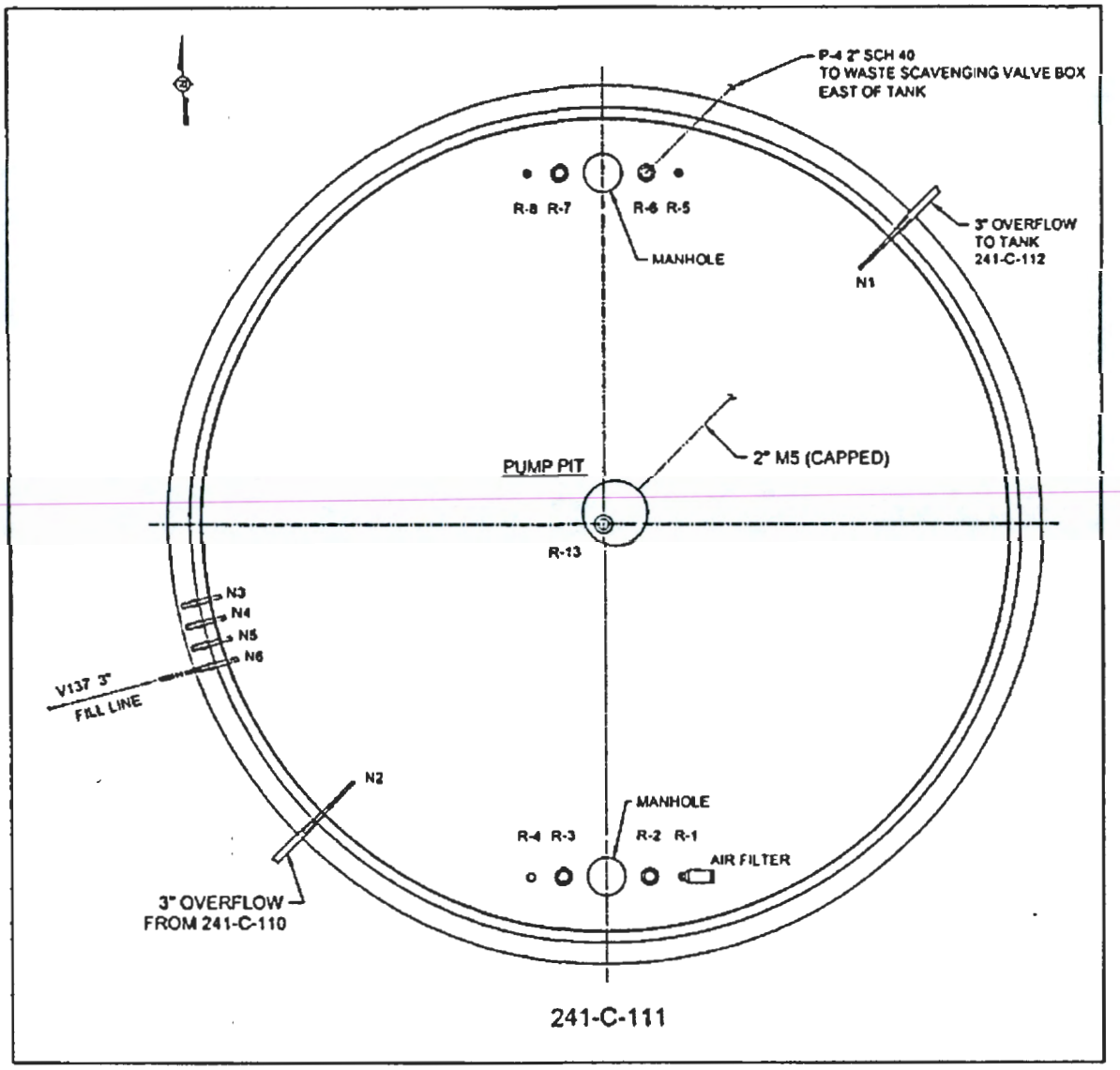
Table 2.16. Tank C-111 Previously Isolated Lines.

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

Table 2.17. 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

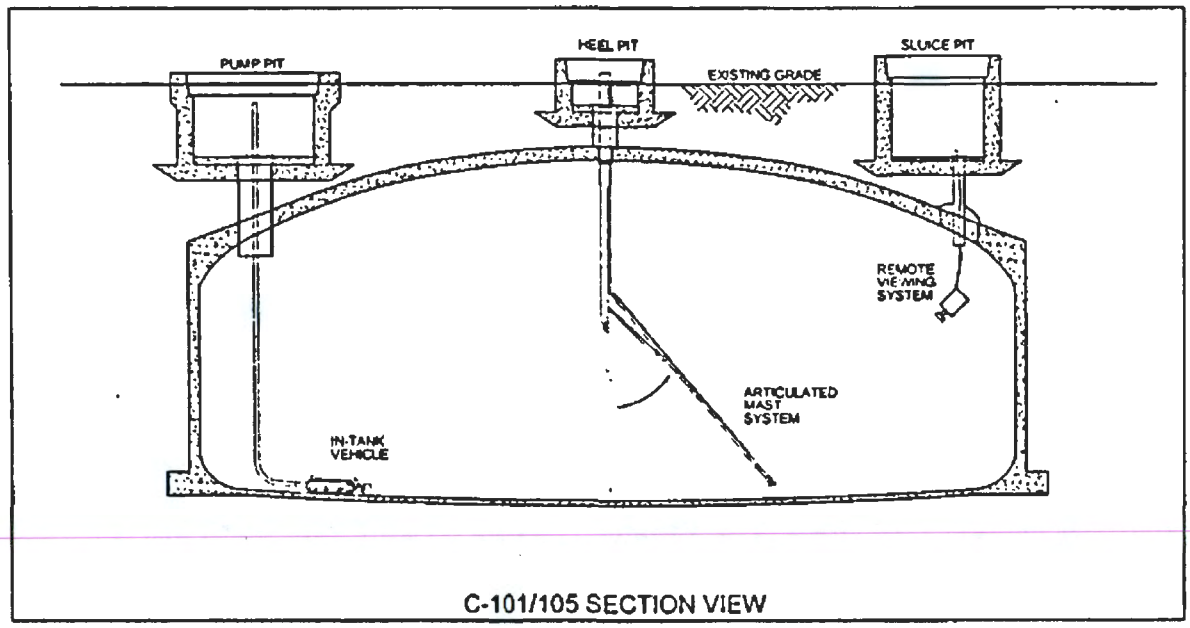
This section provides a description of the WRS and how it will be operated. The WRS description and operating description is based on the current design for the tank C-101 WRS. Continued design development and incorporation of lessons learned may lead to changes in the design and/or operating strategy.

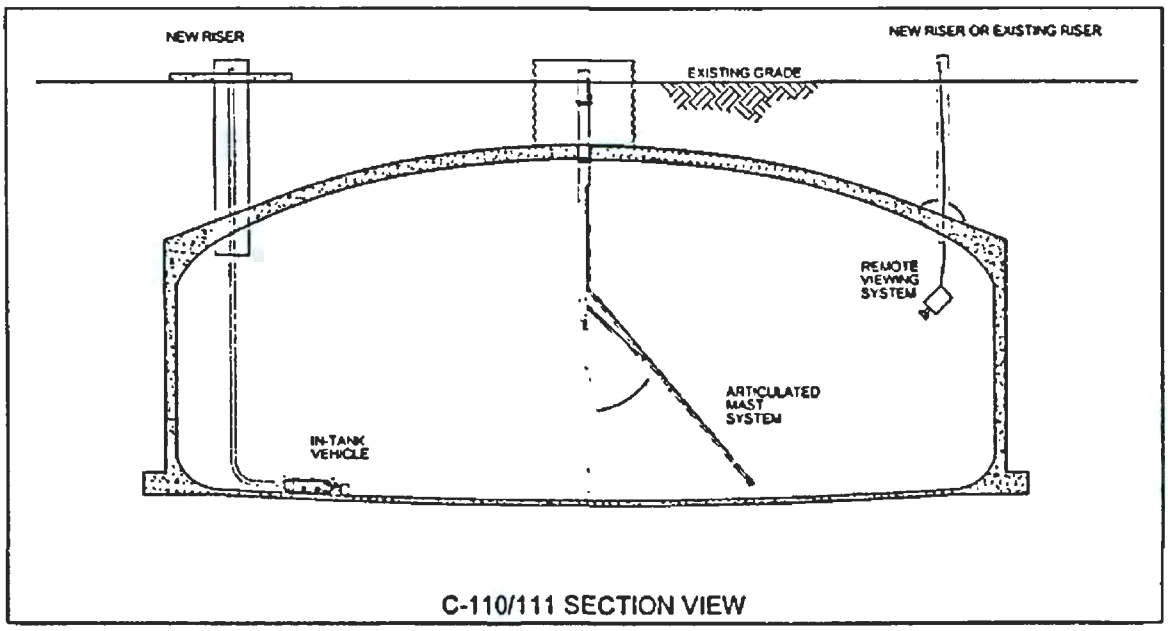
3.1.1 Waste Retrieval System Physical System Description

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 feet. Both air and water are 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 gallons.

The ITV is an adaptation of a commercially available tracked vehicle. The ITV will have a block for pushing 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 will be deployed once the articulated mast has removed waste from the central region of the tank. 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 real in the umbilical line during ITV operation. The umbilical management system is located above grade over a large-diameter (36-inch) 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.

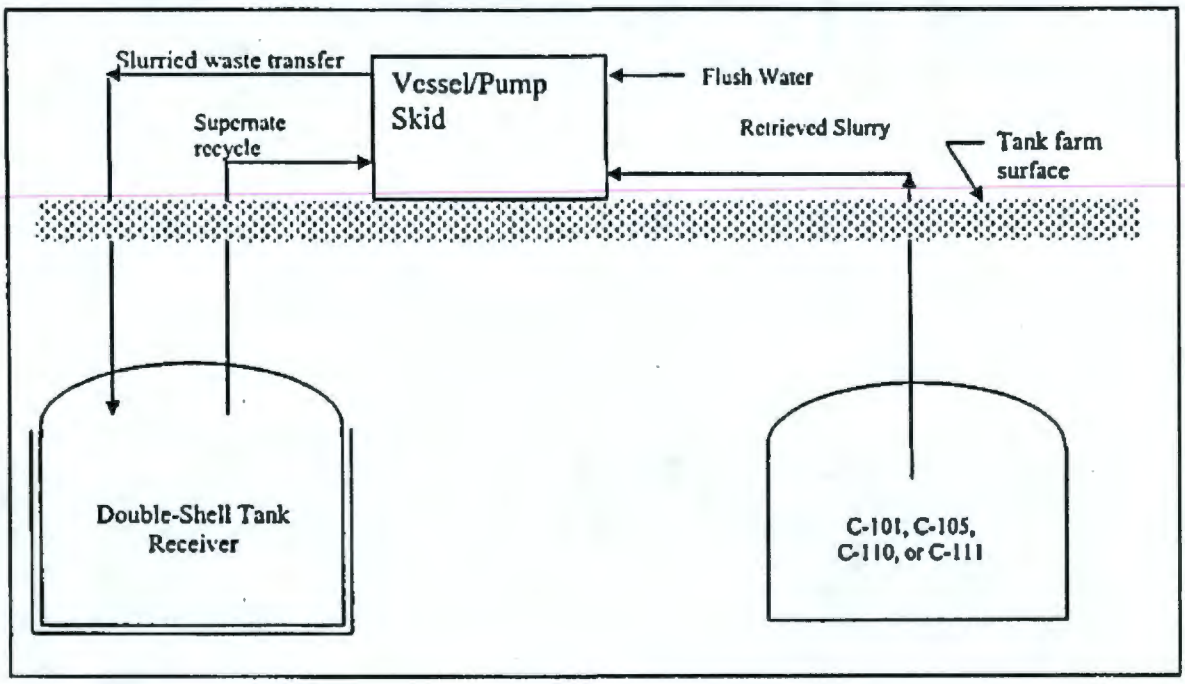
Figure 3.1. Mobile Retrieval System In-Tank Components Conceptual Diagram.





To minimize waste volumes, the current waste retrieval plan includes the use of 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. 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 and Double-Shell Tank Receiver Tank Designation.



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 on the tank, provided by an exhaust system, will filter and monitor the exhaust before discharge to the atmosphere.

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 tanks 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). The existing ENRAF gauges will be retracted during waste retrieval operations and will be used periodically to monitor waste levels. This information will be used to support material balance calculations. Section 4.0 provides details on the material balance calculations to be performed during waste retrieval operations.

Before initiating waste retrieval, a formal waste compatibility assessment will be performed in accordance with *Tank Farm Waste Transfer Compatibility Program* (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. Because of the number and schedule for waste transfers associated with tanks C-101, C-105, C-110, and C-111 an automated compatibility assessment tool has been developed and is in the final stages of verification and validation testing. The automated tool will be used to perform waste compatibility assessments in accordance with the waste transfer compatibility program.

During waste retrieval operations, the tank(s) will be actively ventilated. The ventilation system will consist of skid-mounted high-efficiency particulate air filtered portable exhausters. The ventilation system will be designed to pass air through the tank, thereby reducing condensation and fog within the tank. The vent systems will typically include a heater, prefilter, demister (if necessary), two high-efficiency particulate air filters and test sections, exhaust fan, and stack. Project plans include the design and installation of a new ventilation system to support waste retrieval operations for the C farm tanks as shown in Figure 3.3. Details on the new ventilation system will be provided in a future revision to the *Categorical Tank Farm*

Facility Waste Retrieval and Closure: Phase II Waste Retrieval Operations (AIR 04-1102) and the *Non-Radioactive Air Emission Notice of Construction for Categorical Tank Farm Facility Waste Retrieval and Closure, Phase II, Waste Retrieval*, approval pending. ORP/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 operations Industrial Hygiene (IH) departments 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.

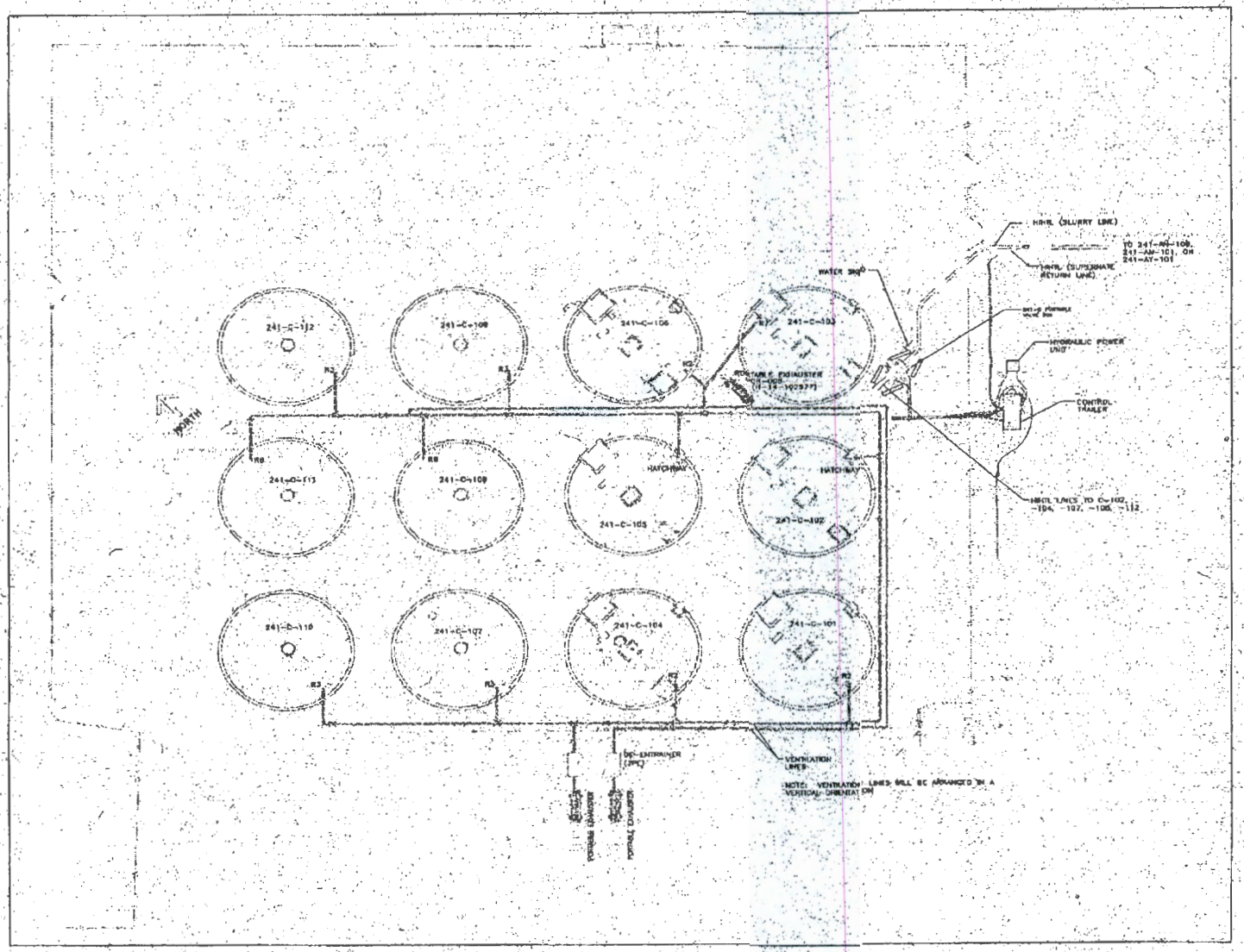
As required, the existing saltwell pumping system and other existing components in the tanks will be replaced by new equipment. The articulated mast will be installed in the center riser located in the heel pit. The configuration of tanks C-110 and C-111 is different in that there are no concrete pits 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.

Table 3.1. Planned Riser Usage for Tank C-101.

Riser Number	Tank C-101
R001	Not used
R002	Camera and ventilation exhaust duct
R003	Not used
R004	Not used
R005	Not used
R006	Not used
R007	Camera and breather filter
R008	Enraf level gauge
R009	In-tank vehicle
R13	AMS
Condenser pit	MRS drain lines and vacuum return

AMS = articulated mast system.
MRS = mobile retrieval system.

Figure 3.3. Potential New Ventilation Equipment Layout.



3.1.2 Double-Shell Receiver Tanks

The current planning includes using tank AY-101 as the receiver tank for waste retrieved from tanks C-101, C-110, and C-111 and tank AN-106 as the receiver tank for waste retrieved from tank C-105. Ongoing evaluations may result in identifying alternate receiver tank(s).
The receiver tanks will have a supernate pump that will be used to pump supernate back to the vessel/pump skid in the C tank farm to support waste transfers. The receiver tanks will also have slurry distributors to distribute the sludge received from the SSTs.

Because the elevation of the AN and AY tank farms is approximately 22 feet higher than the C tank farm, the slurry distributor and the supernate pump incorporate anti-siphon devices to prevent unintentional flow from the DST to the SST. Condensate drain lines from the ventilation system will be routed to the last sound tank scheduled for waste retrieval.

All waste transfers, including transfer of waste from the C farm tanks to the DSTs and the transfer of supernate from DSTs back to 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.

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. When the waste is removed from the central region of the tank, the ITV will be deployed 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.

Waste retrieval operations will normally 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. Before initiating waste transfer, the supernate recycle pump in the receiving DST will divert supernate to the vessel/pump skid and provide supernate as the carrier fluid for the waste transfer.

During the transfer mode, 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. Health physics and industrial health technicians will monitor conditions within the tank farm in accordance with standard operating procedures and 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 and sampling and analysis plan.

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, recycled DST supernate will be used for dilution before transferring the waste to the designated DST receiver tank. Supernate input will be approximately 20 to 30 gal/min. and slurry flow rate outputs will be approximately 75 to 80 gal/min.

The use of recycled supernate instead of water for most solutions used in the batch vessel skid retrieval results in the benefits enumerated below:

- Approximately 1 million gallons less liquid effluent discharged from the Liquid Effluent Treatment Facility in East Area for every 1 million gallons of water not added to the skid.
- An estimated 13 to 22 fewer drums of waste sent to disposal from Liquid Effluent Treatment Facility for every 1 million gallons of water not added to the skid.
- An equivalent increase in DST space available for waste retrieved from SSTs. If this volume is not available, some SST waste retrievals will be delayed, resulting in wastes remaining stored in non-compliant tanks for a longer period.
- A nominal 1 to 2 fewer evaporator campaigns for each 1 million gallons of water not used.

- Less fresh NaOH and $NaNO_2$ needed to bring the resulting DST solutions into the concentration limits specified for corrosion control. Depending upon other constituent concentrations in the DST solutions following mixing with the insoluble solids slurry and flush water, 0 to 44,000 kg of 100% NaOH will need to be added to the DST system to bring each 1 million gallons 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.

The C farm 100-series tank retrieval flowsheet document (*C Farm 100-Series Tanks, Retrieval Process Flowsheet Description* [RPP-21753]) has been prepared to evaluate waste retrievals. The flowsheet document is based on simulations performed with the Hanford Tank Waste Operations Simulator model. The flowsheet uses 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, the approximate number of batches required for waste retrieval, and the planned receiver tank. The volume of DST supernate used is not shown since this volume is not additive to the system, it is current solution that is recycled.

Table 3.2. Tanks C-101, C-105, C-110 and C-111 Retrieval Summary Data.

Tank[a]	Current Waste Volume (kgal)	Estimated Water Volume Used for Retrieval[b] (kgal)	Estimated Number of Batches
C-101	88	204	670
C-111	58	139	490
C-105	132	188	800
C-110	178	219	990

Sources: RPP-21753 for tanks C-105, C-110, and C-111. H-14-106761 for tank C-101.

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.

[a] Listed in sequence currently planned for retrieval.

[b] Data source for tank C-101 is the process flow diagram H-14-106761, with additional water added equal to 10% of the planned supernate usage. Data source for tanks C-111, C-105, and C-110 is RPP-21753. Water volume estimates for tanks C-111, C-105, and C-110 are based on using 160 gallons of water for each 240-gallons batch of waste solids plus an allocation of 1 million gallons to account for water additions that may occur over the course of waste retrieval (e.g., flushes, washing down tank walls, equipment decontamination). This estimate will be revised during development of tank-specific process flow diagrams.

DST = double-shell tank.

SST = single-shell tank.

The timing for waste transfers is dependent upon personnel resource availability, equipment availability, and DST conditions. Once waste retrieval operations are started they will follow the general pattern described in this section. The specific schedule for liquid additions to the tanks or waste transfers to the DSTs cannot be predicted more than a day or two in advance, so a detailed timeline for liquid additions and transfers cannot be developed showing all liquid additions and removals. The addition of water during waste retrieval may be continuous or intermittent. Ideally waste retrieval operations would be completed in accordance with the planned schedule, but delays with tank farm work and the lack of available resources could stretch waste retrieval durations.

Table 3.3 provides an estimate of sum of the various water additions for the tank C-101 retrieval process based on the draft process flow diagram. Process flow diagrams have not been developed for the remaining three tanks, but liquid additions associated with the remaining three tanks are estimated to be in roughly the same proportions as the individual tank waste volumes.

Table 3.3. Estimated Water Usage for Tank C-101.

Stream	Total Volume for Waste Retrieval System (kgal)	Volume Added to C-101 Over Course of Waste Retrieval (kgal)
Low-pressure water to AMS	10	1
High-pressure water to AMS	22	22
Air separator drain	7	7
Batch vessel flush	5	1
Low-pressure water to ITV	105	105
High-pressure water to ITV	29	29
ITV decon water	1	1
Batch vessel & transfer line flush	25	0
Total	204	166

AMS = articulated mast system.
ITV = in-tank vehicle.

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

6. Low-pressure water 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 to prime and flush transfer pump

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

10. Low-pressure water 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.)

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 will also go 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 will either be 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 will either be 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. It is planned to use recycled supernate predominantly for streams 6, 7, 8, 9, and 10 but there may be some times when water will be used instead of supernate.

Stream 18 will consist of a yearly generation of a nominal 2,000 gallons of drain water. This would 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 final tank flush, stream 19, will be made at the end of waste retrieval for each tank. This flush may be done using water from the AMS head or the ITV. If the residual waste adhering to the tank walls and bottom is sufficiently small that there is less than 360 ft^3 of waste remaining in the tank, the flush may not be needed. However, if there is more than 360 ft^3 of waste remaining in the tank it may be necessary to flush material located on the tank walls or bottom to reduce the residual waste volume. Any final flush water is removed after it is added to the tank. Much of the walls will likely be flushed down as the waste level decreases during retrieval so the final tank flush may mostly be of the tank bottom.

Stream 21 liquid will be dependent upon dose rate conditions following retrieval. If personnel exposures can be kept low while handling the equipment, there may be no flush required. High dose rates will require flushing until personnel can effectively handle the equipment. 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 gallons. A flush of the ITV would likely require 300 to 1,000 gallons of water, but the volume could be greater if there was significant waste stuck to the unit.

The flowsheet document addresses the impact of C farm waste retrieval on the DST space and what actions are required to accommodate the C farm waste (as retrieved) in the DST system. The as-retrieved waste volume represents a short-term or transient impact on DST space as any excess water can be removed through evaporation within tank farm operating limits. The impact of C farm waste on the DST system with respect to long-term storage will be addressed in future

revisions of the SST retrieval sequence and DST space evaluation document prepared in response to HFFACO Milestone M-45-02. A number of DST to DST transfers are identified in the flowsheet document to make room for the waste retrieved from the C farm tanks. Because the supernate is recycled for waste transfer dilutions, the net liquid addition to DST receiver tanks will be the water added during waste retrieval.

DST supernate was selected as the transfer medium to minimize the net volume increase in waste requiring storage in the DST system. If water were to be used for transferring waste retrieved from tanks C-101, C-105, C-110, and C-111, the net increase in retrieval waste volume requiring storage in the DST system would be approximately 1.1 million gallons ("Selection of Single-Shell Tanks (SST) to be Retrieved in Fiscal Year (FY) 2005, Single-Shell Tank (SST) Retrieval Selection and Sequence, RPP-21216, Revision 0A" [04-TPD-102]). If water were used for transferring waste retrieved from tanks C-101, C-105, C-110, and C-111, the retrieved waste volume would require additional waste transfers to other DSTs and evaporation of the liquid to reduce the volume.

Other factors, such as staging transfers to accumulate the required volume of waste feed or problems associated with sampling and analysis, could cause additional delays of the evaporator operations and further impact the waste retrieval operations.

If water were used for transferring waste, the additional waste volume would need to be managed within the space constraints of the DST system and would require evaporation resulting in increased effluents going to the Effluent Treatment Facility and caustic additions for corrosion control, which would result in additional chemical load on the Waste Treatment Plant.

Until operating experience is obtained with the vacuum retrieval system, the time required to retrieve waste from the C farm 100-series tanks can only be roughly estimated. A wide range is possible for a tank waste retrieval time since there are many factors unrelated to retrieval operations that can, and will, influence the retrieval times. Should all the equipment operate as designed, with personnel available around the clock to conduct retrieval operations and no other factors unrelated to retrieval that impede operation, retrieval could be completed for a C farm 100-series tank within a few months. Depending upon resource availability, operability of the equipment, and factors unrelated to retrieval, operations could stretch out to a year or more to complete each tank.

Resource limitations, equipment difficulties, and the implementation of a new technology never before used for radioactive waste retrieval make it impractical at this time to provide solid estimates for the times involved. Different batch waste loadings or operating efficiencies, operating problems, and/or different batch cycle times will proportionately affect the waste retrieval times.

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-foot 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, an area approximately 21 feet 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 on the order of 200 to 2,000 gallons 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 will be 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 inches and an average 17% porosity. The waste surfaces vary with location in the tank, but assuming the November 11, 2004 waste levels represent an approximate average, tank C-101 has about 39 inches of waste, tank C-105 has about 53 inches, tank C-110 has about 71 inches, and tank C-111 has about 28 inches. It is unknown what the interstitial liquid level is in each tank, but conservatively assuming only the bottom 24 inches of waste in each of these tanks is saturated tank C-101 could absorb about 6,800 gallons; tank C-105 about 13,000 gallons; tank C-110 about 22,000 gallons; and tank C-111 about 1,800 gallons before a free liquid surface would form. These are conservative values since waste will be retrieved from the center region of the tank out toward the tank walls. Liquid will be removed as practical from the central depression and as the depression gets deeper the volume of interstitial liquid will get less and less. The main thing that can be done about the interstitial liquid is to minimize liquid in the central depression as practical during retrieval. Should the free liquid observed in the tank appear to cover more than one third of the tank surface, as estimated from observation with the video system, retrieval activities will be focused on surface liquid removal. This will amount to about 900 gallons of liquid per 1 inch of depth. The depth will vary some, but most of the depth should be in the area being retrieved. Assuming an average 2-inch depth of a liquid pool, should there be a simultaneous failure of both vacuum pumps or some other equipment failure occur which prevents retrieval of liquid added to a tank the likely volume of pooled liquid that would remain in the tank until the equipment failure was fixed is thus roughly estimated at less than a nominal 1,800 gallons. Should the batch vessel need to be drained during the retrieval an additional 400 gallons could be added. The length of time this free liquid would remain in the tank will be dependent upon the time to repair the equipment, which could be 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. Recycled supernate (or water) 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, recycled supernate (or water) 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.

3.3 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 costs less potentially 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). 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 to the limits of the technology, whichever is less in accordance with the requirements of HFFACO Milestone M-45-00 (see Section 3.6).

3.5 WASTE RETRIEVAL SYSTEM DIAGRAM

A preliminary diagram of the WRS in-tank components is provided in Figure 3.1. A plan view showing the abovegrade skid locations is not available at this time and will be provided in the future. As noted in Section 3.1.1, the elevation in the AN and AY tank farms is approximately 22 feet 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.

Other requirements not directly applicable to the level of definition provided in this document are disseminated to CH2M HILL via the DOE-CH2M HILL Contract (Contract DE-AC-27-99RL14047). Specifically, the functions and requirements included in this document are derived from the need to satisfy the HFFACO Milestone M-45-00 requirements. The functions and requirements are provided in Table 3.4 and are focused on defining the upper-level requirements for the tanks WRS.

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

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. Existing hardware and equipment installed in the tank risers will be removed and disposed of as required for installation of the WRS.

Based on the historical information presented in Sections 2.2 and 2.5, the abandoned process lines used for previous waste transfers will likely be contaminated through contact with the waste but should have limited potential for containing residual liquid or solid waste. These abandoned lines were constructed with a positive slope to facilitate drainage (a design requirement) and 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.

With the exception of the cascade lines, the existing documentation denotes that 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. If it is found that any of these lines have not been isolated during installation of the WRS, then isolation methods will be evaluated and performed by the tank closure program. All isolation methods will be reversible so as not to preclude future closure actions. 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.

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 173-400 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 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 single-shell tanks	The WRS shall be operated to prevent waste level from exceeding 185 inches.	OSD-T-151-00013	Minimize liquid level to the extent practical.
Control waste level in tank 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	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.	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 tank	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, 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.	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.
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.

Given (1) the configuration of the waste transfer lines (isolated), (2) the low potential for residual waste to remain in the lines, and (3) the uncertain physical condition of the lines, the waste retrieval project does not plan to remove any additional residual waste from the transfer lines. In accordance with the WMA C closure action plan (RPP-13774), disposition of the ex-tank ancillary equipment, including pipelines, will be performed in accordance with a separate component closure activity plan.

3.8 INFORMATION FOR NEW ABOVEGROUND TANK SYSTEMS

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

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

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.

3.9 DISPOSITION OF WASTE RETRIEVAL SYSTEM FOLLOWING RETRIEVAL OPERATIONS

Following completion of waste retrieval operations, it is planned that the abovegrade portions of the systems would be flushed to reduce contamination levels and moved for redeployment to

other tanks. Any abovegrade equipment that 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 *Contaminated Equipment Management Practices* (TFC-OPS-WM-C-10). The hose-in-hose transfer lines will be managed in accordance with *Temporary Waste Transfer Line Management Program Plan* (RPP-12711).

4.0 LEAK DETECTION, MONITORING, AND MITIGATION

The integrated leak detection, monitoring, and mitigation strategy for tanks C-101, C-105, C-110, and C-111 has been developed to meet the requirements specified in the HFFACO M-45 series milestones and to manage the risk posed by potential waste leakage during waste retrieval operations. The strategy for leak detection, monitoring, and mitigation 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 leak detection, monitoring, and mitigation strategy:

- Is technically practicable and defensible
- Considers applicable regulations and requirements
- Uses leak detection, monitoring, and mitigation 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 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 *Hanford Tank Farms*

Vadose Zone Monitoring Project, Baseline Monitoring Plan (GJO-HGLP 1.8.1). 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 *Hanford Tank Farms Vadose Zone: C Tank Farm Report* (GJPO-HAN-18) and in *Hanford Tank Farms Vadose Zone Monitoring Project: Quarterly Summary Report for Second Quarter Fiscal Year 2004* (DOE-EM/GJ641-2004). Evaluation of historical drywell monitoring data is provided in *Subsurface Conditions Description of the C and A-AX Waste Management Areas* (RPP-14430).

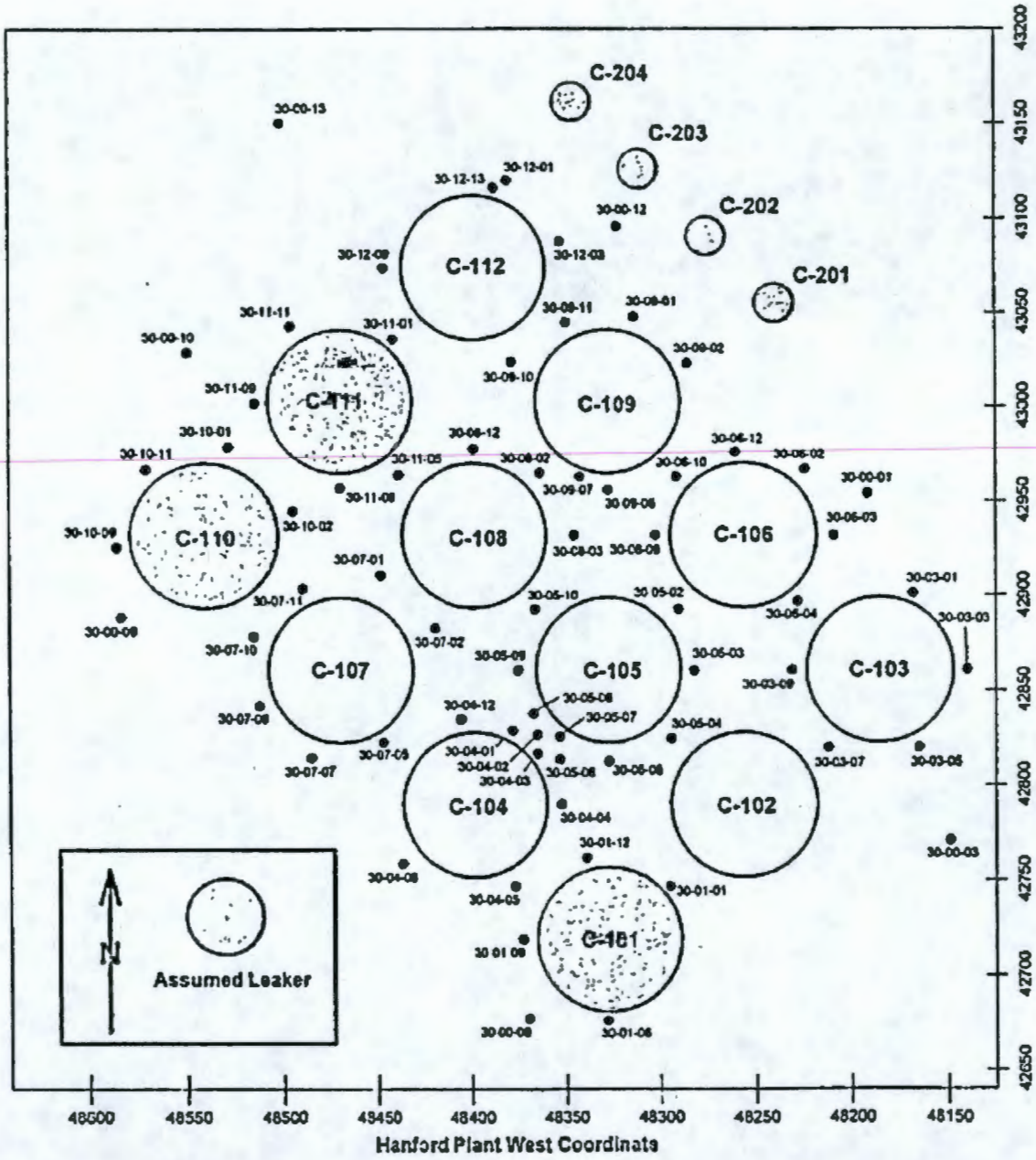
There are six drywells spaced around C-101 that are between 2 and 20 feet from the edge of the tank (Figure 4.1). The six drywells include 30-01-01, 30-01-06, 30-00-06, 30-01-09, 30-04-05, and 30-01-12. Five of the drywells are 100 feet deep. One drywell (30-00-06) is drilled to 150 feet deep but can only be logged to 111 feet because of grouting (*Vadose Zone Characterization Project at the Hanford Site Tank Farms Tank Summary Data Report for Tank C-101* [GJ-HAN-85]).

Ten drywells are spaced around tank C-105 that are between 2 and 12 feet 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 feet deep, 3 drywells are 100 feet deep, and 4 are between 120 and 135 feet deep (*Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-105* [GJ-HAN-83]).

Seven drywells are spaced around tank C-110 that are between 5 and 19 feet 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 feet deep with drywell 30-00-09 being 58 feet deep.

Seven drywells are spaced around tank C-111 that are between 5 and 25 feet 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 feet deep (*Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-111* [GJ-HAN-93]).

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 *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring plan established in 2001 (*RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site* [PNNL-13024]). 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, total uranium, and a low-level gamma scan is performed (*Hanford Site Groundwater Monitoring for Fiscal Year 2003* [PNNL-14548]).

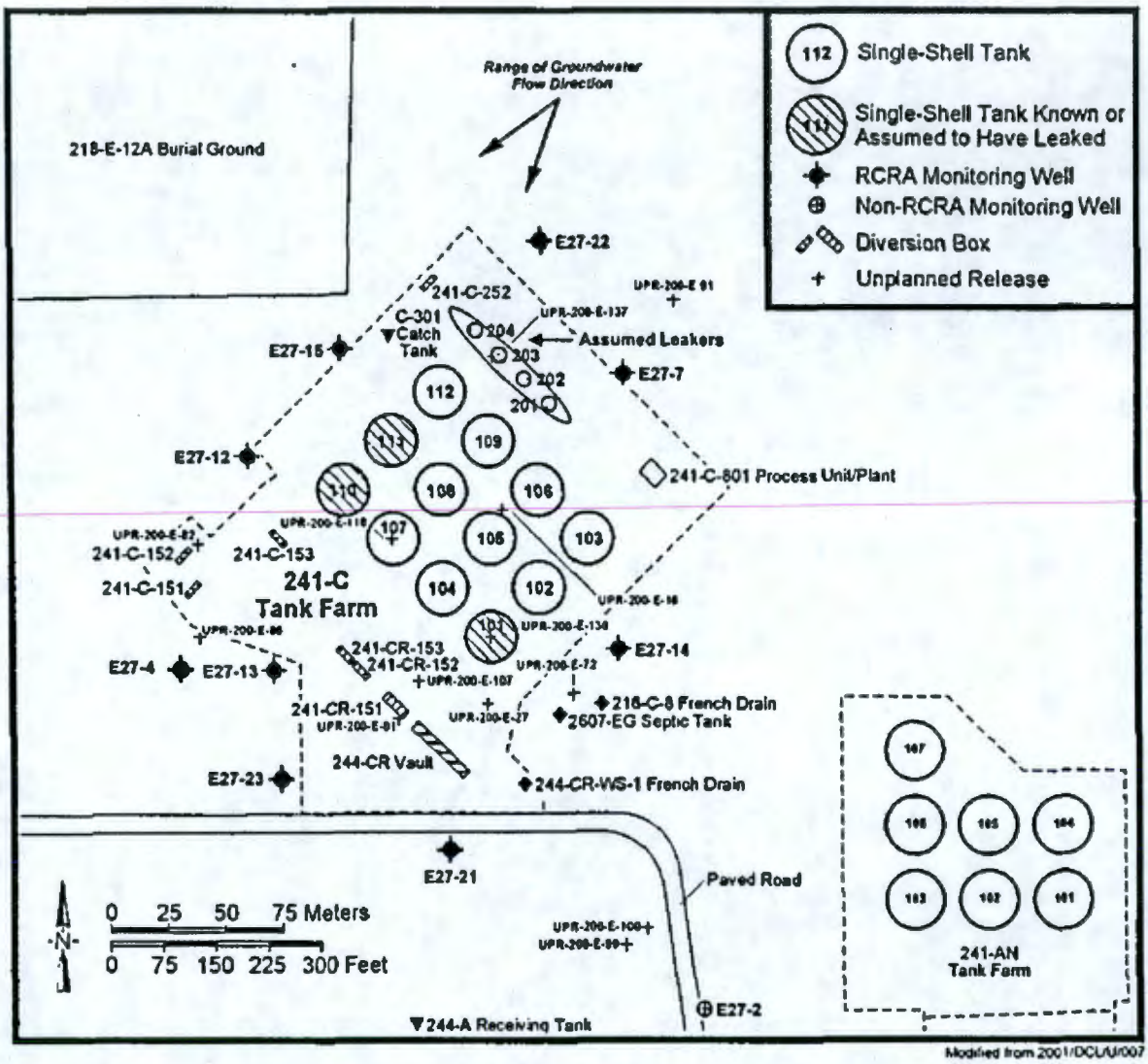
The quarterly groundwater monitoring that is currently performed is adequate for the purpose of supplementary data collection during waste retrieval. If a leak is detected during retrieval, groundwater monitoring frequency will be re-evaluated. As identified in Section 7.0, the calculated time to peak 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. 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 (*Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection* [OSD-T-151-00031]). Because all of the interim stabilization criteria have been met for these tanks, no in-tank leak detection monitoring is currently being performed (OSD-T-151-00031). The basis for in-tank leak detection and intrusion monitoring is provided in *Single-Shell Tank System Leak Detection and Monitoring Functions and Requirements* (RPP-9937).

The waste level in the DST receiver tanks is monitored using an Enraf level gauge for primary level monitoring as described in Section 4.0 of OSD-T-151-00031. Additionally, three annulus leak detector probes provide indication of tank leaks as described in Section 4.0 of OSD-T-151-00031.

Figure 4.2. Waste Management Area C and Regulated Structures.



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 along with a description of how the system will be operated.

4.2.1 Leak Detection and Monitoring for Single-Shell Tanks

The primary method for LDM 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. The high-resolution resistivity (HRR) leak detection system will only be deployed if completion of planned demonstration deployments and testing of the HRR system at other tanks shows this system to be effective. 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.

Additional detail on the SST leak detection approach is provided in the following sections. 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.

4.2.1.1. Ex Tank Leak Detection for Single-Shell Tanks. The existing truck-mounted logging systems will be used along with manually deployed moisture gauges and gross gamma detectors to monitor soil conditions surrounding the tanks for increases in gamma activity and/or moisture content that may be evidence of tank leakage. The truck-mounted system will be deployed by qualified personnel in accordance with the existing procedures before waste retrieval operations begin by deploying calibrated gamma and neutron moisture probes 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). Periodic logging will be performed during waste retrieval operations and for a period of time after retrieval operations have been completed 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, the hand-held moisture gauge will be deployed to monitor specific regions of interest in selected drywells for increases in soil moisture content. The hand-held moisture gauge will be deployed by qualified personnel in accordance with *Operate Model 503DR Hydroprobe Neutron Moisture Detection* (TO-320-022). The neutron moisture probe is used to monitor the moisture (e.g., water) content in the sediments around the drywells. Manually deployed moisture gauges will be used to monitor the drywells at specific regions of interest, including the interval at the base of the tank farm excavation that is 35 to 50 feet 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 the truck-mounted systems will be used if truck access is practical to determine if there have been any changes in gamma-emitting radionuclide concentration surrounding the drywells. The target frequency for deploying the manual moisture gauges will be defined in the process control plan.

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. When approved for use, the new drywell logging system will be substituted for the hand-held moisture gauge and may also be used in place of truck-mounted logging systems. 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.

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.

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 which logging tools and target logging intervals, will be defined in the process control plan.

The spectral gamma logging system (SGLS) is the logging system used to establish baseline conditions in 1995-2000. 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 volume percent 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.

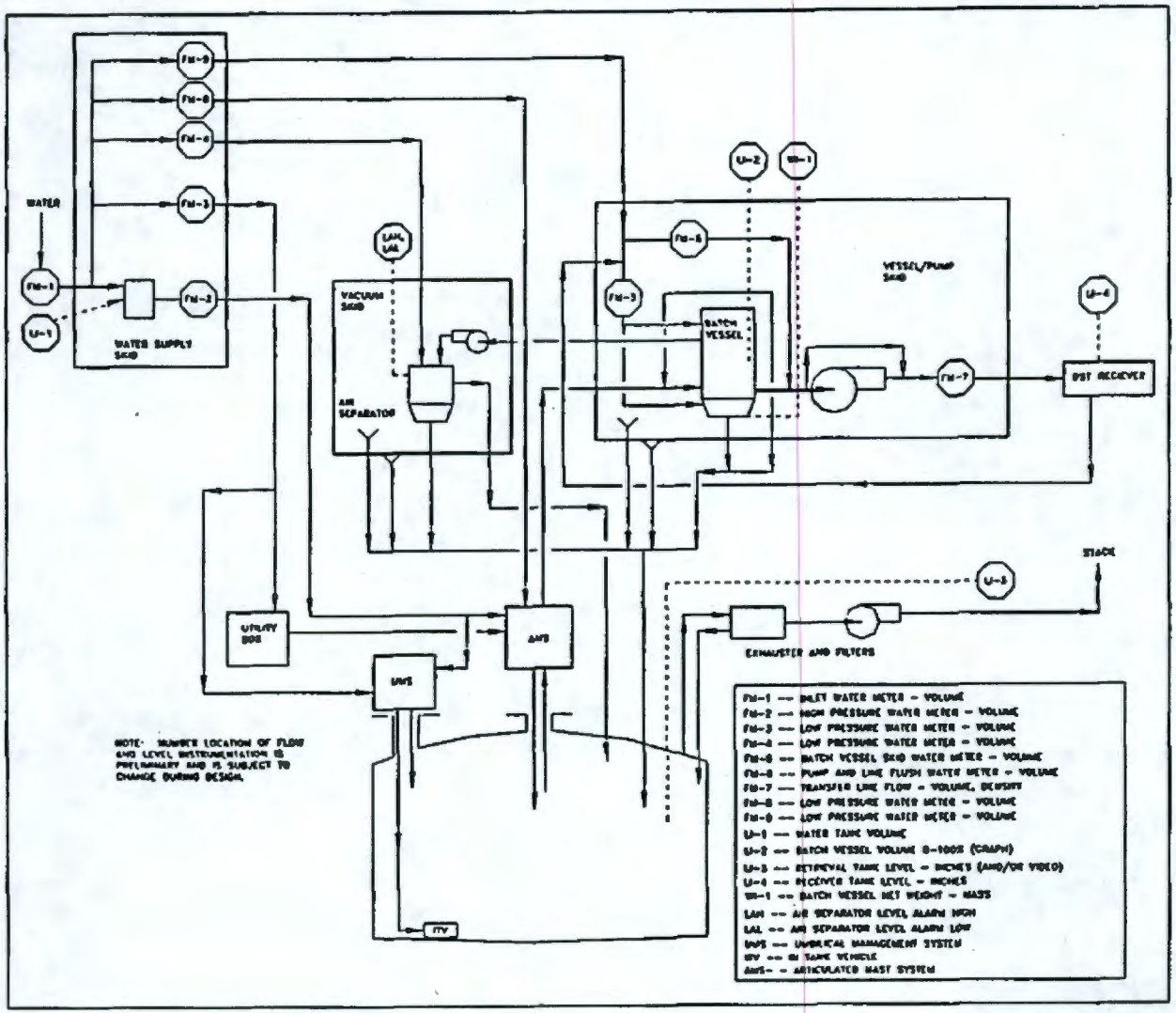
The handheld moisture gauge is a commercially available system (model 503DR Hydroprobe manufactured by CPN International) designed for manual measurement of in situ moisture content at one or more points in the subsurface. Use of the handheld moisture gauge does not require truck access into the tank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

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. DOE is in the process of acquiring the RMS and current planning is for the system to be available for use in 2005. 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 volume percent 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. 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 gallons. 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 4.3. 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.

Figure 4.3. Tanks C-101, C-105, C-110, and C-111 Simplified Flowsheet Schematic Showing Measurement Locations.



4.2.1.3. High-Resolution Resistivity. HRR uses baseline geophysical resistivity measurements as a means to detect changes in baseline moisture levels. The electrical resistivity of the sediments beneath a waste tank depends on a number of parameters, one of which is moisture content. The leakage of water or tank waste into these sediments lowers the sediment resistivity. The HRR method detects changes in soil moisture content by comparing a current resistivity measurement against a previously obtained baseline measurement, or a 'pre-leak' measurement. This delta processing allows the HRR method to discount existing resistivity differences in the soil caused by factors that include conductive structures or prior leaks. Changes in soil moisture from precipitation will need to be taken into consideration during monitoring to reduce the potential for making an incorrect leak determination.

A probable limitation to the HRR system is that it will largely provide data as a two-dimensional diagram from the viewpoint of looking down on the tank. As deployed with the long-length electrodes (drywell pipes), the system will likely only permit an evaluation of data in a two-dimensional view.

The basic resistivity measurement concept utilizes the existing drywells as measurement electrodes. By applying power to each electrode pair and making resistivity measurements from all other electrode pairs, an 'image' of the sediment resistivity can be obtained.

HRR is an ex-tank LDM technology that is currently undergoing evaluation for use during waste retrievals. A decision on deploying the HRR system on tanks C-101, C-105, C-110, and C-111 is on hold pending evaluation of the demonstration deployments and the results from the planned leak injection testing (near tank S-102). HRR leak detection has been deployed in a demonstration mode on tank S-102 and is planned as a demonstration deployment on tanks C-103 and C-109. Following completion of waste retrieval at tank S-102, a leak injection test will be performed to establish how well the HRR system performs in terms of detectable leak volumes and leak monitoring as discussed in *Test Plan for SST Deployment Demonstration and Injection Leak Testing of the HRR Long Electrode LDM System* (RPP-17191). These demonstration deployments of the HRR system (tanks S-102, C-103, and C-109) and the leak injection test are needed to validate and verify this method before it can be used as a baseline LDM method. Based on current planning, the results of the three demonstration deployments and the leak injection test will be available before the start of tank C-101 waste retrieval operations.

Following completion of the demonstration deployments and liquid injection test, a determination will be made regarding the viability of HRR for use in the tank farms. If it is determined that HRR is viable as the primary method for LDM, it will be utilized as the primary method of ex tank leak detection for the tanks addressed in this document. If it is determined that HRR is not viable as a LDM method, it would not be deployed at tanks C-101, C-105, C-110, or C-111 during waste retrieval.

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 leak detection monitoring 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, and liquid waste and slurries will be transferred 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 *Tank Farms Documented Safety Analysis* (RPP-13033) 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 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 a receiver DST will be detected by a conductivity probe installed in the annulus or leak detection pit.

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 demonstrated technologies that are 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 calculations will be performed throughout waste retrieval operations.

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 (RPP-8144) 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 tank	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 tank 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 tank 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 4.0
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, WAC 173-303-640(4), 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.

4.5 ANTICIPATED TECHNOLOGY PERFORMANCE

The performance of drywell logging for leak detection is dependent upon a number of variables. Two of the most significant variables are leak rate and the travel distance from a leak site to a drywell. Previous analysis, performed in support of the tank S-112 waste retrieval leak detection monitoring and mitigation strategy (*Tank S-112 Saltcake Waste Retrieval Demonstration Project Leak Detection, Monitoring, and Mitigation Strategy* [RPP-10413]), showed that a slow leak corresponding to historical Hanford tank leak rates (less than 2 gal/hr), drywell logging techniques have a 95th percentile volume range of 300 to 18,000 gallons for a drywell located 10 to 45 feet from the leak site. The travel times associated with leaks from the edge of a tank range from 1 to 70 days and the travel times from the center of the tank floor range from 4 days to 12 years depending on the leak rate. The variation between the low and high end of this range illustrates the dependence on the distance between leak location, location to the drywell, and the leak rate as described in RPP-10413. A leak from the tank floor is unlikely to be consistently detected by drywells during waste retrieval operations. To monitor for high rate leaks near the center of the tank floor, periodic verification of static liquid level will be used. This combination of drywell monitoring and static liquid level monitoring covers the full range of potential leak cases.

Allowing the leak site to vary over the bottom and side surfaces of the tank, the 95th percentile for a tank with 3 equally spaced drywells is approximately 8,000 gallons (RPP-10413). Most of the drywells identified in Section 4.1.1 are located within 10 feet of the tanks.

As noted in Section 4.2.1.1, the process control plan will define the details of the drywell monitoring to be performed during waste retrieval operations. Data collected with the hand-held 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 daily basis when waste retrieval and transfers are being performed.

While it is estimated that an 8,000-gallon 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 nominal 24-inch capillary height plus the volume of free liquid above the sludge. Per Section 3.2 it is unknown exactly how much interstitial liquid there is in the four tanks at this time, but when saturated tank C-101 could have up to 6,800 gallons; tank C-105 13,000 gallons; tank C-110 22,000 gallons; and tank C-111 1,800 gallons of interstitial liquid in the sludge above the 24-inch capillary height. 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. Thus, the volume of drainable interstitial liquid in a tank could range from zero to the values stated, but will most likely be significantly less.

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, which is equivalent to approximately

900 gallons per 1 inch of free liquid depth. The free liquid depth could be 12 inches or more in specific locations, but should not average over 1 or 2 inches without being vacuumed up. Therefore, it is roughly estimated that each tank could have 0 to 1,800 gallons of free liquid present.

The total liquid volume available to leak at any point in time following the start of waste retrieval and the addition of water to the tanks are estimated at 0 to 8,600 gallons for tank C-101; 0 to 15,000 gallons for tank C-105; 0 to 24,000 gallons for tank C-110; and 0 to 3,600 gallons for tank C-111.

Three of the four tanks (C-101, C-110, and C-111) are classified as 'assumed leakers.' Tank C-105 is classified as 'sound.' The estimated leak volumes for the first three tanks are 20,000 gallons for tank C-101; 2,000 gallons for tank C-110; and 5,500 gallons for tank C-111 (*Single-Shell Tank Leak History Compilation* [HNF-4872]). Only tank C-101 had a leak rate estimated. This rate is reported as 1.14 gal/hr in HNF-4872. Based upon a review of the timeframe over which the tanks were suspected of leaking (WHC-MR-0132), it appears the leak rate from tank C-101 would bound any leak rate from tanks C-110 or C-111.

All three tanks 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 gallons 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-gallon range. If retrieval takes a year the leak volume would be expected to be in the 0- to 13,000-gallon 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) has two aspects. The operational strategy involves taking actions to minimize leakage potential from the onset of waste retrieval and, if a leak is detected, involves responding to minimize the overall environmental impact. The selection of MRS for retrieving waste from tanks C-101, C-105, C-110, and C-111 mitigates the potential for leakage by using smaller liquid volumes for waste retrieval when compared to sluicing. The operational strategy to minimize the leak potential (initiation of a leak and leak volume) from the tank structure during waste retrieval in the absence of any indication of a leak involves the following:

- Control the in-tank liquid inventory during waste retrieval.
- Retrieve waste from an advantageous location; using the articulated mast located near the center of the tank waste retrieval operations will focus on retrieving waste from the center region of the tank first and removing free liquids as soon as practical.
- Limit the use of water to the minimum necessary to mobilize and remove using the vacuum system.
- Retrieval activities are only performed while a video camera is in place to observe the AMS suction nozzle, ITV, and waste surface.

If a belowgrade leak from the tank is indicated during waste retrieval, liquid additions to the tank will be suspended and actions defined in *Tank Leak Assessment Process* (TFC-ENG-CHEM-D-42) will be implemented. The response to a potential leak will be the same regardless of the leak rate. Retrieval of liquid waste shall continue during the leak assessment process if possible to remove the maximum practical amount of liquid from the tank. If the leak assessment concludes that no leak is indicated, waste retrieval operations will continue under normal operating procedures. However, if a leak is validated, the operating contractor will notify the appropriate regulatory agencies in accordance with *Environmental Notification* (TFC-ESHQ-ENV_FS-C-01). This includes notification to Ecology within 24 hours of a validated leak in accordance with WAC 173-303-640 (7)(d).

If a visible (aboveground) leak or release is detected during waste retrieval operations, response actions defined in *Building Emergency Plan for Tank Farms* (HNF-IP-0263-TF) will 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 in accordance with WAC 173-303-640(7)(c).

If a leak is 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.

Any occurrence within tank farms is evaluated per *Occurrence Reporting and Processing of Operations Information* (TFC-OPS-OPER-C-24). For spills, releases, or tank leaks associated with an SST, aboveground skid, transfer line, or receiving tank, the steps in TFC-OPS-OPER-C-24, Revision A-6 require an assessment of the severity of the event and a prescriptive set of responses depending on the results of the assessment.

If the event or condition meets one of the occurrence reporting criteria TFC-OPS-OPER-C-24, Revision A-6 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. The significant

steps associated with occurrence reporting excerpted from TFC-OPS-OPER-C-24, Revision A-6 include:

- Initiate or complete the immediate actions necessary to stabilize the facility/operation to a safe condition and preserve conditions for subsequent investigation.
- Gather all pertinent information relating to the event/condition with as minimal operational interference as possible.
- Notify the building emergency director and shift manager, as appropriate.
- If the event is a spill, release, fire, explosion, or permit exceedence, contact Tank Farm Contractor Environmental Program in accordance with the on-call list. Describe the circumstances of the event, the substance, and the quantity released. Refer to TFC-ESHQ-ENV_FS-C-01 for further information.
- Report in accordance with TFC-ESHQ-ENV_FS-C-01.

Procedure TFC-ESHQ-ENV_FS-C-01 implements regulatory agency reporting requirements and applies to all Tank Farm Contractor activities. This procedure provides instructions for the reporting of spills, releases, fires, explosions, etc., to regulatory agencies. Section 4.2 of TFC-ESHQ-ENV_FS-C-01, Revision B-1 provides the response for spills and releases and Section 4.5 provides the response for DST RCRA leak detection.

There are 19 steps to follow for spills and releases. 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 the 40 CFR 302 reportable quantity for the material.
- Determine if a RCRA contingency plan needs to be implemented.
- Notify Ecology and 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 two page 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, Revision B-1:

- 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; intrusion caused alarms which do not clear within four 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.
- The hydraulic pressure to the AMS is reduced to the extent practical while still permitting acceptable AMS operation to minimize the potential for putting excessive pressure on the tank wall during waste retrieval operations.
- 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 Environmental Compliance group would be notified and the steps in procedure TFC-ESHQ-ENV_FS-C-01 implemented for reporting requirements and in adherence with WAC 173-303-640(7).

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 *Double-Shell Tank Emergency Pumping Guide* (HNF-3484) and *Time Deployment Study for Annulus Pumping* (RPP-5482).

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 stopping the flow of waste into the tank system (stopping the transfer) pumping waste in the primary tank to another DST until the liquid level in the secondary containment is no longer increasing, and 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 salt well 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

Response to transfer leak detection alarms is performed per procedure (e.g., *Transfer from 241-C-200 Series Tanks to 241-AN-106* [TO-220-106]). 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 C-101, C-105, C-110, and C-111 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, "Hazardous Waste Management Act" and its implementing regulations, and WAC 173-303. The SSTs do not provide secondary containment and are not compliant with RCRA and "Hazardous Waste Management Act" the interim facility standards of Subpart J of "Interim Status Standards for Owners and Operators of Hazardous Waste, Treatment, Storage, and Disposal Facilities" (40 CFR 265). The SSTs are currently authorized to continue operations under the "Hazardous Waste Management Act" pending closure in accordance with WAC 173-303-610 under the authority of HFFACO Milestone M-45-00. 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). WAC 173-303-400(3) incorporates by reference the interim status performance standards set forth by the U.S. Environmental Protection Agency 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 incorporated into the contract between the Office of River Protection and CH2M HILL (DE-AC27-99RL-14047). 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 U.S. Environmental Protection Agency 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.

If required, approval to retrieve waste that could contain polychlorinated biphenyls (PCBs) from tanks C-101, C-105, C-110, and C-111 and to use supernate from the receiver DST for diluting the as retrieved solids and transferring the resulting slurry to the respective receiver tank will be obtained from the Environmental Protection Agency before initiating waste retrieval operations. DST supernate is classified as PCB remediation waste in accordance with *Framework Agreement for Management of Polychlorinated Biphenyls (PCBs) in Hanford Tank Waste* (Ecology et. al. 2000). Because the DST supernate is PCB remediation waste, the retrieval of waste from SSTs may require management of PCBs under the *Toxic Substances Control Act of 1976*.

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 changers 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 SST and DST is guided by emergency pumping guides HNF-3484 and HNF-SD-WM-AP-005. 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 measure 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 [WAC 173-303-640 (2)], 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 [WAC 173-303-640 (3)], 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 HHHTL 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 HHHTL.

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 [WAC 173-303-640 (4)], 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 [WAC 173-303-640 (5)], 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 [WAC 173-303-640 (6)], 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. 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 173-303-640 (7)], 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	
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 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 by the TFC industrial health program.
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. Incorporates WAC 173-303-640 (5) (d), marking. Replaces federal terms in 40 CFR 265 (i.e., regional administrator, hazardous) with state terms (i.e., department, dangerous)	

CH2M HILL = CH2M HILL Hanford Group, Inc.
DST = double-shell tank.
HFFACO = *Hanford Federal Facility Agreement and Consent Order.*
HHHTL = hose-in-hose transfer line.
IQRPE = independent, qualified, registered professional engineer.
ITEM = Integrated Training Electronic Matrix.
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. New isolation drawings or modifications to existing drawings will be prepared to define methods for isolation of 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.

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, (2) long-term human health risk associated with inadvertent post-closure human intrusion.

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

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 first-order 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 the following equation.

$$R_i = I_i \times C_i \times H_i \qquad \text{Equation 1}$$

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 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 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 health impact metrics used were radiological ILCR and noncarcinogenic chemical HI. Nonradiological ILCR was also included for information purposes.

Indicator contaminants for each 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 *Inventory and Source Term Data Package* (DOE/ORP-2003-02) for which a toxicity factor was available. Exposure scenarios and risk factors used for the RPP-13774 analysis were obtained from *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment* (HNF-SD-WM-TI-707).

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 Federal Guidance Report Number 13 (EPA-402-R-99-001) were used. For chemicals, the non-cancer toxicity reference doses and cancer induction slope factors adopted by the U.S. Environmental Protection Agency 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 *Health Effects Assessment Summary Tables (HEAST) FY 1997* (EPA-540/R-97/036) 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 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-gallon 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 ILCR		Nonradiological ILCR		Noncarcinogenic Chemical HI	
		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%) Total 8.1E-06 (100%)	Tc-99 1.7E-04 (95%) I-129 3.7E-06 (2%) C-14 3.9E-06 (3%) 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%) Total 6.5E-06 (100%)	Tc-99 1.4E-04 (98%) I-129 3.2E-06 (2%) C-14 9.0E-07 (<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 ILCR		Nonradiological ILCR		Noncarcinogenic Chemical HI	
		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%) Total 1.0E-06 (100%)	Tc-99 2.2E-05 (97%) I-129 5.2E-07 (2%) C-14 8.8E-08 (<1%) 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%)

[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-gallon 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).

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

HI = hazard index.

ILCR = incremental lifetime cancer risk.

The RPP-13774 analysis results indicate the primary contributors to total WMA C radiological ILCR at the fenceline would be the highly mobile (distribution coefficient [K_d] = 0 mL/g) radionuclides: technetium-99, iodine-129, and carbon-14 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.

The RPP-13774 analysis results indicate the primary contributors to the total WMA C noncarcinogenic chemical HI at the fenceline 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.

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 nonradiological 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. Because of

these uncertainties, and the fact that hexavalent chromium ILCR is generally two to three orders of magnitude lower than total radiological ILCR, radiological ILCR was selected as the cancer risk metric over nonradiological ILCR for purposes of supporting informed decision making during waste retrieval operations.

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 resuspended soil and volatilized water. The soil is assumed to be contaminated by irrigation with contaminated groundwater. 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.

7.1.1.2. Potential Retrieval Leak Inventories. The retrieval leak impact graphs provided in the appendices were generated by applying Equation 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-gallon retrieval leak. The 8,000-gallon volume was used only for information purposes to provide a point of reference on the graphs. Use of the 8,000-gallon value also maintains consistency and allows comparison with previous retrieval leak analyses (e.g., RPP-13774).

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 12,000). 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 curie of radionuclide or 1 kilogram 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 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

* Source: RPP-13774, Addendum C1, Figure 9.

WMA = waste management area.

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 the HFFACO Appendix I. Both scenarios are based on scenarios described in *Hanford Site Risk Assessment Methodology* (DOE/RL-91-45). 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	HI per mg/L	3.88E+00	2.34E+01
Nitrite	HI per mg/L	9.89E-02	6.36E-01

[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.
HI = hazard index.
ILCR = incremental lifetime cancer risk.

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 HI per unit concentration in the groundwater. The factors were applied to the retrieval leak impact calculations as shown in Equation 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 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 and lower the risks 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-gallon 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 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.

Table 7.4. Peak Impacts at the Waste Management Area C Fenceline from Potential Retrieval Leaks.

Contaminant	Time of Peak (Yr AD)	Incremental Lifetime Cancer Risk[a]		Hazard Index[b]		Groundwater Concentration[c]	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[d]
Nitrite	2082	NA	NA	2.6E-02	1.7E-01	0.26 mg/L	3.3 mg/L[e]
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

[a] Source: RPP-13774, Addendum C1, Table 36.
[b] Source: RPP-13774, Addendum C1, Table 37.
[c] Source: RPP-13774, Addendum C1, Table 38.
[d] The MCL for chromium is for total chromium, not just hexavalent chromium.
[e] Concentration for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

MCL = maximum contaminant level.
NA = not applicable.

The RPP-13774 retrieval leak assessment results shown in Table 7.4 included an 8,000-gallon 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 *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106* (RPP-20577).

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 12 C-100-series tanks and 4 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 gallons). 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 contribution 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 Residual Tank Waste.

Contaminant	Time of Peak (Yr AD)	Incremental Lifetime Cancer Risk[a]		Hazard Index[b]		Groundwater Concentration[c]	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[d]
Nitrite	5614	NA	NA	3.4E-03	2.2E-02	0.034 mg/L	3.3 mg/L[e]
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

[a] Source: RPP-13774, Addendum C1, Table 30.
[b] Source: RPP-13774, Addendum C1, Table 31.
[c] Source: RPP-13774, Addendum C1, Table 38.
[d] The MCL for chromium is for total chromium, not just hexavalent chromium.
[e] Concentration for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.
MCL = maximum contaminant level.
NA = not applicable.

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 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 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 to 7 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, and noncarcinogenic chemical HI for the indicator contaminants at the downgradient fenceline from the WMA C past leak source term.

The RPP-13774 base case simulation results indicate the 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). Although the peak from the release near tank C-105 was projected to arrive ahead of the peak from the pipeline releases by approximately 26 years, the contributions from those sources were summed and reported as a single peak arriving in the hear 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.

Table 7.6. Peak Impacts at the Waste Management Area C Fenceline from Past Leaks.

Contaminant	Time of Peak (Yr AD)	Incremental Lifetime Cancer Risk[a]		Hazard Index[b]		Groundwater Concentration[c]	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[d]
Nitrite	2117	NA	NA	1.4E-02	9.1E-02	0.14 mg/L	3.3 mg/L[e]
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

[a] Source: RPP-13774, Addendum C1, Table 33.
[b] Source: RPP-13774, Addendum C1, Table 34.
[c] Source: RPP-13774, Addendum C1, Table 38.
[d] The MCL for chromium is for total chromium, not just hexavalent chromium.
[e] Concentration for nitrite reported as the ion. The MCL for nitrite reported as nitrogen is 1 mg/L.

MCL = maximum contaminant level.
NA = not applicable.

Seven C farm tanks (C-101, C-110, C-111, and the four C farm 200-series tanks) are currently classified as 'assumed leakers' (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 tank C-105 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 *Vadose Zone Characterization Project at the Hanford Tank Farms, Addendum to the C Tank Farm Report* (GJO-98-39-TARA GJO-HAN-18). Additional perspective on the integrity of tanks in WMA C can be found in *Single Shell Tank Integrity Assessment Report* (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.

Inadvertent intruder impacts were analyzed using the same methodology used to analyze WMA C intruder impacts in *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (DOE/ORP-2003-11). 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 (*Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds* [WHC-EP-0645], *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Burial Grounds* [WHC-EP-0875], *Hanford Immobilized Low-Activity Tank Waste Performance Assessment* [DOE/RL-97-69], *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version* [DOE/ORP-2000-24]).

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 diary 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 feet 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 for a one-time exposure. The performance objective for the post-intrusion residential scenarios was 100 mrem/yr effective dose equivalent for a continuous exposure. Doses were calculated at 100-year intervals 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, and 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 inches for well driller and suburban resident with a garden and 10.5 inches for rural farmer with a diary 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. Although 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, the rural farmer with a dairy cow was used 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. The DOE/ORP-2003-11 analysis considered a rural resident 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.

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 gallons) 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 the following equations.

$$I_{EX} / V_{EX} = I_T / V_t$$

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

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

$$I_{EX} = I_T (r / R)^2$$

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 the following equation.

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

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
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

[a] Source: HNF-SD-WM-TI-707, Tables 7, 8, and 10.
[b] Values shown are total dose (sum of internal and external dose) after reducing internal dose by 90% to account for the waste form.
+D = includes short-lived radioactive progeny in secular equilibrium with parent nuclide.

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 (effective dose equivalent) 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 the following equation.

$$M_{EX} = \pi r^2 h \rho$$

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 *S-102 Initial Waste Retrieval Functions and Requirements* (RPP-10901). 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 *Performance Evaluation for C-106, S-102/112 and C-200 Series Tank Retrieval Activities* (RPP-18629) 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 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 walk-downs 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 retrieval system is significantly reduced when the vacuum line length exceeds approximately 90 feet.

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APPENDIX A

TANK C-101 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

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

This appendix provides tank-specific pre-retrieval risk assessment results for 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 *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan* (RPP-22521).

A2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures A.1 through A.3 provide the tank C-101 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.

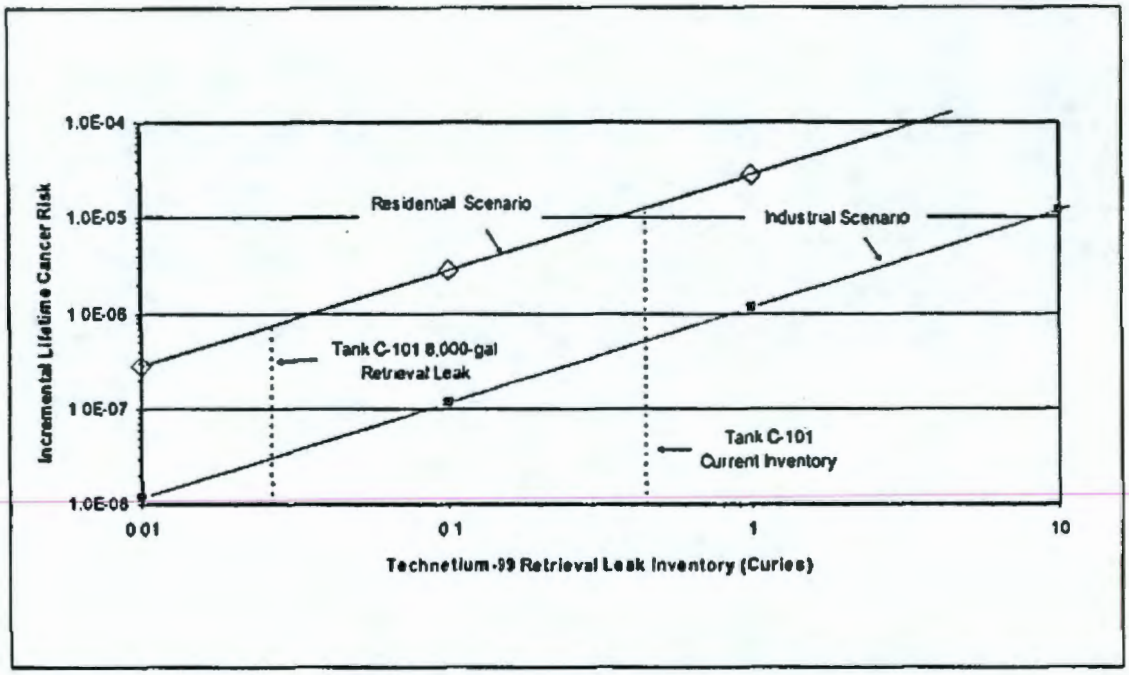

Figure A.2. Tank C-101 Hexavalent Chromium Hazard Index Plot.

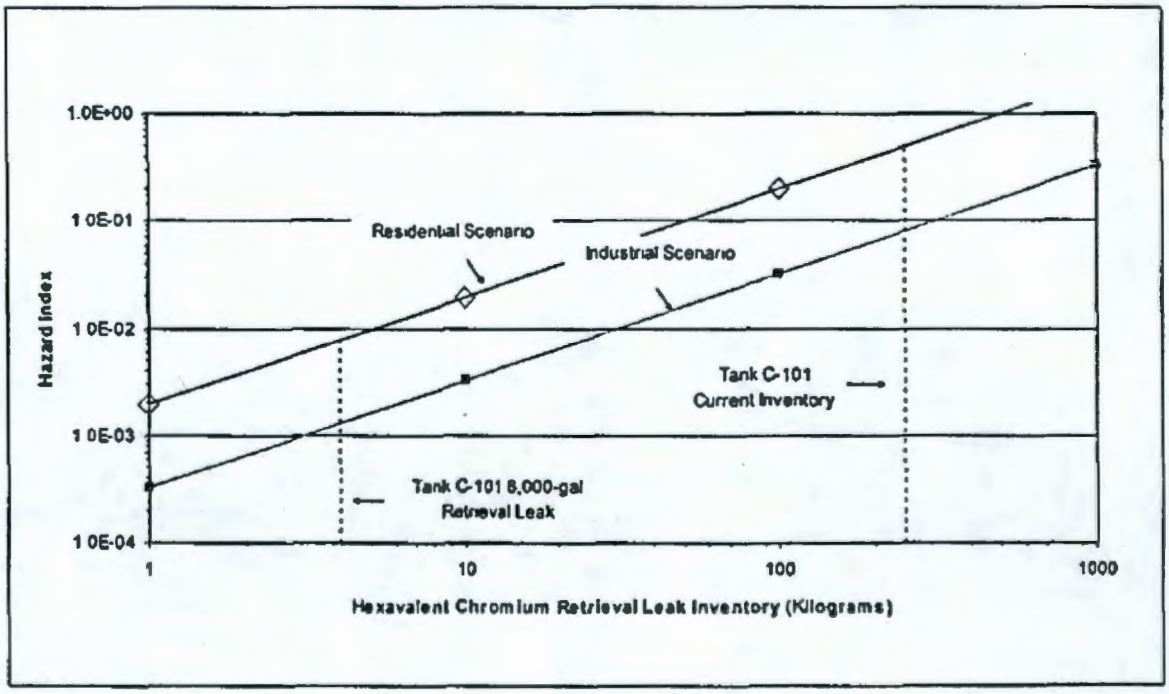

Figure A.3. Tank C-101 Nitrite Hazard Index Plot.

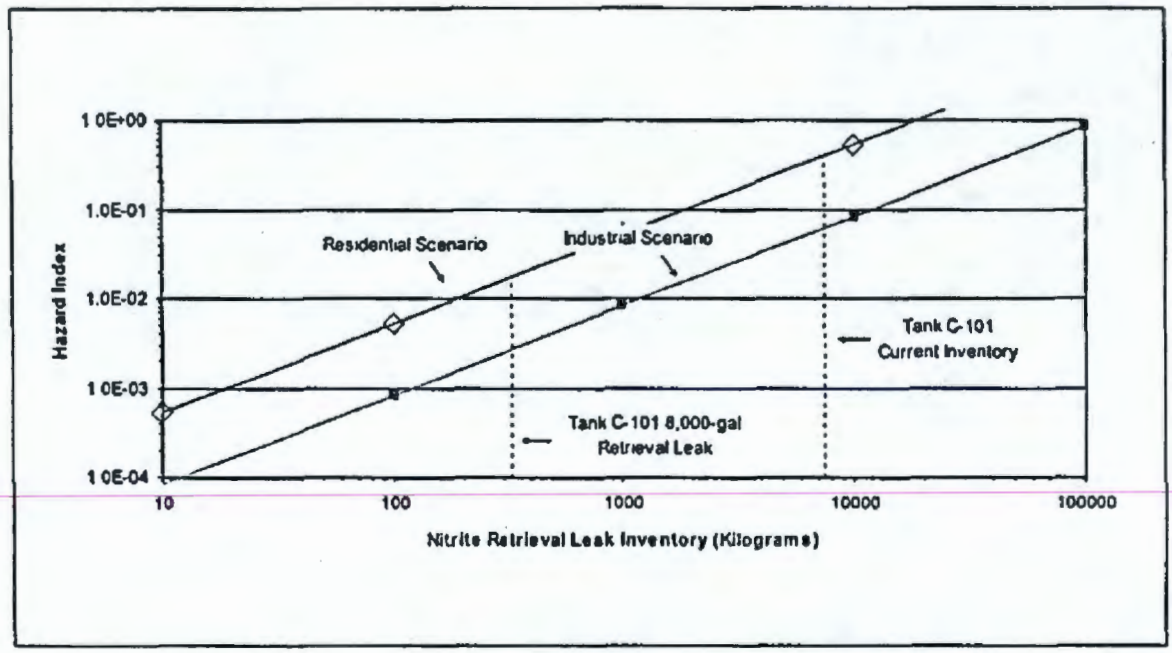

Figure A.1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-101 during retrieval. Figures A.2 and A.3 show the peak groundwater pathway hazard index (HI) from hexavalent chromium and nitrite,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

The ILCR and HI values shown on the graphs were based on the predicted peak groundwater concentrations at the 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 *Single-Shell Tank System Closure Plan* (RPP-13774). 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 data points 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 gallon 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 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-gallon 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 BBI by downloading from the TWINS database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gallons) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-101 using the mobile retrieval system (MRS). 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 as well as the fluids inside the MRS batch vessel and 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-Gallon Retrieval Leak
Technetium-99	8.71E-07 Ci/L	2.64E-02 Ci
Hexavalent Chromium	1.34E-04 kg/L	4.04E+00 kg
Nitrite	1.09E-02 kg/L	3.31E+02 kg

* Source: RPP-21753, Appendix D, Table D-1.

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 0.03 curie. As shown in Figure A.1, this corresponds to an ILCR of approximately 3×10^{-8} for the industrial scenario and 7×10^{-7} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 2 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000 gal retrieval leak from tank C-101 was estimated to be approximately 4 kg. As shown in Figure A.2, this corresponds to

a HI of approximately 0.001 for the industrial scenario and 0.008 for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 0.0003 mg/L.

The nitrite inventory associated with an 8,000 gal retrieval leak from tank C-101 was estimated to be approximately 330 kg. As shown in Figure A.3, this corresponds to a HI of approximately 0.003 for the industrial scenario and 0.02 for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 0.03 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 3×10^{-8}. Using Equation 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:

$$\text{ILCR} = (0.0264\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 3.06 \times 10^{-8}$$

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 HFFACO interim retrieval goal of 360 cubic feet (2,700 gal) of residual waste. These inventories were taken from *241-C Waste Management Area Inventory Data Package* (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 (RPP-22521). Inventories for the subset of BBI radionuclides that were shown in *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (DOE/ORP-2003-11) to dominate (contribute 98% of total) 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 Cubic Feet of Residual Waste*.

Radionuclide	Units	Tank C-101
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

*Source = RPP-15317, Table 7-1

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 360 cubic feet. Table A.3 indicates that tank C-101 would not exceed the performance objectives of 500 mrem EDE for acute exposure and 100 mrem/yr EDE 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
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	0.003	0.000
TOTAL	0.126	0.704	0.032

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

A4.0 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.

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, 2004, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-22521, 2004, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX B

TANK C-105 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

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

This appendix provides tank-specific pre-retrieval risk assessment results for 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 *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan* (RPP-22521).

B2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures B.1 through B.3 provide the tank C-105 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.

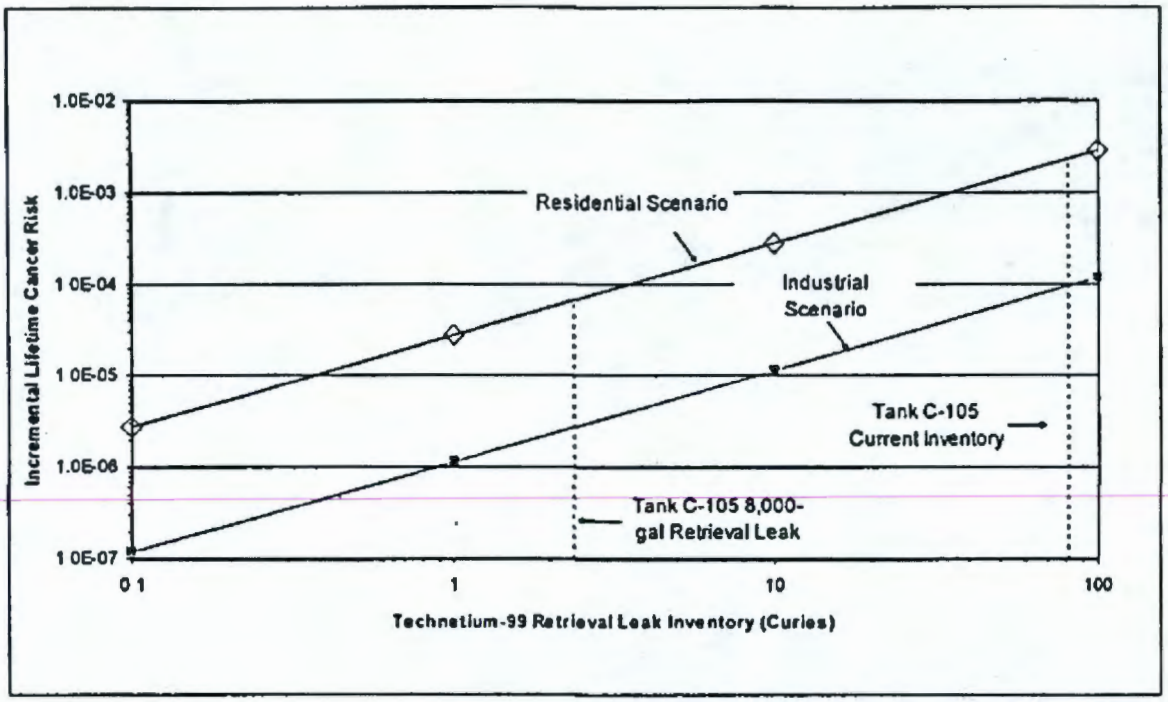

Figure B.2. Tank C-105 Hexavalent Chromium Hazard Index Plot.

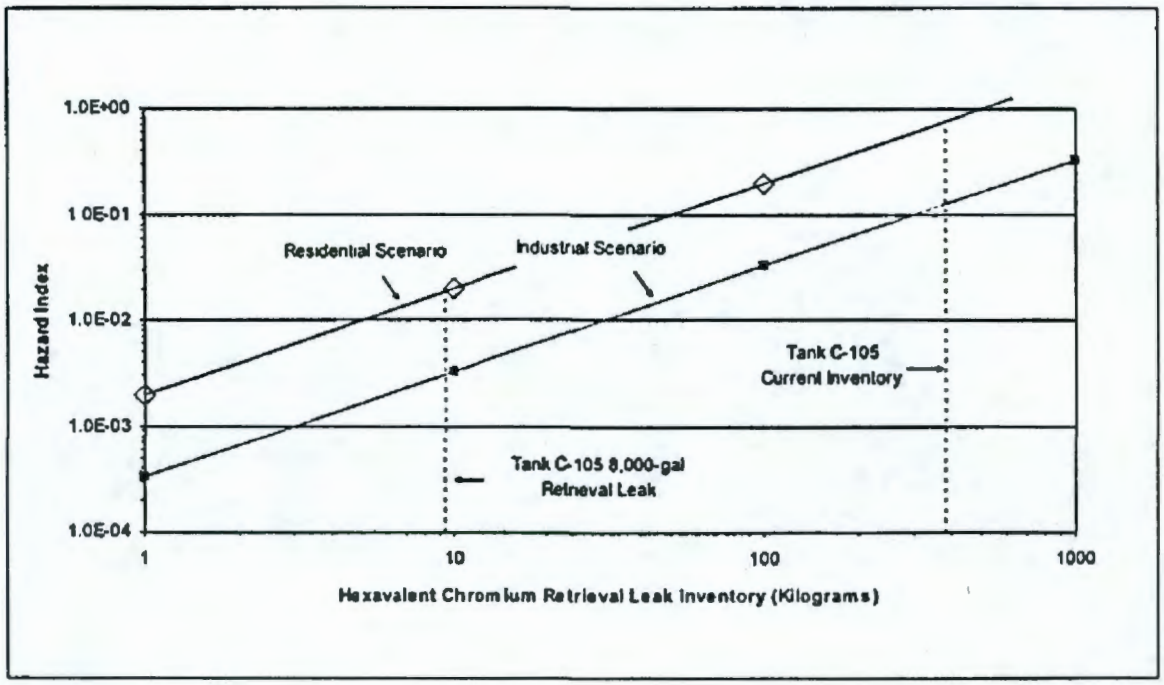

Figure B.3. Tank C-105 Nitrite Hazard Index Plot.

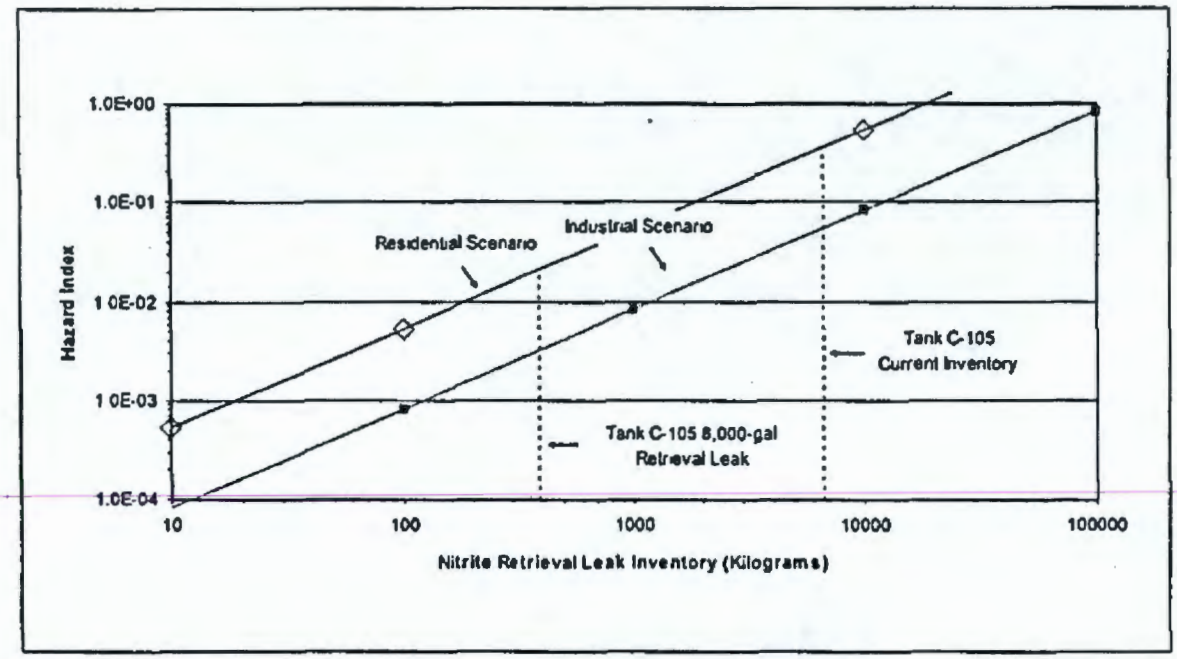

Figure B.1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-105 during retrieval. Figures B.2 and B.3 show the peak groundwater pathway hazard index (HI) from hexavalent chromium and nitrite,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

The ILCR and HI values shown on the graphs were based on the predicted peak groundwater concentrations at the 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 *Single-Shell Tank System Closure Plan* (RPP-13774). 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 data points 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 gallon 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 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-gallon 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 BBI by downloading from the TWINS database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gallons) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-105 using the mobile retrieval system (MRS). 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 as well as the fluids inside the MRS batch vessel and 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-Gallon Retrieval Leak
Technetium-99	7.91E-05 Ci/L	2.40E+00 Ci
Hexavalent Chromium	3.11E-04 kg/L	9.42E+00 kg
Nitrite	1.31E-02 kg/L	3.97E+02 kg

* Source: RPP-21753, Appendix D, Table D-1.

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 2.4 curies. As shown in Figure B.1, this corresponds to an ILCR of approximately 3×10^{-6} for the industrial scenario and 7×10^{-5} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 200 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000 gal retrieval leak from tank C-105 was estimated to be approximately 9 kg. As shown in Figure B.2, this corresponds to

a HI of approximately 0.003 for the industrial scenario and 0.02 for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 0.0008 mg/L.

The nitrite inventory associated with an 8,000 gal retrieval leak from tank C-105 was estimated to be approximately 400 kg. As shown in Figure B.3, this corresponds to a HI of approximately 0.003 for the industrial scenario and 0.02 for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 0.03 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 3×10^{-6}. Using Equation 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:

$$\text{ILCR} = (2.4\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 2.78 \times 10^{-6}$$

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 HFFACO interim retrieval goal of 360 cubic feet (2,700 gal) of residual waste. These inventories were taken from *241-C Waste Management Area Inventory Data Package* (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 (RPP-22521). Inventories for the subset of BBI radionuclides that were shown in *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (DOE/ORP-2003-11) to dominate (contribute 98% of total) 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 Cubic Feet of Residual Waste*.

Radionuclide	Units	Tank C-105
Strontium-90	Ci	9.70E+03
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

*Source = RPP-15317, Table 7-1

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 cubic feet. Table B.3 indicates that tank C-105 would not exceed the performance objectives of 500 mrem EDE for acute exposure and 100 mrem/yr EDE 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
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	0.045	0.000
TOTAL	0.418	2.223	0.100

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

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.

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, 2004, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-22521, 2004, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX C

TANK C-110 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

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

This appendix provides tank-specific pre-retrieval risk assessment results for 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 *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan* (RPP-22521).

C2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures C.1 through C.3 provide the tank C-110 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.

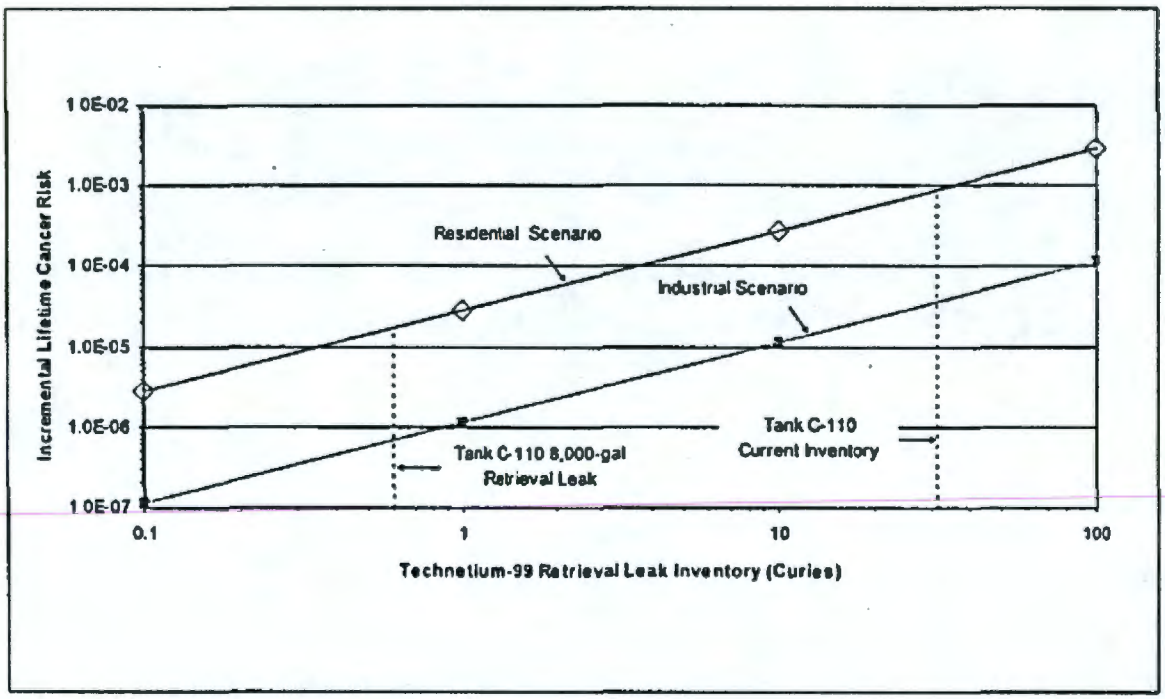

Figure C.2. Tank C-110 Hexavalent Chromium Hazard Index Plot.

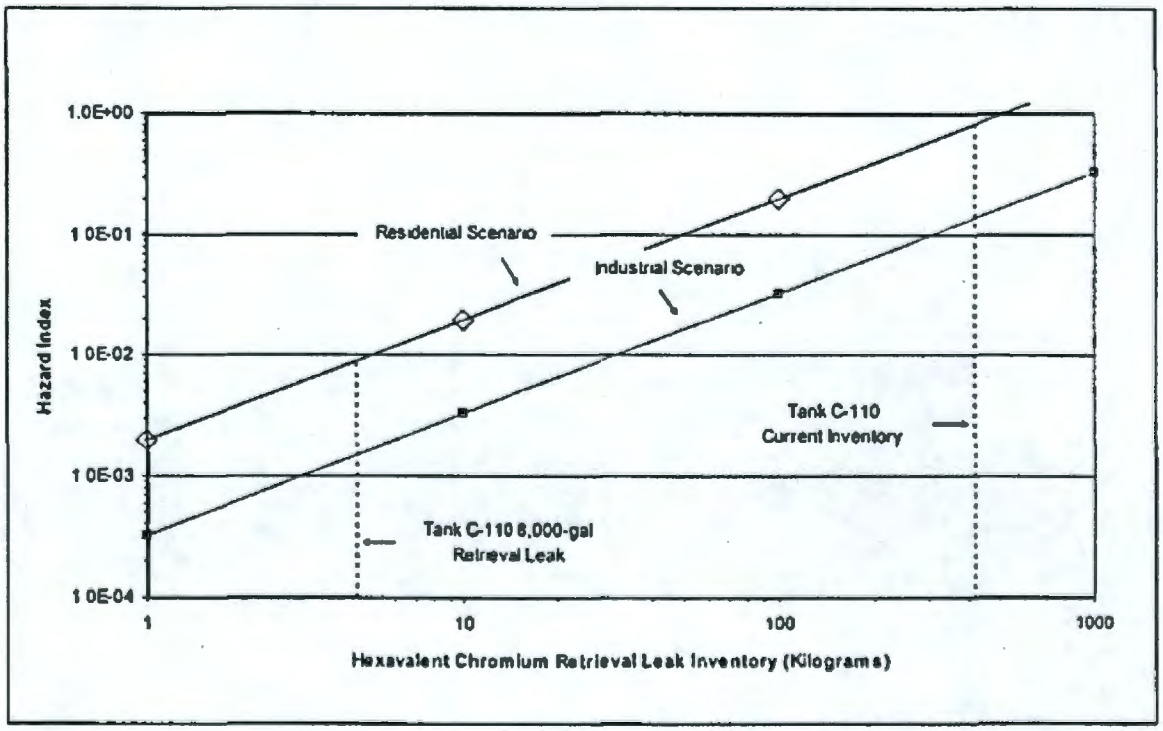

Figure C.3. Tank C-110 Nitrite Hazard Index Plot.

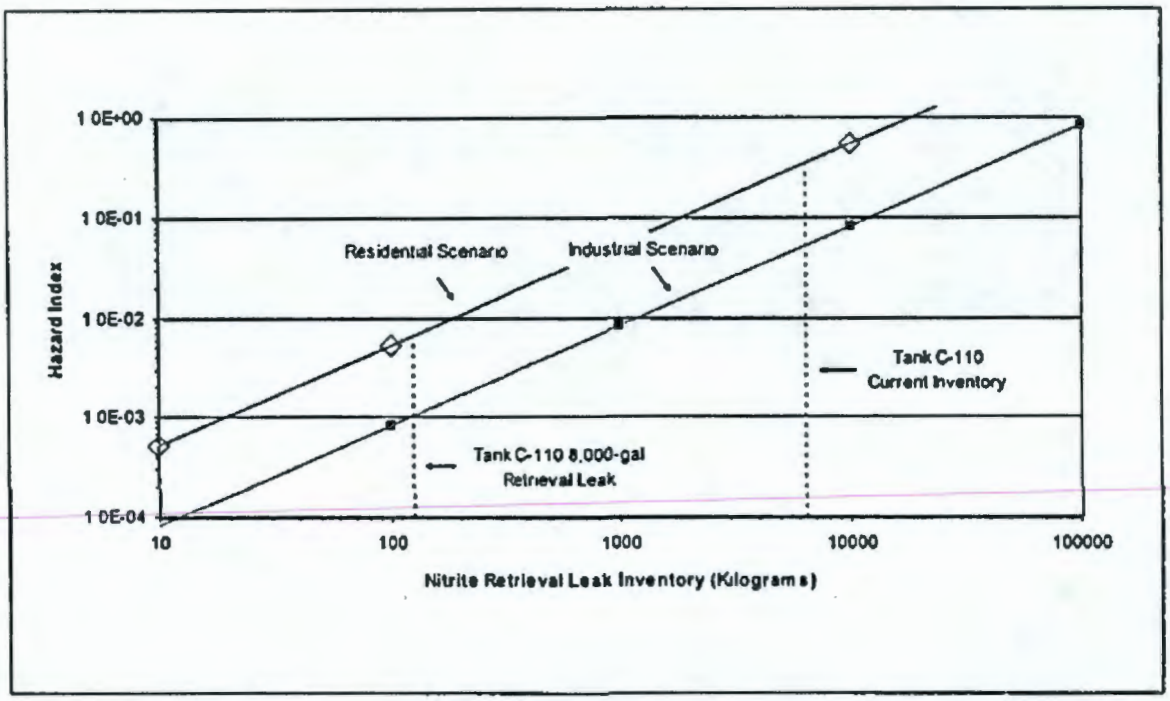

Figure C.1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-110 during retrieval. Figures C.2 and C.3 show the peak groundwater pathway hazard index (HI) from hexavalent chromium and nitrite,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

The ILCR and HI values shown on the graphs were based on the predicted peak groundwater concentrations at the 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 *Single-Shell Tank System Closure Plan* (RPP-13774). 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 data points 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 gallon 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 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-gallon 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 BBI by downloading from the TWINS database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gallons) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-110 using the mobile retrieval system (MRS). 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 as well as the fluids inside the MRS batch vessel and 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-Gallon Retrieval Leak
Technetium-99	2.01E-05 Ci/L	6.10E-01 Ci
Hexavalent Chromium	1.51E-04 kg/L	4.56E+00 kg
Nitrite	4.19E-03 kg/L	1.27E+02 kg

* Source: RPP-21753, Appendix D, Table D-1.

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 0.6 curie. As shown in Figure C.1, this corresponds to an ILCR of approximately 7×10^{-7} for the industrial scenario and 2×10^{-5} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 51 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000 gal retrieval leak from tank C-110 was estimated to be approximately 5 kg. As shown in Figure C.2, this corresponds to a HI of approximately 0.001 for the industrial scenario and 0.009 for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 0.0004 mg/L.

The nitrite inventory associated with an 8,000 gal retrieval leak from tank C-110 was estimated to be approximately 130 kg. As shown in Figure C.3, this corresponds to a HI of approximately 0.001 for the industrial scenario and 0.007 for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 0.01 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 7×10^{-7}. Using Equation 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 HFFACO interim retrieval goal of 360 cubic feet (2700 gal) of residual waste. These inventories were taken from *241-C Waste Management Area Inventory Data Package* (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 (RPP-22521). Inventories for the subset of BBI radionuclides that were shown in *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (DOE/ORP-2003-11) to dominate (contribute 98% of total) 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 Cubic Feet of Residual Waste*.

Radionuclide	Units	Tank C-110
Strontium-90	Ci	5.66E+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

*Source = RPP-15317, Table 7-1

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 360 cubic feet. Table C.3 indicates that tank C-110 would not exceed the performance objectives of 500 mrem EDE for acute exposure and 100 mrem/yr EDE 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
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	0.013	0.000
TOTAL	0.010	0.063	0.003

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

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.

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

RPP-21753, 2004, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-22521, 2004, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX D

TANK C-111 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

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

This appendix provides tank-specific pre-retrieval risk assessment results for 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 *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan* (RPP-22521).

D2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures D.1 through D.3 provide the tank C-111 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.

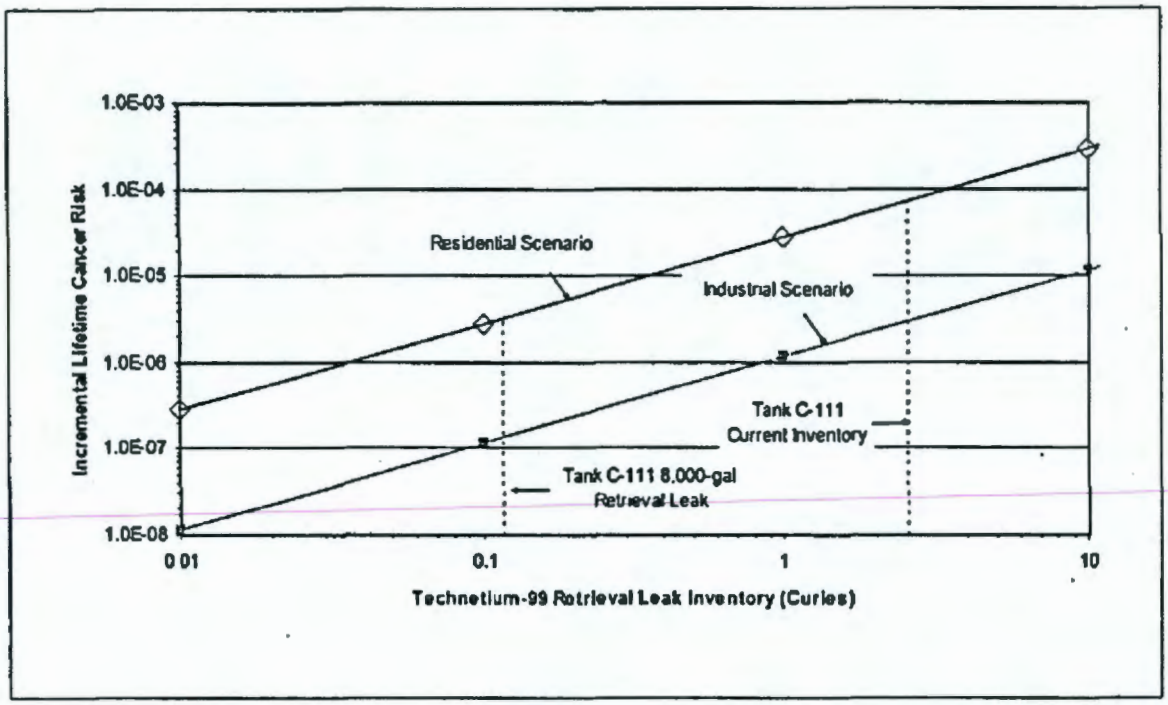

Figure D.2. Tank C-111 Hexavalent Chromium Hazard Index Plot.

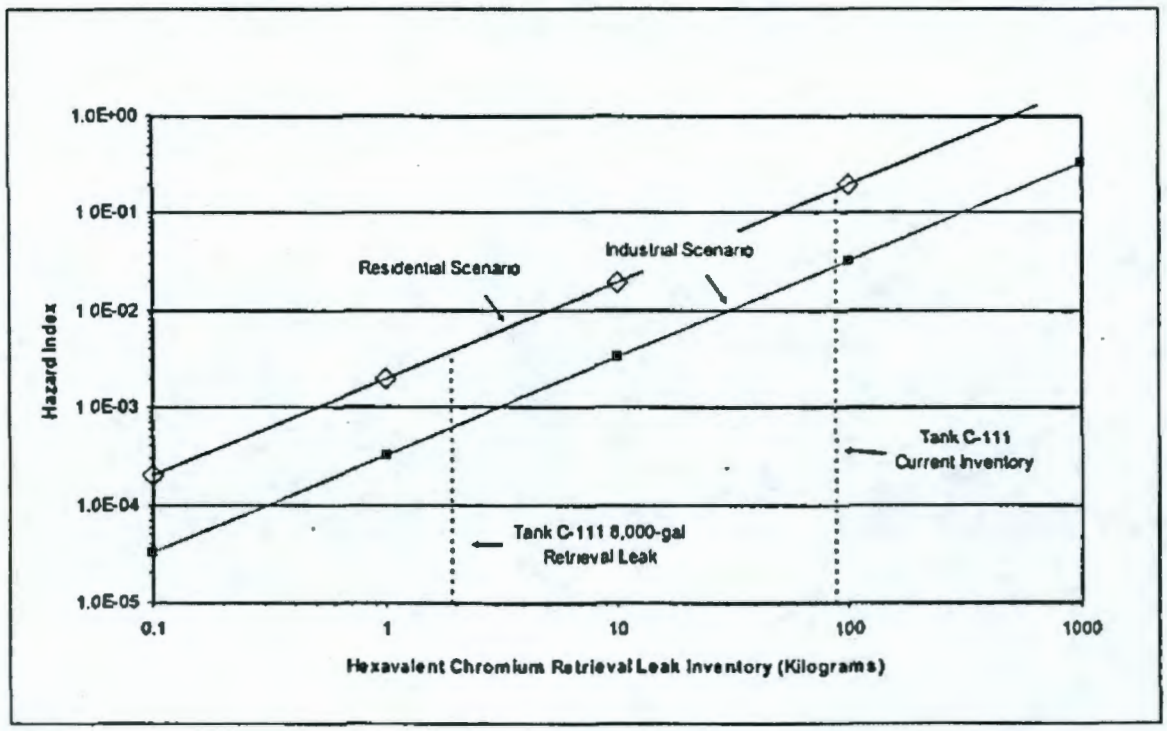

Figure D.3. Tank C-111 Nitrite Hazard Index Plot.

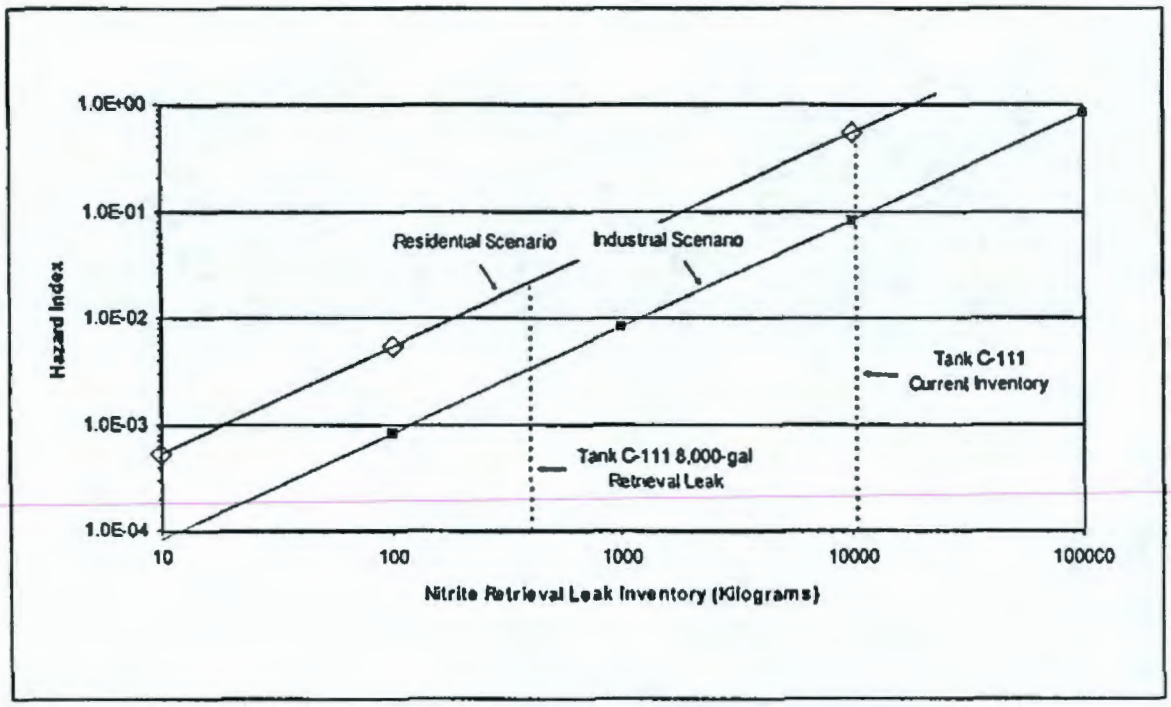

Figure D.1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-111 during retrieval. Figures D.2 and D.3 show the peak groundwater pathway hazard index (HI) from hexavalent chromium and nitrite,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

The ILCR and HI values shown on the graphs were based on the predicted peak groundwater concentrations at the 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 *Single-Shell Tank System Closure Plan* (RPP-13774). 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 data points 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 gallon 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 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-gallon 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 BBI by downloading from the TWINS database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gallons) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-111 using the mobile retrieval system (MRS). 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 as well as the fluids inside the MRS batch vessel and 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-Gallon Retrieval Leak
Technetium-99	3.93E-6 Ci/L	1.19E-01 Ci
Hexavalent Chromium	6.33E-05 kg/L	1.92E+00 kg
Nitrite	1.36E-02 kg/L	4.12E+02 kg

* Source: RPP-21753, Appendix D, Table D-1.

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 0.1 curie. As shown in Figure D.1, this corresponds to an ILCR of approximately 1×10^{-7} for the industrial scenario and 3×10^{-6} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 10 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 kg. As shown in Figure D.2, this corresponds to a HI of approximately 0.0006 for the industrial scenario and 0.004 for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 0.0002 mg/L.

The nitrite inventory associated with an 8,000 gal retrieval leak from tank C-111 was estimated to be approximately 410 kg. As shown in Figure D.3, this corresponds to a HI of approximately 0.003 for the industrial scenario and 0.02 for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 0.03 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 1×10^{-7}. Using Equation 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:

$$\text{ILCR} = (0.119\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 1.38 \times 10^{-7}$$

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 HFFACO interim retrieval goal of 360 cubic feet (2700 gal) of residual waste. These inventories were taken from *241-C Waste Management Area Inventory Data Package* (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 (RPP-22521). Inventories for the subset of BBI radionuclides that were shown in *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (DOE/ORP-2003-11) to dominate (contribute 98% of total) 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 Cubic Feet of Residual Waste*.

Radionuclide	Units	Tank C-111
Strontium-90	Ci	4.18E+04
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

*Source = RPP-15317, Table 7-1

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 360 cubic feet. Table D.3 indicates that tank C-111 would not exceed the performance objectives of 500 mrem EDE for acute exposure and 100 mrem/yr EDE 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
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	0.006	0.001
TOTAL	0.091	0.466	0.023

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

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.

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.

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RPP-22521, 2004, *Tanks C-101, C-105, C-110, and C-111 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.