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  Title: 241-C-103 and 241-C-109 Tanks Waste Retrieval Work Plan
  Author: R. S. Robinson
  Date: May 2005

- Record of Revision

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LIST OF TERMS

ALARA	as low as reasonably achievable
BBI	best-basis inventory
CH2M HILL	CH2M HILL Hanford Group, Inc.
COPC	constituent of potential concern
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HI	hazard index
HIHTL	hose-in-hose transfer line
HRR	high-resolution resistivity
IH	industrial hygiene
ILCR	incremental lifetime cancer risk
LDM	leak detection and monitoring
ORP	Office of River Protection
PUREX	plutonium-uranium extraction
RCRA	*Resource Conservation and Recovery Act of 1976*
RMS	retrieval monitoring system
SST	single-shell tank
WMA	waste management area
WRS	waste retrieval system
WTP	Waste Treatment Plant

1.0 INTRODUCTION

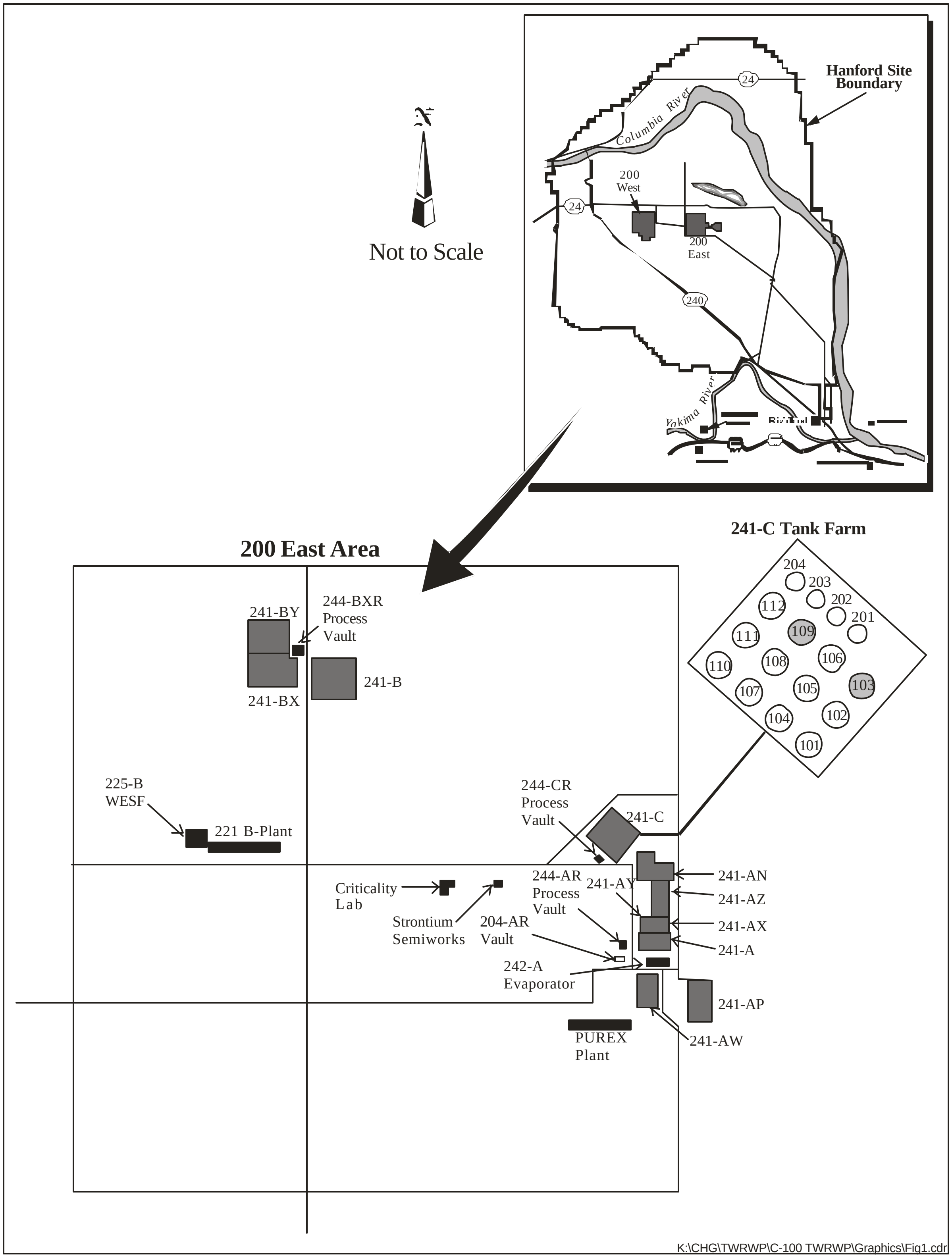
The U.S. Department of Energy (DOE), Office of River Protection (ORP) River Protection Project mission includes storage, retrieval, immobilization, and disposal of radioactive mixed waste presently stored in underground tanks located in the 200 East and 200 West Areas of the DOE Hanford Site. The 241-C-103 (C-103) and 241-C-109 (C-109) single-shell tanks (SSTs), located in the 200 East Area (Figure 1-1), are scheduled for waste retrieval using the modified sludge sluicing system retrieval technology. Tanks C-103 and C-109 are classified as sound tanks per HNF-EP-0182, *Waste Tank Summary Report for Month Ending February 28, 2005*, and are suitable for deployment of existing modified sluicing waste retrieval technology.

This is a primary document developed to meet the requirements identified in Change Request M-45-04-01 of Ecology et al. (1989), *Hanford Federal Facility Agreement and Consent Order* (HFFACO). The relationship of the tank waste retrieval work plans to the overall SST waste retrieval and closure process is described in Appendix I of the HFFACO under Change Request M-45-04-01. The purpose of this document is to provide the Washington State Department of Ecology (Ecology) information on the planned approach for retrieving waste from tanks C-103 and C-109 to allow Ecology to approve the waste retrieval action.

Tank waste retrieval work plans have been developed for the other 100-series tanks in the C farm including RPP-22520, *241-C-101, 241-C-105, 241-C-110, and 241-C-111 Tanks Waste Retrieval Work Plan*, and RPP-22393, *241-C-102, 241-C-104, 241-C-107, 241-C-108, and 241-C-112 Tanks Waste Retrieval Work Plan*. Additionally, a similar document was also prepared for the C-200-series tanks, RPP-16525, *C-200 Series Tanks Retrieval Functions and Requirements*. Neither a functions and requirements document nor a work plan was developed for tank C-106. Regulatory approval to retrieve waste from tank C-106 was established through the HFFACO.

Where information regarding treatment, management, and disposal of the radioactive source, byproduct material, and/or special nuclear components of mixed waste (as defined by the *Atomic Energy Act of 1954*) has been incorporated, it is not incorporated for the purpose of regulating the radiation hazards of such components under the authority of this tank waste retrieval work plan or Chapter 70.105 RCW.

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



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

2.1 RETRIEVAL START DATES

A summary of the current schedule baseline for waste retrieval from the two tanks addressed in this document is provided in Figure 2-1. Current plans include initiating waste retrieval from tank C-103 in late summer 2005 and tank C-109 in mid 2006. The schedule information provided in this document is current as of the first quarter of calendar year 2005 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 two 100-series tanks, C-103 and C-109, located in the C tank farm in the 200 East Area (Figure 2-2). Summary-level historical data related to the configuration and operating history for tanks C-103 and C-109 are provided in Table 2-1.

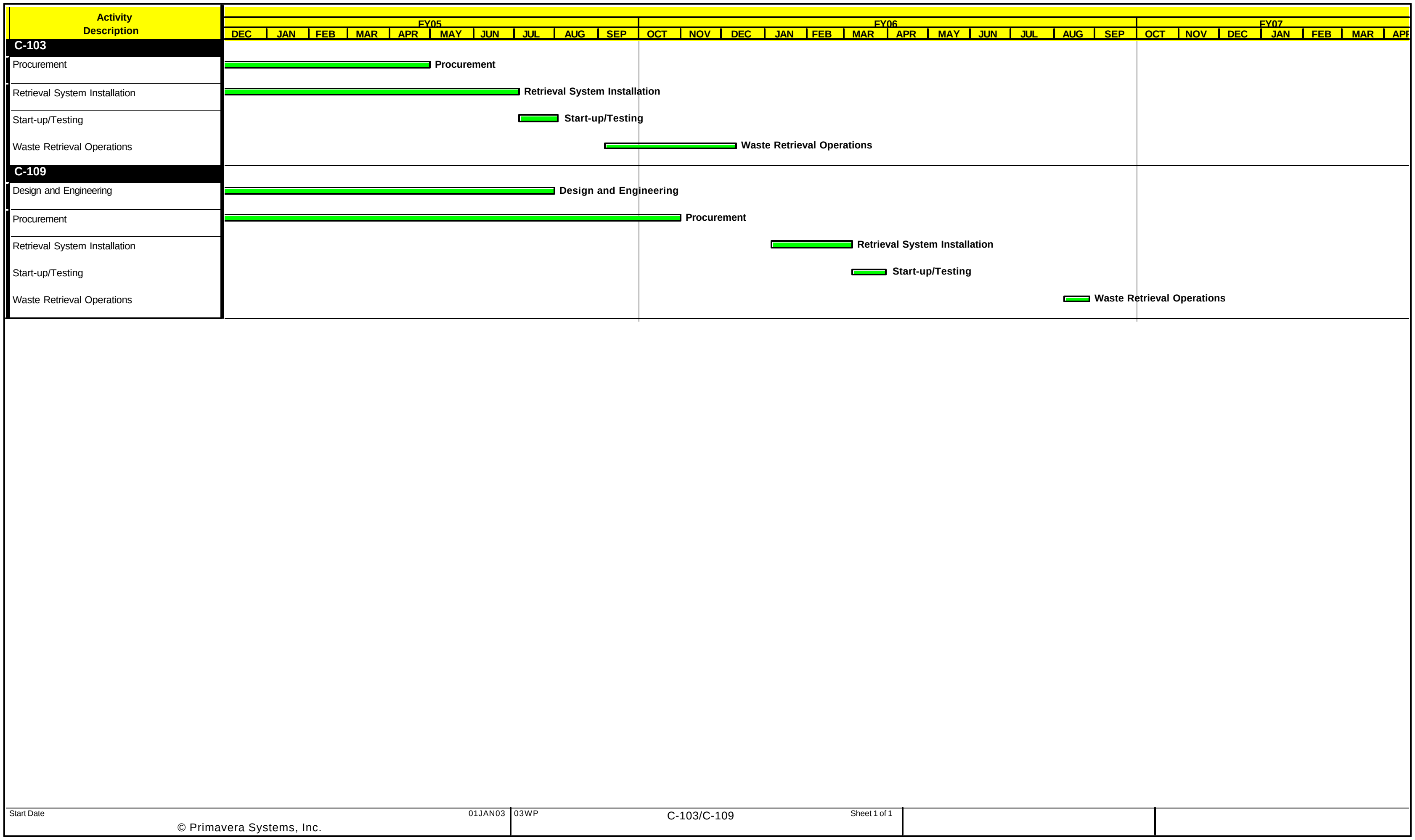
Table 2-1. Summary-Level Tank Data.*

Tank	C-103	C-109
Constructed	1943-44	1943-44
In service	1946	1948
Diameter (ft)	75	75
Operating depth (in.)	185	185
Design capacity (gal.)	530,000	530,000
Bottom shape	Dish	Dish
Ventilation	Passive	Passive
Nominal burial depth (ft)	6	6
Declared inactive	1979	1976
Integrity	Sound	Sound
Interim stabilized	July 2003	November 1983

* Best-basis inventory AutoTCR documents (4-13-2005) from TWINS, Web Site - http://twinsweb.pnl.gov/twins.htm.

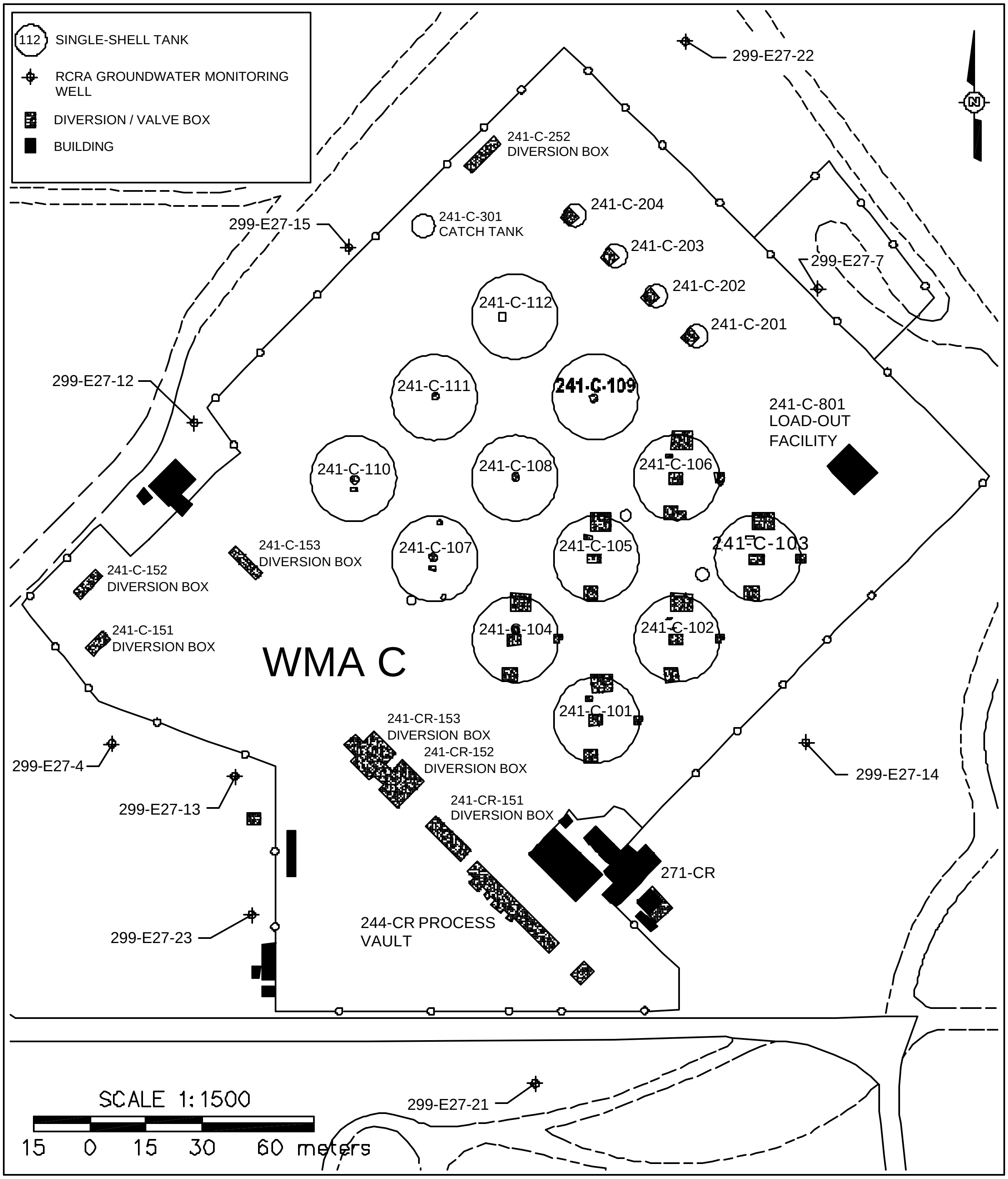
TWINS = Tank Waste Information Network System.

Figure 2-1. Waste Retrieval Schedule.*



*CH2M HILL Hanford Group, Inc., IMES schedule 5/18/2005.

Figure 2-2. Location of Tanks C-103 and C-109.*



H:\CHG\241-C TF\2E-C109-C2

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

Both of these tanks are designated as sound in HNF-EP-0182. The designation of sound is based upon tank surveillance data that indicates no loss of liquid attributed to a breach of integrity. See Section 2.4 for a discussion of the basis for tank designation.

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

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

Tanks C-101 through C-106 were modified after initial tank construction to add pits at the tank farm surface. Tanks C-107 through C-112 were also subsequently modified to add central saltwell pump pits. Because of these modifications, the configuration of tank C-103 is different than tank C-109, as described in the following sections.

2.2.1 Tank C-103 Configuration

The existing configuration of tank C-103 is depicted in the cross-section view in Figure 2-3.

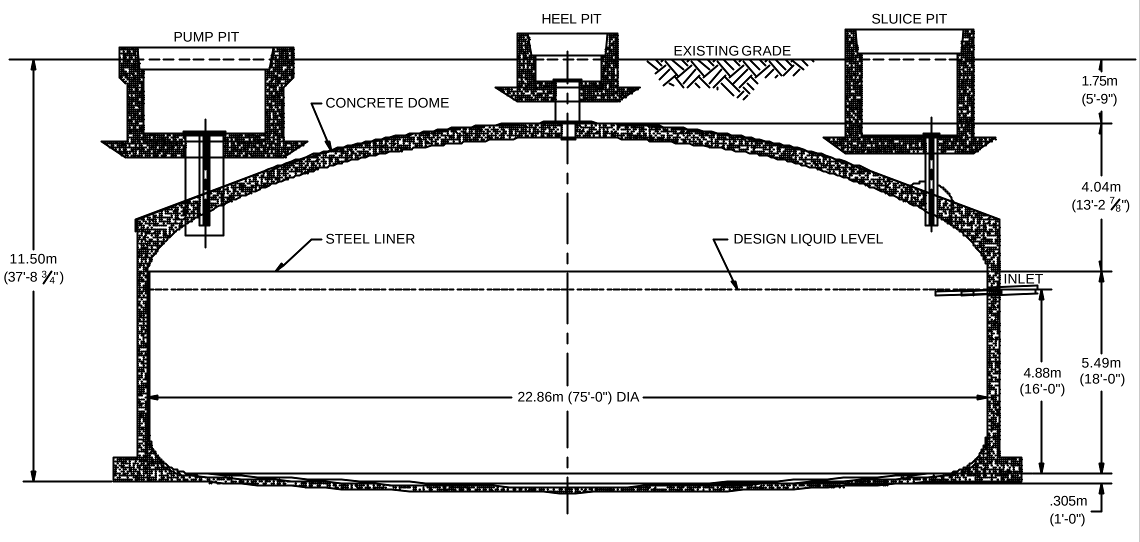


Figure 2-3. Tank C-103 Cross-Section View.*

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

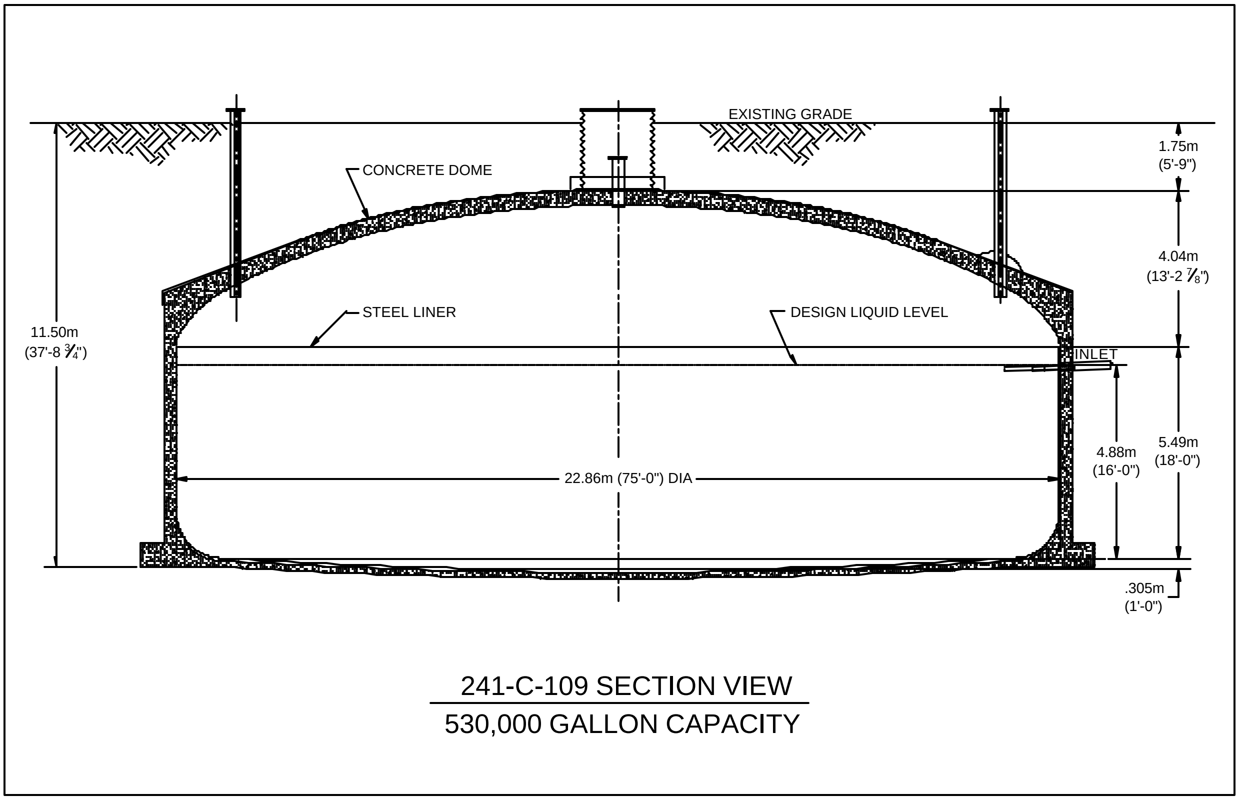
Tank C-103 has three reinforced concrete process pits that were installed after initial tank construction to facilitate waste retrieval. These pits are constructed of reinforced concrete and extend above grade. The pits provide secondary containment for the primary transfer piping within, and have removable cover blocks or plates that allow entry into the pits. The pit floors were constructed with drains that direct any liquid back into the tank through a tank riser located in the pit. The condenser hatchway (not shown in Figure 2-3) located above the outside edge of the tank provided an indirect access path into the tank for ventilation.

Each pit used for waste retrieval will have a conductivity probe leak detector.

2.2.2 Tank C-109 Configuration

The configuration of tank C-109 is depicted in the cross-section view in Figure 2-4.

Figure 2-4. Tank C-109 Cross-Section View.*



H:\CHG\241-C TF\2E-C109-C3

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

Tank C-109 does not have any concrete pits, but does have a caisson that was installed over the center riser after initial tank construction to facilitate waste retrieval. The caisson is 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. The caisson extends above grade and is closed off on the top with a coverplate.

Drawing H-2-38597, *Salt Well Pump Pit Assembly for Std. 12" Riser*, shows the original installation of the corrugated caisson. The caisson was installed in a groove in the concrete bottom of the pit and sealed with grout. A drain, flush with the bottom of the pit, previously routed drainage to the 12-in. riser. Drawing H-14-106599, *241-C Sluice Retrieval Mechanical Equipment Installation*, shows the equipment installation to be used during tank C-109 retrieval. A conductivity probe leak detector will be used in the pit. A sump pump is used to pump leakage into the tank.

2.3 TANK RISER AND FILL/CASCADE LINE INFORMATION

This section identifies the "as is" configuration of the risers and fill/cascade lines. Table 2-2 provides the size and current use/contents of tank C-103 risers and fill/cascade lines, and Figure 2-5 provides the tank C-103 riser plan view. Table 2-3 provides the size and current use/contents of tank C-109 risers and fill/cascade lines. Figure 2-6 provides the tank C-109 riser plan view. Use of the risers for waste retrieval is described in Section 3.0.

Table 2-2. Tank C-103 Riser and Fill/Cascade Line Descriptions.*

Riser Number	Diameter (in.)	Use Description
R1	4	Temperature probe (benchmark)
R2	12	Breather filter
R3	12	Sluicing nozzle (weather covered)
R4	4	Recirculating dip leg
R5	4	Recirculating dip leg
R6	12	Sluicing nozzle [a]
R7	12	Spare
R8	4	Level gauge (ENRAF) [b]
R9	42	Special probe
R13	26	Spare (saltwell pump has been removed)
B [c]	3	Overflow inlet (cascade line from tank C-102)
C1 [c]	3	Spare inlet (capped)
C2 [c]	3	Spare inlet (capped)
C3 [c]	3	Spare inlet (capped)
C4 [c]	3	Spare inlet (capped)

*Reference documents from TWINS, Web Site – http://twinsweb.pnl.gov/twins.htm and H-14-010613, *Waste Storage Tank (WST) Riser Data*, Sheets 1 and 2 (with Engineering Change Notices).

TWINS = Tank Waste Information Network System.

[a] Preliminary information indicates there may be an old equipment item in this pit that may have to be removed.

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

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

Figure 2-5. Tank C-103 Riser and Fill/Cascade Line Plan View.

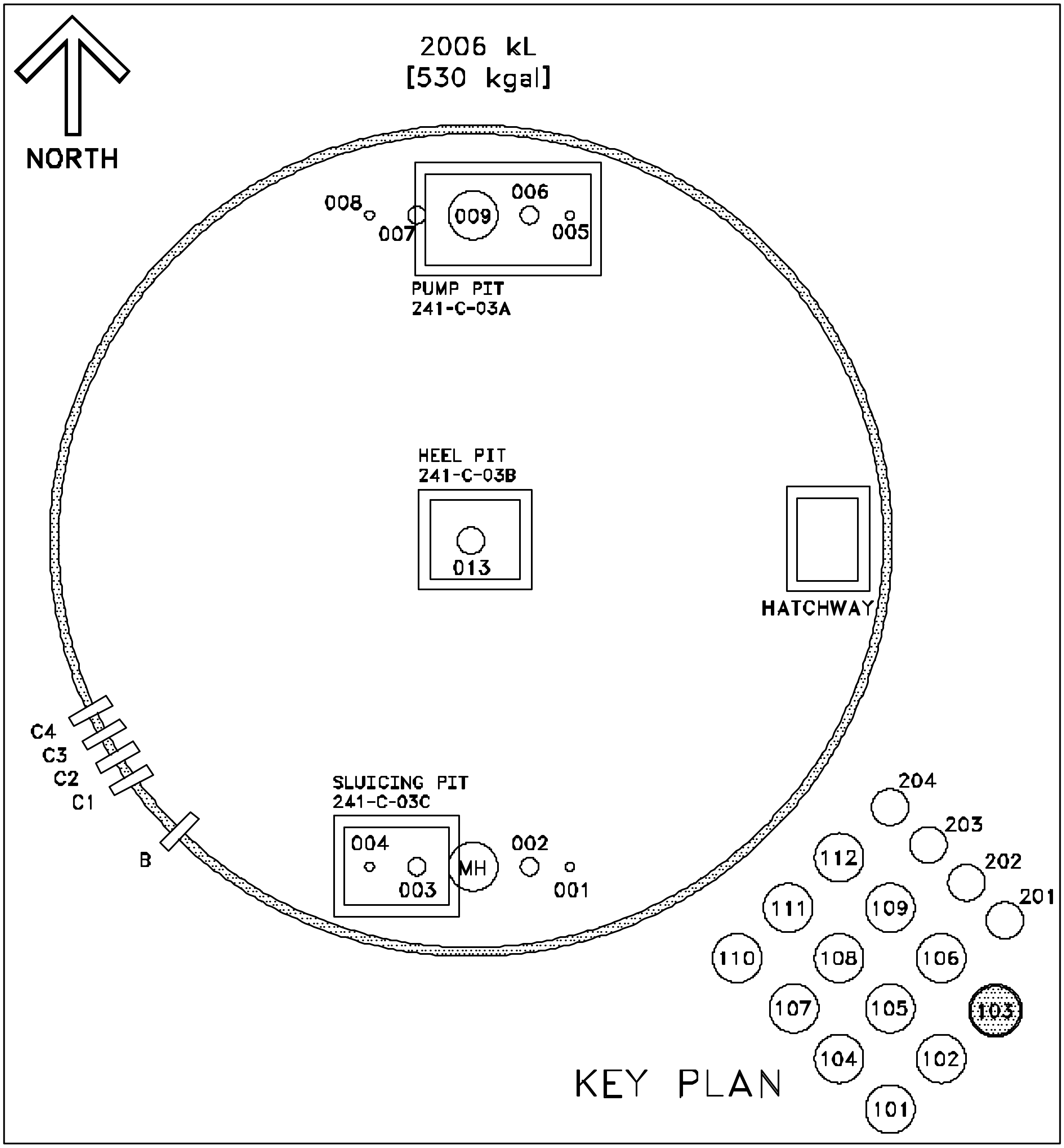


Table 2-3. Tank C-109 Riser and Fill/Cascade Line Descriptions.*

Number	Diameter (in.)	Use Descriptions
R1	4	Level gauge (Enraf) [a]
R2	12	Flange (bench mark)
R3	12	Temperature probe
R4	4	Breather filter on Y-adapter
R5	4	Drywell
R6	12	Spare
R7	12	B-222 observation port
R8	4	Temperature probe
R13	12	Saltwell pump (in weather-covered corrugated pit)
B [b]	3	Overflow inlet, from tank C-108 (cascade line)
C1 [b]	3	Spare, capped
C2 [b]	3	Spare, capped
C3 [b]	3	Spare, capped
C4 [b]	3	Spare, capped

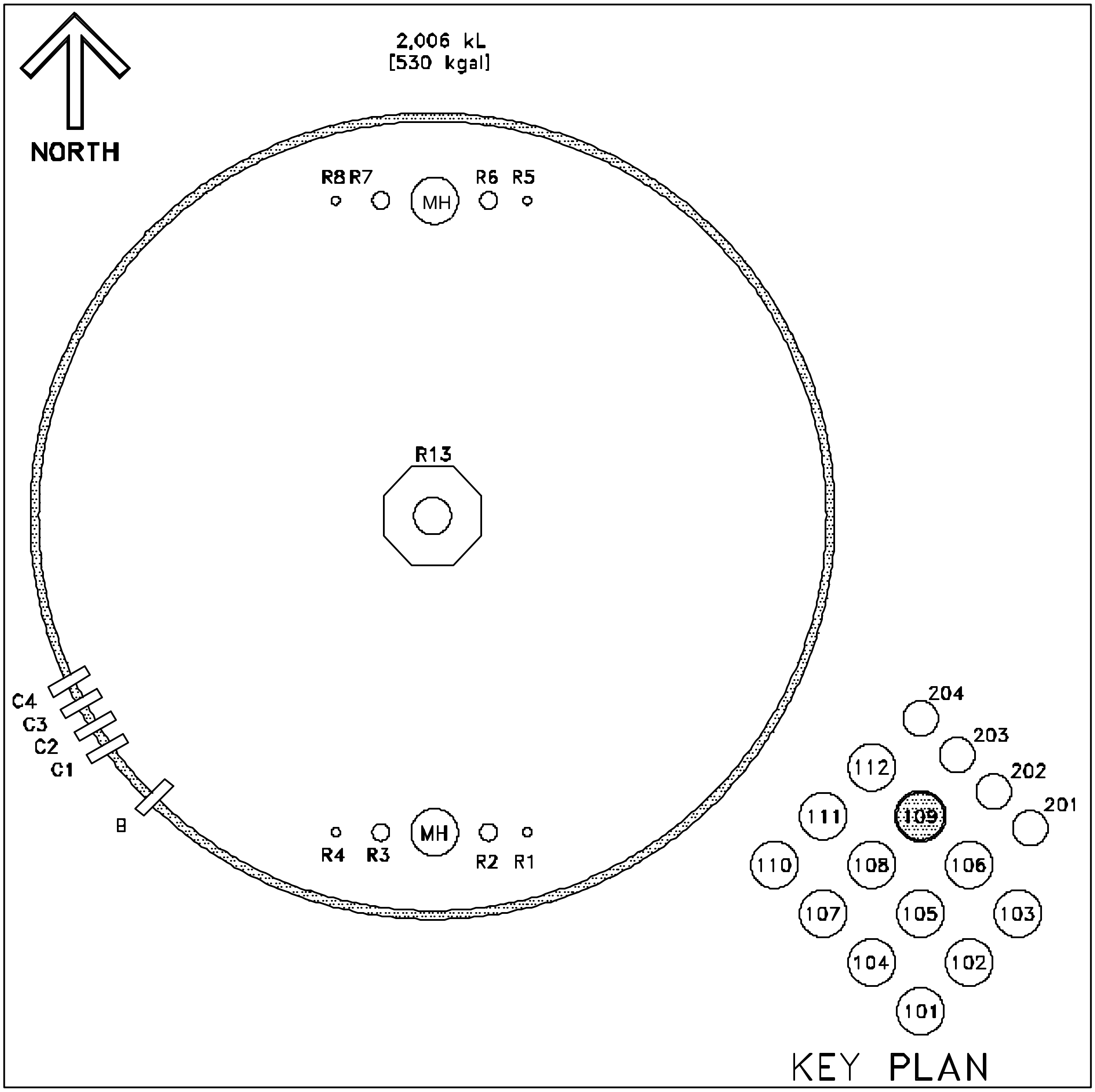
*Reference documents from TWINS, Web Site – http://twinsweb.pnl.gov/twins.htm and H-14-010613, *Waste Storage Tank (WST) Riser Data*, Sheets 1 and 2 (with Engineering Change Notices).

TWINS = Tank Waste Information Network System.

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

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

Figure 2-6. Tank C-109 Riser and Fill/Cascade Line Plan View.



2.4 TANK CLASSIFICATION

Tanks C-103 and C-109 are classified as "sound" in HNF-EP-0182. "Sound" classification is assigned to a tank when surveillance data indicates no loss of liquid attributed to a breach of integrity. A description of the 100-series tanks is provided in RPP-13774, *Single-Shell Tank System Closure Plan*, Appendix C, Section C2.0.

WHC-SD-WM-ER-313, *Supporting Document for The Historical Tank Content Estimate for C-Tank Farm*, discusses all the past level (and other) data used to provide an estimate of the tank contents in the mid-1990s timeframe. No unexplained level drops are mentioned for any of these tanks. The document states that occurrence reports were issued for tank C-103 in 1988 and 1990 because of a decease in surface level that was attributed to natural breathing of tank and evaporation. The document states that an occurrence report was issued in 1982 for tank C-109 because of increasing activity in a drywell, but the activity was caused by migration of existing contamination in the vicinity of tank C-108.

RPP-14430, *Subsurface Conditions Description of the C-A-AX Waste Management Area,* provides an evaluation of the available drywell logging information for each tank in Section 3.3 and Appendix E. No significant indications of unexplained gamma radiation are evident in the drywells surrounding tank C-103 or tank C-109 that indicates a leak occurred in that tank. Additional references for drywell monitoring results are provided in Section 4.1.1.

RPP-10435, *Single-Shell Tank System Integrity Assessment Report*, was prepared and issued in response to HFFACO Milestone M-23-24. This document provided an integrity assessment for the SSTs and some ancillary equipment used with the tanks. Appendix C of RPP-10435 discusses tank leak history. There is no mention in Appendix C of RPP-10435, or anywhere else in the document, of any known leaks from these tanks nor is there any wording that would indicate tanks C-103 and C-109 should not be classified as sound.

2.5 TANK WASTE VOLUME/CHARACTERISTICS

The waste volume and physical properties of the waste currently stored in tanks C-103 and C-109 and awaiting retrieval are summarized in Table 2-4.

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

Waste Property	Unit	Tank C-103	Tank C-109
Solids volume [a]	gal	71,000	63,000
Supernate volume [a]	gal	1,000	0
Interstitial liquid volume [a]	gal	10,000	4,000
Sludge density [b]	kg/L	1.60	1.57
Sludge percent water [b]	%	60	35 to 55

[a] Source: HNF-EP-0182, 2005, *Waste Tank Summary Report for Month Ending February 28, 2005*, Rev. 203, CH2M HILL Hanford Group, Inc., Richland, Washington.

[b] Source: Best-basis inventory download from http://twinsweb.pnl.gov/twins.htm dated 7/7/04.

The tank waste inventory data extracted from the best-basis inventory (BBI) (http://twinsweb.pnl.gov/twins.htm) is provided in Appendix C (Tables C-1 and C-2 for tanks C-103 and C-109, respectively). There are varying degrees of uncertainty associated with the waste inventory. The inventory uncertainty is a combination of the uncertainty associated with measurements of waste volume and concentration. Inventory uncertainty estimates have been completed for some but not all constituents and for some but not all waste types. The available inventory uncertainty data for tanks C-103 and C-109 are provided in Appendix C (Tables C-1 and C-2). The standard deviation is calculated from the variation in the sample analysis results. Details on the methodology used for developing inventory uncertainty values reported in the BBI are provided in RPP-7625, *Best Basis Inventory Process Requirements*. The inventory uncertainty data associated with contaminants that drive long-term risk (e.g., technetium-99) can be used for tank C-109 to provide insight to the uncertainty in long-term human health risks presented in Section 7.0. Indicator contaminants identified in Section 7.1.1.1 are noted in Tables F-1 through F-5.

Although there are uncertainties associated with contaminant inventories in the tanks, the following items show that there is sufficient information on the characteristics that affect waste retrieval, transfer, and storage in the double-shell tanks (DSTs) to proceed with waste retrieval:

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

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

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

There are currently no plans to perform additional characterization (e.g., sampling and analyses) of the waste in tank C-103 or tank C-109 to support waste retrieval and transfer. Sampling and analyses of the waste from tank C-103 and tank C-109 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 and to be approved by Ecology.

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

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

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

2.5.1 Tank C-103 Operating History

The following information is taken from HNF-SD-WM-ER-558, *Tank Characterization Report for Single-Shell Tank 241-C-103*. The purpose of WHC-SD-WM-ER-558 was to summarize the information on the historical uses, current status, and sampling and analysis results of waste stored in tank C-103. HNF-SD-WM-ER-558 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, "General Waste Analysis."

Tank C-103 was placed into service in 1946 and received bismuth phosphate first-cycle decontamination (1C) waste from the other two SSTs in the cascade (241-C-101 and 241-C-102). The bismuth phosphate first-cycle decontamination (1C) waste originated from the bismuth phosphate separations process used at B Plant. The purpose of cascading the tanks together was to allow for solids settling. Tank C-103 was filled in October 1946 and stood idle until it was sluiced for uranium recovery in 1953; it was declared empty in August 1953. The tank was re-filled with uranium recovery waste. This uranium recovery waste was removed during 1957 for ferrocyanide scavenging in the 244-CR process vault, then directed to other tanks in the C tank farm. Between 1960 and 1980 the tank received transfers from A, B, BX, and C farm tanks and made transfers to A, C, S, SX, and TX farm tanks. During this period the solids level in tank C-103 rose approximately 5 ft (WHC-SD-WM-ER-349, *Historical Tank Content Estimate for the Northeast Quadrant of the Hanford 200 East Area*).

Tank C-103 received cladding waste transfers directly from the Plutonium-Uranium Extraction (PUREX) Plant during 1960. From 1963 to 1966, the tank received PUREX high-level and organic wash wastes transferred from A farm tanks. In 1969, most of this waste was transferred to SST 241-C-105, a feed tank for the B Plant cesium recovery operation.

During 1970 and 1971, the tank received B Plant low-level waste and PUREX sludge supernate. A high-strontium sludge layer (washed PUREX sludge or PUREX sludge washed in 244-AR vault solids) resulted from PUREX sludge supernate transfers from SST 241-C-106. Most of the supernate from transfers during this period were removed by 1971, thereby reducing the tank waste volume to 92,000 gal.

From 1973 to 1978, tank C-103 received waste transfers from other tanks in the C tank farm as the P-10 pumping program receiver tank. Most of these transfers were a mixture of dilute wastes to be concentrated in the B Plant evaporator. The tank is believed to have received an organic layer during a transfer from SST 241-C-102 in the fourth quarter of 1975. This organic layer floats on the aqueous layer; its thickness is not determined, although it was expected to be less than 13 in. The organic layer originated from PUREX organic wash waste; it is thought to be a solvent mixture of 70% normal paraffin hydrocarbons and 30% tributyl phosphate (HNF-SD-WM-ER-558).

The waste volume of tank C-103 was reduced to 200,000 gal. during a final transfer of supernate in 1979 to SST 241-C-104. Subsequently, the tank was declared inactive in 1979 and was partially isolated in December 1982 (GJ-HAN-82, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-103*). Based on transfer history, the supernate remaining in the tank was a mixture of wastes received by the tank from 1973 to 1978. The wastes include PUREX cladding, PUREX high-level, organic wash, PUREX sludge supernate, B Plant high-level, B Plant low-level, decontamination, N Reactor, ion exchange, reduction-oxidation high-level, reduction-oxidation ion exchange, uranium recovery, laboratory, and flush water wastes (HNF-SD-WM-ER-558).

The existence of a separable organic layer was verified during a December 5, 2001, grab sampling event. An assessment of the organic volume was performed (Aromi [2002], *Recommendation to Proceed with Interim Stabilization of Tank 241-C-103*) and concluded that less than 2,100 gal. of organic are in tank C-103, and probably only 700 gal. of organic existed before initiating interim stabilization.

Interim stabilization pumping was completed for tank C-103 on March 3, 2003, approximately 10 months ahead of schedule. A total of 114,000 gal. of waste was removed. Tank C-103 was declared interim stabilized on July 11, 2003 because of major equipment failure; the declaration letter to DOE was issued August 13, 2003 (HNF-EP-0182).

2.5.2 Tank C-109 Operating History

The following information is taken from HNF-SD-WM-ER-402, *Tank Characterization Report for Single-Shell Tank 241-C-109*. The purpose of HNF-SD-WM-ER-402 was to summarize the information on the historical uses, current status, and sampling and analysis results of waste stored in tank C-109. HNF-SD-WM-ER-402 supported requirements of the 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-109 was placed into service in 1948 receiving bismuth phosphate first-cycle decontamination (1C) waste from the other two SSTs in the cascade (241-C-107 and 241-C-108). The bismuth phosphate first-cycle decontamination (1C) waste originated from the bismuth phosphate separations process used at B Plant. A maximum waste volume of approximately 530,000 gal. in tank C-109 was reached in the third quarter of 1948 and remained at that level until the third quarter of 1952. Supernate from tank C-109 was transferred to SST 241-B-106 in 1952, leaving a 10,000-gal. heel. The tank was re-filled to a total volume of approximately 530,000 gal. through the cascade line with unscavenged uranium recovery waste in 1953 and the tank remained at that level until the fourth quarter of 1955 (HNF-SD-WM-ER-402). From late 1955 until 1958, tank C-109 was used for settling scavenged ferrocyanide waste. Transfer data for this period show several transfers out of the tank to the BC-10 ditch, BC-6 crib, BC-20, BC-17 trench, BC-15 ditch, BC-21 and BC-22. During the ferrocyanide-scavenging operations, tank C-109 did not receive cascaded waste from SST 241-C-108. Tank C-109 received the waste slurry in direct transfers from the process vessels. This is the period when tank C-109 accumulated most of its solids contents. Tank C-109 received alkaline cladding waste and evaporator bottoms transfers of 415,000 gal. in the third and fourth quarters of 1959. Cladding waste supernate transferred to tank C-109 from tank C-105 in 1959 likely contained very little solids content. Although cladding waste tends to be relatively high in solids, these solids likely had already settled in tank C-105 and were probably not included in the supernate transferred to tank C-109.

In 1962, 137,000 gal. was transferred from tank C-109 to the BY tank farm. Waste from the strontium semiworks/hot semiworks was then added at different times to tank C-109, filling it to capacity by the end of 1964. The waste volume remained essentially unchanged until a transfer of 397,000 gal. from tank C-109 to SST 241-C-104 in the first quarter of 1970 and the receipt of 19,000 gal. from tank C-203. In the second quarter of 1970, there was an additional transfer of 375,000 gal. from SST 241-C-110 to tank C-109 (HNF-SD-WM-ER-402). In 1976 approximately 445,000 gal. of supernate was transferred from tank C-109 to tank C-103, and tank C-109 was removed from service. Tank C-109 was declared inactive in 1977. WHC-MR-0132, *A History of the 200 Area Tank Farms*, indicates that the tank was saltwell pumped in 1976 and 1977; however, no saltwell pumped volumes were reported (LA-UR-96-3860, *Waste Status and Transaction Record Summary (WSTRS)*). Saltwell pumping was completed in April 1979. In November 1983, tank C-109 was declared interim stabilized.

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 and route it to a collection tank.

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 2-5 provides a summary of the C tank farm ancillary equipment connected to tanks C-103 and C-109.

Based on the historical information presented in Sections 2.2 and 2.5, the abandoned process lines used for previous waste transfers will be internally contaminated through contact with the waste 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.

The existing buried waste transfer lines routed to tanks C-103 and C-109 have been isolated to prevent the inadvertent transfer of waste or intrusion of water into the tanks following waste retrieval with the exception of the cascade lines and saltwell transfer line. 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 2-5. C Tank Farm Components Associated with Tanks C-103 and C-109.*

Single-Shell Tanks			
Tank 241-	**Constructed**	**Declared Inactive**	**Constructed Operating Capacity (gal.)**
C-103	1943 – 1944	1979	530,000
C-109	1943 – 1944	1976	530,000
Diversion Boxes			
Unit 241-	**Constructed**	**Removed from Service**	**Description**
C-252	1946	1985	Interconnected 241-C-151 diversion box and C farm
CR-152	1946	1985	Interconnected 241-C-151 diversion box and C farm
Valve Pits			
Facility Number		**Description**	
241-C		Valve pit	
Tank Pits			
Facility Number		**Description**	
241-C-03A		Pump pit	
241-C-03B		Heel pit	
241-C-03C		Sluice pit	
241-C-09		No pit, covered saltwell caisson	
Transfer Lines			
Line Number	**Connecting Facilities**		
8002	241-C-103-03A-U1	241-CR-152-L13	
8014	241-C-103-03C-U1	241-CR-152-L10	
8032	241-C-103-03A-U2	241-CR-152-U6	
8035	241-C-103-03C-U2	241-CR-152-U5	
Drain line	241-C-103	241-C-valve pit	
Unknown	241-C-103-03B-U1	241-C-valve pit -L6	
Unknown	241-C-103-03B-U2	Line 8002	
Unknown	241-C-109	241-C-108	
V172	241-C-252-U1	241-C-109/241-C-112	

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

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

- **UPR-200-E-16.** In 1959, the transfer line between 241-C-105 and 241-C-108 leaked and contaminated the soil near the 241-C-105 tank pit.

- **UPR-200-E-81.** In 1969, a transfer line leaked at the 241-C-151 diversion box resulting in a surface puddle (approximately 6 ft by 40 ft) a few feet west of 241-C-151 diversion box. Waste was being transferred from the 202-A building to tank C-102 via the 241-C-151 diversion box at time of leak discovery.

- **UPR-200-E-82.** In 1968, a transfer line leaked near the 241-C-152 diversion box resulting in an approximately 1,000 gal. surface pool of waste. Waste was being transferred from tank C-105 to the 221-B building via the 241-C-152 diversion box at the time of leak discovery.

- **UPR-200-E-86.** In 1971, transfer line 812 leaked outside the southwest corner of the tank farm fence. Waste was being transferred from the 244-AR vault to the C tank farm at time of leak discovery.

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

2.6.1 Tank C-103 Ancillary Equipment

Tank C-103 is connected to SST 241-C-102 by a 3-in.-diameter cascade line (HNF-SD-WM-ER-558). Tank C-103 has 10 risers of varying diameters and lengths of protrusion into the tank. The risers provide access to various in-tank equipment. Table 2-2 identifies the purpose of each riser. A cross-section view of tank C-103 is shown in Figure 2-3. Figure 2-7 illustrates the line and riser locations into and around tank C-103 along with their current uses and some of the planned equipment additions. The latter are subject to change.

Sixty three pathways enter tank C-103 or its associated pits. The pathways include lines, risers, pit drains, weep holes, and ventilation ducts. Fifty two pathways into tank C-103 have already been isolated, as shown in Table 2-6. Current plans for isolation of all remaining pathways are shown in Table 2-7. This work will be accomplished in accordance with the tank closure plan.

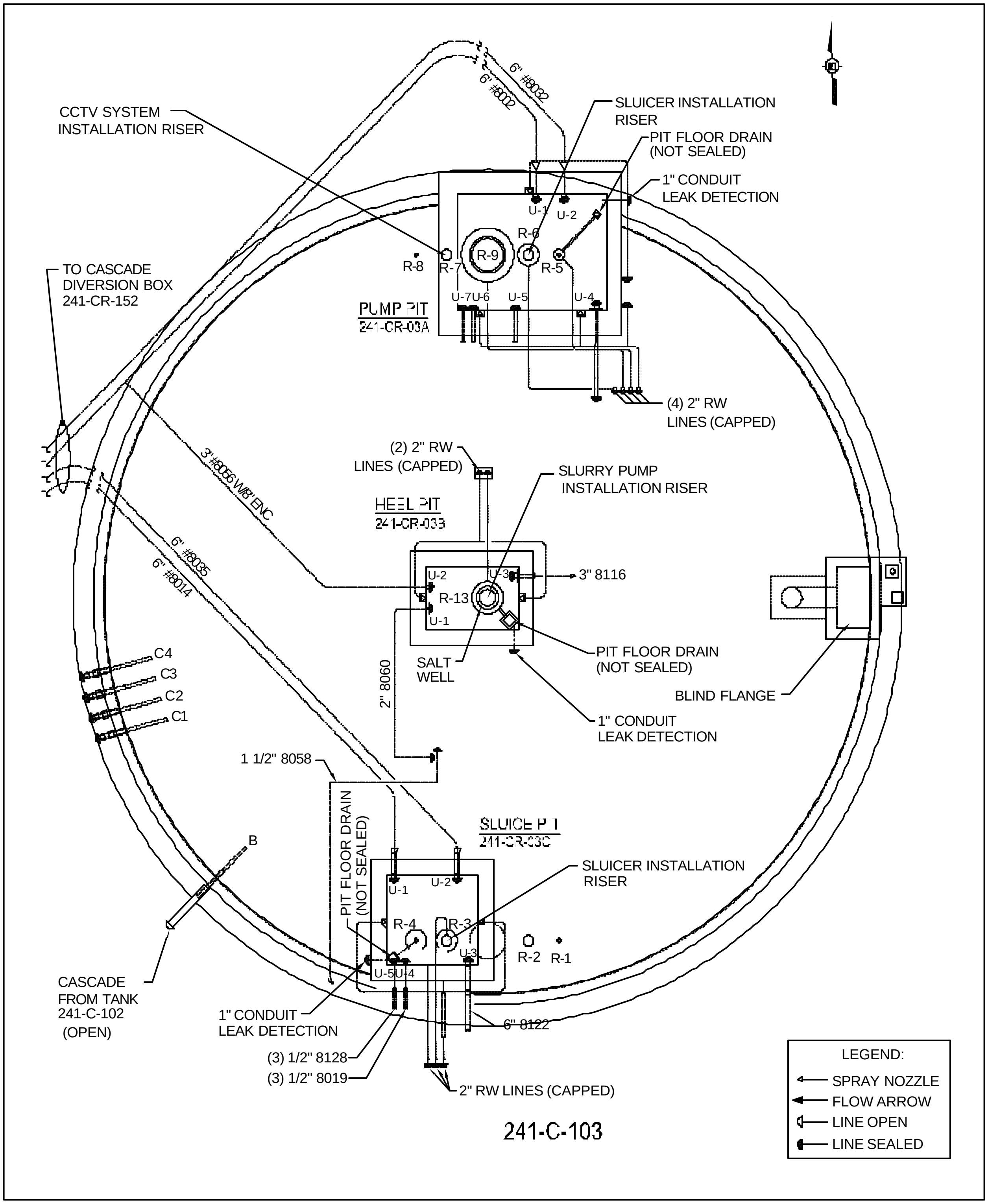


Figure 2-7. Tank C-103 Plan View.

Table 2-6. Tank C-103 Previously Isolated Lines. (2 Sheets)

Intrusion Path	Description	Tank Waste Transfer Line?	Isolation Technique and Status	Verification*
8002	Transfer line	Yes	Isolation blank at 241-CR-152, L13	H-14-104175
8014	Transfer line	Yes	Isolation blank at 241-CR-152, L10	H-14-104175
8019	Air line at nozzle 03C-U4	No	Sluice pit penetration is isolated with a nozzle seal installed on nozzle U-4	H-2-73343 H-2-73453
8032	Transfer line	Yes	Isolation blank at 241-CR-152, U6	H-14-104175
8035	Transfer line	Yes	Isolation blank at 241-CR-152, U5	H-14-104175
8056	Transfer line	Yes	Line T's into 8002 which is isolated with an isolation blank at 241-CR-152, L13	H-14-104175
8116	Spare transfer line	No	Capped outside heel pit, never used	H-2-73343 H-2-41191
8122	Spare nozzle, 241-C-03C, U3	No	Capped outside pit, never used	H-2-73343
8128	Spare air line at nozzle 03C-U5	No	Line capped outside pit	H-2-73343
C1	Spare tank nozzle	No	Capped during tank construction, never used	H-2-73343
C2	Spare tank nozzle	No	Capped during tank construction, never used	H-2-73343
C3	Spare tank nozzle	No	Capped during tank construction, never used	H-2-73343
C4	Spare tank nozzle	No	Capped during tank construction, never used	H-2-73343
1 ½ in. M-21-P to C-801 bldg, no line #	Transfer line connecting pump pit nozzle U-4 to cesium loadout facility (241-C-801)	Yes	Cut and capped outside pump pit	H-2-73343
3 in. M-21-P to C-801 bldg, no line #	Transfer line that interconnects to riser R-5 in pump pit, the cesium loadout facility, and SST 241-C-102	Yes	Cut and capped outside pump pit, open at SST 241-C-102, R2	H-2-73343
Water lines	Four raw water lines to the pump pit	No	Cut and capped above grade just outside of pump pit	H-2-73343
Water lines	Two raw water lines to the 03B heel pit	No	Cut and capped at grade just outside of the heel pit	H-2-73343 Detail A of H-2-71842

Table 2-6. Tank C-103 Previously Isolated Lines. (2 Sheets)

Intrusion Path	Description	Tank Waste Transfer Line?	Isolation Technique and Status	Verification*
Water lines	Three raw water lines to the sluice pit at 03C	No	Cut and capped below grade just outside of the sluice pit	H-2-73343
Utility lines (3)	Utility lines between pump pit (riser R-9) and cesium loadout facility. ((4) 3/8 in. M32, 2 in. raw water and 1 in. air lines)	No	All three lines currently isolated at C-801 bldg. (unknown configuration)	H-2-73343
Air and steam lines	Three lines (2 air, 1 steam) south of heel pit. Serviced gang valve	No	Cut and sealed (unknown configuration)	H-2-73343 H-2-41847
Utility lines	Seven lines, (air, electrical, and water, 5 with penetrations through heel pit wall) serviced weight factor enclosure	No	Weight factor enclosure removed; penetrations isolated per details, H-2-73451	H-2-73343 H-2-41191
Electrical conduit	Electrical conduit on nozzles pump pit U5	No	Plugged	H-2-73343
Electrical conduit	Electrical conduit on nozzles pump pit U6	No	Plugged	H-2-73343
Electrical conduit	Electrical conduit on nozzles pump pit U7	No	Plugged	H-2-73343
Instrument and electrical lines	Through instrument enclosure SW of pump pit	No	Isolated - removed enclosure and filled pit with concrete	H-2-73343
Hatchway cover	Exhaust hatchway	No	Currently weather sealed	H-2-73343 H-2-90251 H-2-38785 H-2-41785 H-2-73632
Risers (10)	4 in., 12 in., and 36 in.	No	Contained in pits, blank flanged, or connected to sealed equipment	H-2-73343 H-14-010613

SST = single-shell tank.

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

Table 2-7. Tank C-103 Currently Open Lines.

Line	Description	Tank waste transfer line?	Planned isolation technique
SN-250	Waste transfer line between heel pit 03B, nozzle U1 and 241-C valve pit, nozzle L6. Ref H-2-73876	Yes	Verify current condition. Remove jumper and install isolation blanks at 241-C, U6 and L6, if required. Drawing H-2-73338 indicates this line was to be isolated.
Nozzle B	Cascade line from SST 241-C-102	Yes	No action until final closure fill in SST 241-C-103 blocks this line.
241-C valve pit drain line, no line #	3 in. M25 drain line connecting to a vertical line core drilled through the tank dome, ref. H-2-73876	No	Identified as to be plugged in 241-C valve pit, ref. H-2-73338.
Pit drain	Pump pit 03A	No	(Open) separate isolation not required.
Pit drain	Heel pit 03B	No	(Open) separate isolation not required.
Pit drain	Sluice pit 03C	No	(Open) separate isolation not required.
Pipe trench weep holes	Pits 03A and 03C	No	Seal.
Pit cover	03A pump pit cover	No	Weather seal removed in preparation for waste retrieval.
Pit cover	03B heel pit cover	No	Weather seal removed in preparation for waste retrieval.
Pit cover	03C sluice pit cover	No	Weather seal removed in preparation for waste retrieval.

SST = single-shell tank.

H-2-73338, 1998, *Piping Waste Tank Isolation C-Tank Farm Plot Plan*, Rev. 5, CH2M HILL Hanford Group, Inc., Richland, Washington.

H-2-73876, 1984, *Piping Plan 241-C Tank Farm*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

2.6.2 Tank C-109 Ancillary Equipment

Tank C-109 is connected to SST 241-C-108 by a 3-in.-diameter cascade line (HNF-SD-WM-ER-402). Tank C-109 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-109 is shown in Figure 2.4. Figure 2.8 illustrates the line and riser locations into and around tank C-109 along with their current uses and some of the planned equipment additions. The latter are subject to change.

Twenty pathways enter tank C-109 or its associated pit. The pathways include lines, nozzles, and risers. Nineteen pathways into tank C-109 have already been isolated, as shown on Table 2.8. Current plans for isolation of all remaining pathways are shown in Table 2.9. This work will be accomplished in accordance with the tank closure plan.

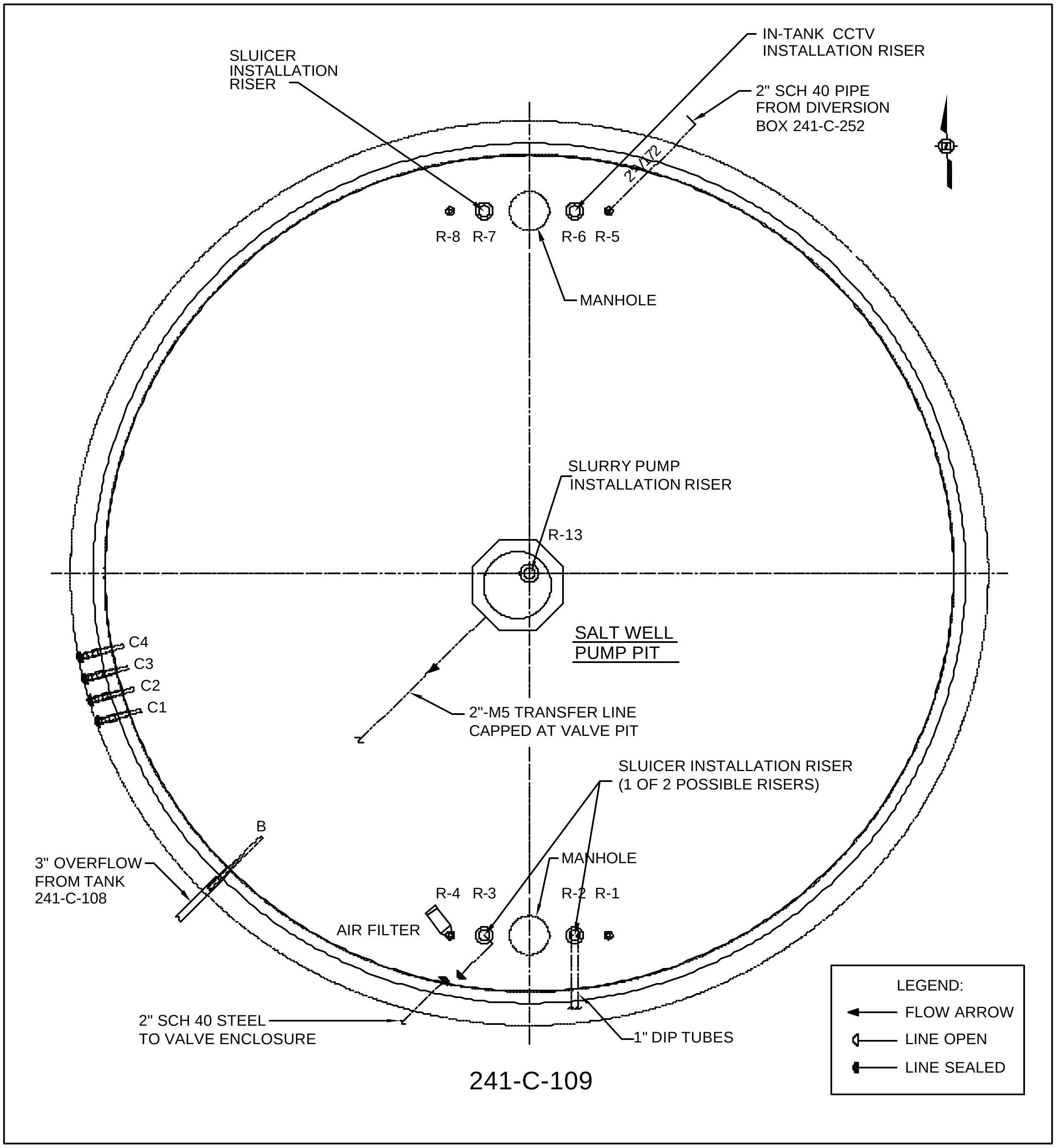


Figure 2-8. Tank C-109 Plan View.

Table 2-8. Tank C-109 Previously Isolated Lines.

Line	Description	Tank waste transfer line?	Isolation technique and status	Verification*
Undesignated line	Transfer line - saltwell	Yes	Capped outside of valve pit 241-C	H-2-73876 H-2-73877
V172	Transfer line	Yes	Isolated at 241-C-252, U1	H-14-104175
C1	Spare tank nozzle	No	Capped during tank construction, never used	HW-72743
C2	Spare tank nozzle	No	Capped during tank construction, never used	HW-72743
C3	Spare tank nozzle	No	Capped during tank construction, never used	HW-72743
C4	Spare tank nozzle	No	Capped during tank construction, never used	HW-72743
No line #	Transfer line (first-cycle waste scavenging)	Yes	Blanked when valve enclosure was removed	H-2-73450
--	Valve enclosure (first-cycle waste scavenging)	Yes	Valve removed and isolated with blind flange	H-2-73450
--	Valve manifold (first-cycle waste scavenging)	Yes	Valve manifold removed and both ends of line blanked	H-2-73450
--	Saltwell pump pit	No	Lines isolated and pit weather enclosed	H-2-73634
Risers (9)	4 in., 12 in.	No	Weather covered in corrugated pit, blank flanged, connected to sealed equipment	H-2-73349

Notes: Raw water, steam, and air lines have been cut and capped.
* Verification documents reference information is provided in Section 9.0 of this document.

Table 2-9. Tank C-109 Currently Open Lines.

Line	Description	Tank waste transfer line?	Planned isolation technique
B	Cascade line from SST 241-C-108	Yes	No action until final closure fill in SST 241-C-109 blocks this line

SST = single-shell tank.

3.0 PLANNED WASTE RETRIEVAL TECHNOLOGY

This section provides a description of the planned waste retrieval technology for retrieving the waste from tanks C-103 and C-109.

3.1 SYSTEM DESCRIPTION

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

3.1.1 Physical System Description

The WRSs will consist of a modified sludge sluicing system to mobilize and retrieve waste from tanks C-103 and C-109. The sluicing system will consist of two (or more) sluice nozzles and a slurry pump in each tank. The sluice nozzles or hydraulic sluicers will be controlled from a control trailer located near the tanks. The sluice nozzles will be installed in existing tank risers located around the perimeter of the tank. The sluice nozzles will have the capability to direct liquid at various locations in the tanks. The flow rate through the sluice nozzles will be adjusted based on the pump-out rate so that the rate of liquid introduction will approximately equal the rate of solution removal with the objective of minimizing the liquid waste volume in the retrieval tank. The waste retrieved from tanks C-103 and C-109 will be transferred to a DST.
To minimize the overall volume of waste requiring storage in the DST system, the waste retrieval project plans to use DST supernate as the primary sluice liquid (see Section 3.1.2 for operating description). The WRS will also have the capability to use raw water for sluicing with minor modifications.

The waste retrieval project currently plans to use DST 241-AN-106 (tank AN-106) for waste receipt and as the source tank for supernate recycle for waste retrieval from tanks C-103 and C-109. Tank AN-106 was selected based on its location, available space, and existing or planned equipment upgrades. Additional detail on the planned use of supernate during waste retrieval is discussed in Section 3.2.

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).
This information will be used to support material balance calculations. The existing ENRAF[1]

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

level gauges will be retracted during waste retrieval operations and will be used periodically to monitor waste levels.

Before initiating waste retrieval, a formal waste compatibility assessment will be performed in accordance with HNF-SD-WM-OCD-015, *Tank Farm Waste Transfer Compatibility Program*. 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. In the absence of a formal waste compatibility assessment, preliminary evaluations have been completed for tank C-103 and for tank C-109. The separable organic phase in tank C-103 will need to be addressed in the waste compatibility assessment, but will not impact waste storage in a DST. At this time there are no known chemical compatibility issues that would prevent the retrieval and transfer of waste from tanks C-103 and C-109 to tank AN-106.

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 3-1. Details of the new ventilation system are provided in AIR 05-407, *Categorical Tank Farm Facility Waste Retrieval and Closure: Phase II Waste Retrieval Operations* and DE05NWP-002, *Notice of Construction (NOC) Application for Operations of Waste Retrieval Systems in the Single-Shell Tank (SST) Farms*.

ORP and CH2M HILL Hanford Group, Inc. (CH2M HILL), pursuant to federal requirements for protection of their workers, will develop and implement a personal exposure sampling and monitoring plan for SST waste retrievals. This plan will be developed and implemented by the 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.

New equipment will be installed in the tanks to support waste retrieval. Existing equipment will be removed if and as required to make room for the new equipment. The new slurry pump will be installed in the center riser located in the center pit. The slurry pump designs for tanks C-103 and C-109 will allow the pump installation height to be adjusted so that the pump suction is as low as possible in each tank to facilitate maximum waste removal. The C-109 pump suction will be installed just under the waste surface to start, so little or no water should be required for this pump installation. The C-103 pump suction will be installed to near the bottom of the tank, so some water could be needed for installation. As described in the following paragraphs, the water needed for C-103 pump installation should be small due to the sludge nature (i.e., not hard saltcake) of the waste and the small submergence of the pump suction. The tank C-103 pump will include a jack screw system that will allow the pump baseplate to be raised above the riser mounting flange. This will provide approximately 2 ft of height adjustment. The tank C-109 pump will be mounted on a winch system that will allow the pump to be lowered as waste retrieval progresses. The system will be designed to allow the pump suction to be lowered as low as possible in the tank to facilitate maximum waste removal. This will allow approximately 10 ft of height adjustment.

In tank C-103, the pump installation will be performed by lowering the pump into the tank with a crane. The pump will be installed as close to the bottom of the tank as practical. As near to the bottom of the tank as practical means the pump is installed until the pump appears to be resting on or near the tank bottom or some hard immovable object. The pump should be installed in the nominal depression left where the saltwell pump and screen were removed. The pump may go into the sludge with its own weight and not need any water addition because the tank C-103 waste is sludge, not saltcake, and the BBI indicates that the tank C-103 sludge is approximately 60 wt% water. If water is needed for pump addition, it would likely be in the 100 to 1000 gal. range. Excessive water would not be added to tank C-103 during pump installation, because there is no benefit in doing so; all water added must be subsequently removed.

In tank C-109, the pump installation will also be performed by lowering the pump into the tank with a crane. The pump will be installed with the suction just into the waste surface a few inches. No water addition should be necessary for the tank C-109 pump because the pump suction will be located just under the waste surface. If the pump suction is too shallow when waste retrieval is started, the sluice nozzle discharges can be aimed at the pump inlet to enable to the pump to be inserted a little deeper.

A booster pump, if used, will be located within the central riser pit. The WRS for tank C-109 may require modifications to the saltwell pit to accommodate installation of a slurry pump in the center of the tank.

The pump adjustment features described previously should allow the tank C-109 pump to be installed with little or no water addition and the tank C-103 pump installed with water addition more likely, but still low in the estimated range stated. However, if tank conditions require water additions to successfully install the pumps (e.g., debris under the pump installation riser) water additions would be controlled in accordance with OSD-T-151-00013, *Operating Specifications for Single-Shell Waste Storage Tanks*, Section 4.1). This water would be added through one or both of the sluicers by lancing or by back flushing through the pump. Lancing refers to lowering a water lance into the waste and adding water to fluidize hard material under the addition point. The initial installation height of the pump will be determined using the in-tank video system.

The sluice nozzles in tank C-103 will be installed within the existing pump and sluice pits. The configuration of tank C-109 is different in that there are no concrete pits and only a single central corrugated metal saltwell pump pit. The WRS for tank C-109 will require design and construction of riser extensions to support the installation of the two sluice nozzles and slurry pump. The in-tank imaging system will be installed in an available riser in the tank. Table 3-1 provides the planned riser usage for tanks C-103 and C-109 WRSs. This riser usage may change.

Figure 3-1. Potential New Ventilation Equipment Layout.

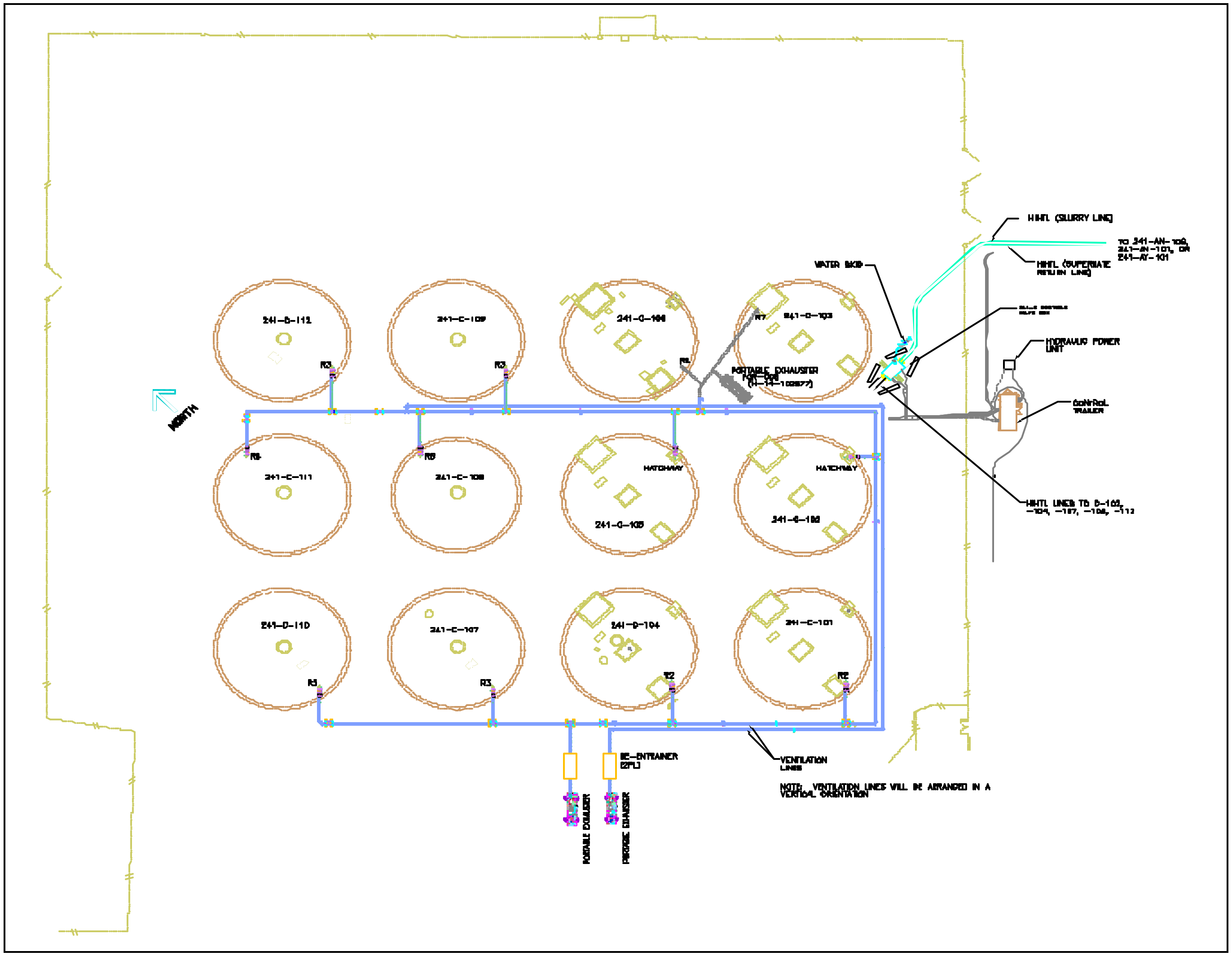


Table 3-1. Planned Riser Usage for Tanks C-103 and C-109 Waste Retrieval Systems.

Riser Number	Tank C-103	Tank C-109
1	--	Enraf* level gauge
2	Vacuum relief	Sluicer
3	Sluicer	Ventilation exhaust duct
4	--	Camera
6	Sluicer	Vacuum relief
7	Camera / POR-008 ventilation duct	Sluicer
8	Enraf* Level Gauge	--
13	Slurry pump	Slurry pump

* ENRAF is a trademark of Enraf, Inc., Enraf B.V., Delft, The Netherlands.

A sketch of the WRS installation planned for tank C-103 is provided in Figure 3-2. A sketch of the WRS installation planned for tank C-109 is provided in Figure 3-3. A potential equipment layout in the tank farm is provided in Figure 3-4.

The portable valve box serves to control the routing and flow of liquid to the sluice nozzles and to control water additions to the waste retrieval process. The valve box provides secondary containment and the collection/detection of any leakage in a sump. The portable valve box has a leak detector that is connected to the pump shutdown system in the control trailer. In the event that a leak is detected in the portable valve box, the transfer pumps in tanks C-103 and C-109 and in the receiver DST would be shut down. The portable valve box has a sump and a sump pump that can be configured to transfer any leakage to the SST being retrieved.

3.1.2 Double-Shell Receiver Tanks

The current planning includes using tank AN-106 as the receiver tank for waste retrieved from tanks C-103 and C-109. Ongoing evaluations may result in identifying alternate receiver tank(s). The receiver tanks will have a supernate pump that will be used to pump liquid back to tank C-103 or tank C-109. The receiver tanks will also have slurry distributors to distribute the sludge received from the SSTs.

Because the elevation of the AN tank farm is approximately 22 ft 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 in C tank farm scheduled for waste retrieval.

Figure 3-2. Tanks C-103 Waste Retrieval System In-Tank Components.

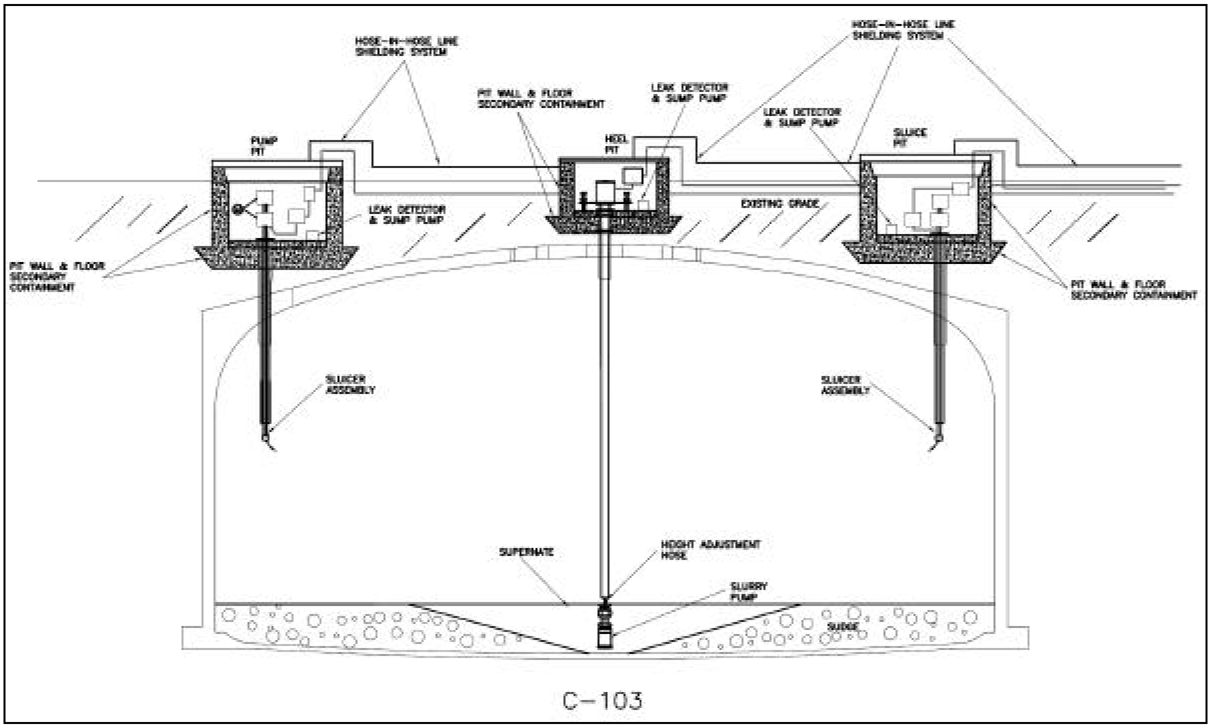


Figure 3-3. Tank C-109 Waste Retrieval System In-Tank Components.

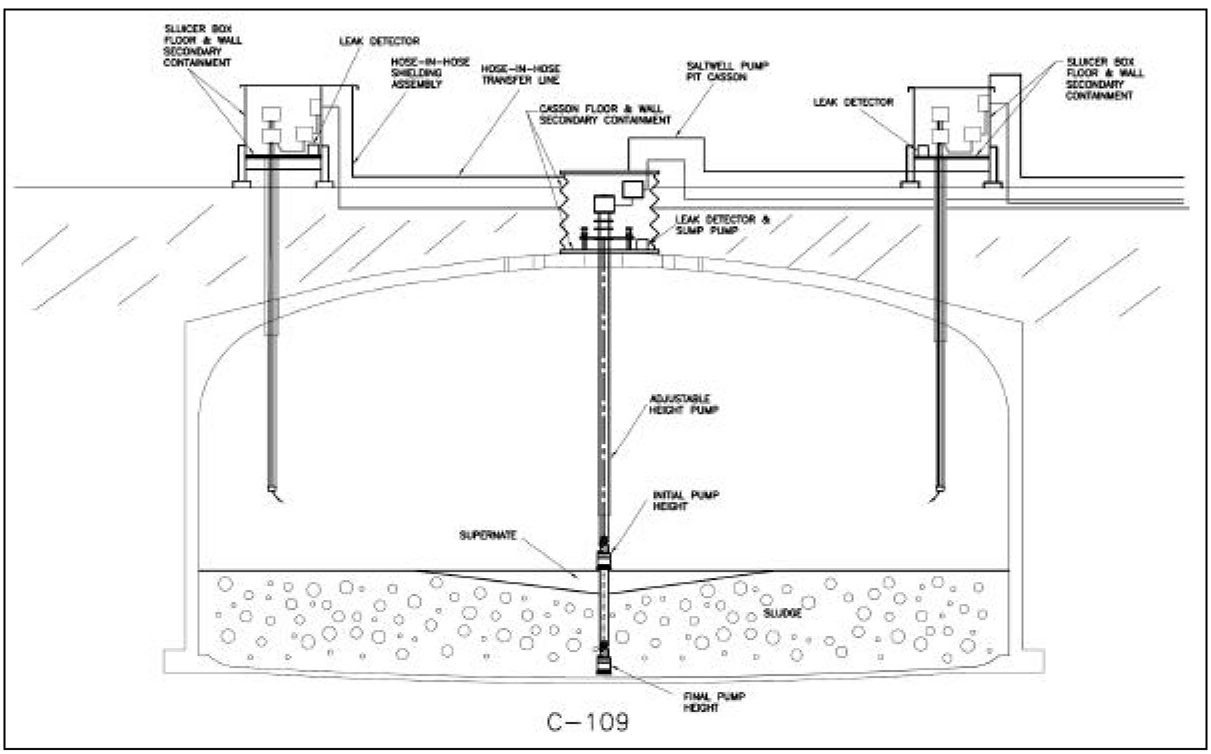
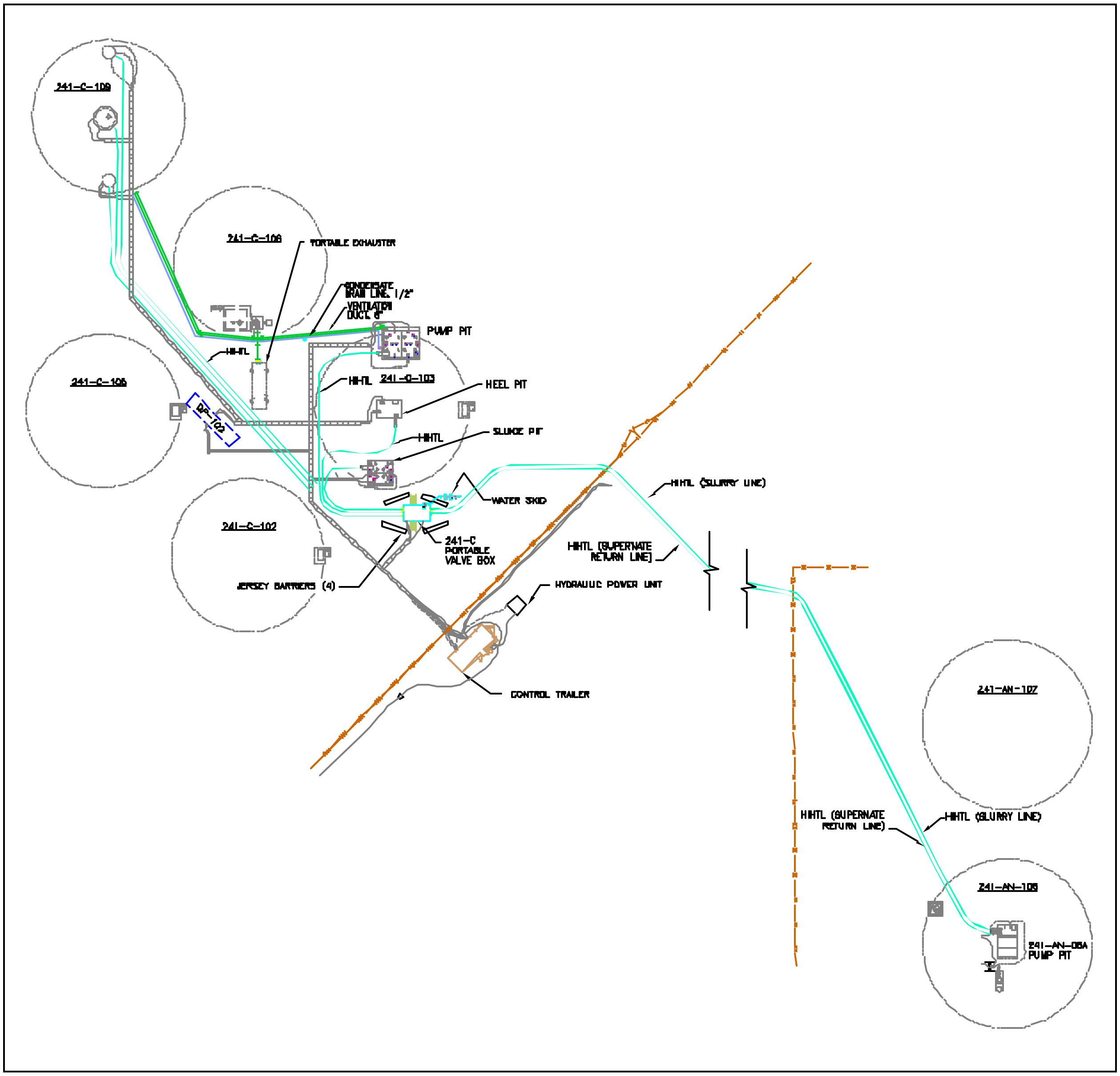


Figure 3-4. Potential Equipment Layout for Tanks C-103 and C-109 Waste Retrieval.



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 (HIHTLs) and the *Resource Conservation and Recovery Act of 1976* (RCRA)-compliant DST transfer system.

3.1.3 Waste Retrieval System Operating Description

The overall WRS operating strategy will consist of reducing the tank waste inventories. The process will be monitored using closed-circuit television to facilitate waste retrieval and minimize any liquids in the tanks. Supernate will be used as the primary retrieval liquid. Raw water will be used in limited quantities as necessary for waste conveyance and transfer line flushing.

During routine operations, waste retrieval will be initiated by starting the supernate pump in the DST source tank and using the pumped supernate to provide sluicing fluid to the selected sluice nozzle. Initial sluicing will be focused in the center portion of the tank to minimize the time required to get liquid to the slurry pump to allow it to be started. The in-tank camera will be used to provide visual input for directing the sluice nozzle. The slurry pumps in tanks C-103 and C-109 will be started as soon as liquid from the sluicer operation reaches the area of the pump inlet and there is enough liquid present to prime and operate the pumps. During waste retrieval, the flow of liquid into the tanks through the sluice nozzles will be controlled to both limit accumulation of liquid in the tank and to maximize waste retrieval efficiency. The slurry removed will consist of both mobilized tank waste and DST supernate used for mobilization. Maintaining a balanced pumping rate into and out of the tanks is integral to minimizing the liquid volume in the tanks and reducing the potential for leakage.

If initial sluicing efforts show the tank C-103 or C-109 sludge is not readily mobilized, it may be necessary to add sufficient liquid to the tank(s) to cover the sludge and allow it to sit for a period of time to soften the solid waste before sluicing is resumed. It is not likely that there will be any need to soften the waste. The tank C-103 waste is estimated in the BBI to be about 60 wt% water and the tank C-109 waste is estimated to be about 35 to 55 wt% water. The only reason to soften the waste would be if the surface had become so hard it resisted breakup by solution from the sluicing nozzles. Extensive dryout of the waste (not likely at the estimated water levels and the 70 to 100 ºF waste temperatures) could cause some agglomeration of the material. The waste could also be held together with salt crystals from supernate that had evaporated. Should either of these occur and the waste not breakup effectively when hit with solution from the sluicing nozzles, adding liquid to the waste surface may be tried to soften it for retrieval. Liquid breaks down the bonds in dried out waste or dissolves most salt crystals. The supernate used will not be saturated at the start of retrieval in a tank and thus will be expected to dissolve such salts or break the crystal structure down sufficiently to permit retrieval.

The volume of free liquid added to soften any waste would be minimized by keeping the free liquid height above the waste to as small as practical. Any free liquid added beyond this would provide little benefit. The time period needed to soften the waste is unknown, but would not be expected to be more than a few hours to a few days.

Pumping during sluicing will maintain minimum liquid volume in the tanks. This will be performed by initially directing the nozzle flow towards the center of the tanks. As the sluice liquid contacts the tank waste, the sludge will be mobilized and retrieved via the slurry pumps. Typically, one sluicer will be operated at a time operating at a flow rate of approximately 60 to 120 gal/min.

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

Liquid will not be added to an SST for the sole purpose of obtaining a level measurement. However, heel submergence remains the best and easiest measurement readily available for estimating the heel volume, and level data will be obtained on an opportunistic basis when performing flushes or during retrieval activities in the latter stages or at the end of the waste retrieval process.

When the level of residual solids gets low in the tank, the volume of solids removed per unit volume of sluicing fluid removed from the tank will be tracked. The units used will be selected by engineering personnel. Waste retrieval operations will continue until less than 360 ft^3 of residual waste remains in the tank, and/or the limits of technology have been reached for this retrieval method. The limit of technology will occur when there are little or no waste solids being removed per unit volume of sluicing fluid used.

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

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

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

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

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

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

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

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

Following completion of waste retrieval and final tank flushing, the residual waste volume will be determined using the methodology defined in RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*, and RPP-PLAN-23827, *Sampling and Analysis Plan for Single-Shell Tanks Component Closure*.

3.2 LIQUID ADDITIONS DURING WASTE RETRIEVAL

Supernate from DST AN-106 will be introduced to tanks C-103 and C-109 to mobilize sludge. Supernate will be added at a rate of approximately 60 (or less) to 120 gal/min. The retrieval liquid along with tank solids will be removed from tanks C-103 and C-109 at approximately the same rate. Utilizing recycled supernate to retrieve the waste from tanks C-103 and C-109 minimizes the overall volume of waste generated during the waste retrieval process. The modified sludge sluicing process will minimize the volume of liquid in the SST during waste retrieval operations.

The use of supernatant will be limited by the following:

1. The waste compatibility assessment for supernatant recycle will be completed and reported to Ecology. This compatibility assessment shall be made to determine if the solution is acceptable for use in retrieving the C-103/109 solids. Ecology will be notified of the results of this assessment, before initiation of retrieval operations. Following

notification of the results of this assessment, a copy of the assessment report shall be provided to Ecology.

2. Submittal of a Retrieval Data Report, as described in the TPA Action Plan, Appendix I, Section 2.0, Figure I-1, 120 days following DOE's completion of retrieval actions for each tank. This report shall include a review of the efficiency and performance of the in-tank settling of the retrieved solids in the receiving DST, an estimate of the amount of solids that were recycled during retrieval of C-103 and C-109, and the impacts these solids have on removing additional solids from C-103 and C-109.

3. A chemical analysis of the Tc-99 in the supernatant of the receiving double shelled tank (currently AN-106) shall be obtained for DST samples taken during the retrieval process. This value will be reported in the Retrieval Data Report, and compared with (a) the currently estimated BBI concentration, and (b) estimated flowsheet changes in the supernate Tc-99 concentration.

4. Ecology will be notified when the cumulative volume of supernatant liquid being recycled exceeds the estimated quantity of 1,000,000 gallons, and for each incremental million gallon quantity recycled. Timely notification by e-mail will be sufficient.

5. Following the use of supernatant, a minimum of three tank heel rinses using a minimum volume of raw water that is three times the estimated residual waste volume will be required to insure that residual waste is removed to the extent practical.

A process flowsheet has been prepared for the C farm 100-series tanks (RPP-21753, *C Farm 100-Series Tanks, Retrieval Process Flowsheet Description*). The calculations performed in support of the flowsheet assume that the retrieved solids are about 3 vol% in the slurry transferred to the receiving DST. The waste retrieval process flowsheet estimate of the total liquid volume transferred during the sluicing of each tank is provided in Table 3-2. In addition, the flowsheet allocates a nominal 105,000 gal. of water for tank and equipment flushing during each tank's waste retrieval operations.

Table 3-2. Tanks C-103 and C-109 Waste Retrieval Summary Data.*

Tank	Initial Tank Waste Volume prior to Retrieval (kgal)	Retrieval Flush Volume (kgal) [a]	DST Supernate Recycle (kgal)	Estimated Operating Duration, days [b]
C-103	72	105	2,350	62
C-109	63	105	2,120	49

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

DST = double-shell tank.

[a] Flushing volume allocation from RPP-21753.

[b] Durations estimated based on the general operating assumptions of 3 shifts operating 7 days/week with 60% operating efficiency. Sluicing durations assume 3 vol% solids loading in slurry and an average transfer rate of 75 gal/min.

At the cessation of waste retrieval operations, the tank walls and heel will be flushed with water. When performing the tank flushes the flush water may be used to push some of the residual waste to a convenient sampling location. For each flush, the volume of water added will be metered and recorded. The flush liquid will be pumped to a minimum heel following each flush addition. It is assumed that performing the final tank flushes will remove residual solids to the extent practical on the walls and dilute soluble radionuclides and chemicals in the tank liquid. The ENRAF level gauge readings taken during the flushing will provide backup data for final tank residual waste measurement.

Assuming a 2,700-gal. liquid heel in a tank with no solids present before rinsing (solids are expected), rinsing with 33,333 gal. of fresh water, pumping down to 2,700 gal. and repeating twice more, the concentration of soluble constituents in the final 2,700 gal. in the tank would be approximately 5×10^{-4} of the original heel concentrations. If the pump heel is below 2,700 gal. or there are solids present in the heel, the dilution would be more. Performing the final tank flushes will remove residual solids to the extent practical on the walls and dilute soluble radionuclides and chemicals in the liquid in the tank.

The final flush volume will be dependent upon the final heel composition and volume. As a minimum, there will be three flushes with a minimum flush volume of three times the volume of the estimated waste heel volume.

The ‘limit of technology’ related to waste removal from a tank is predominantly concerned with solids removal; liquids can continue to be removed from the tank as long as the pump suction is submerged and not plugged by any solids or foreign material in the tank. The ‘limit of technology’ occurs when the point is reached that the quantity of waste removed per unit volume or per batch by the selected retrieval method has become so low as to no longer be effective on a meaningful scale. A final tank flush would be expected to not remove many insoluble solids, but it will proportionately dilute and remove any liquid heel. The ‘technology’ involved with liquid heel removal is dilution and pumping. As explained, a 2,700-gal. supernate heel subjected to three 30,000 to 35,000 gal. flushes will be diluted to a concentration of about 0.0005 of the initial starting concentration. This is a 99.95% removal. Should the 2,700 gal. contain more solids (and thus less liquid), the supernate dilution will be even greater. There is no ‘limit of technology’ wherein no more liquid is removed with dilution; the more dilution performed the more residual contaminated liquid that is removed. The question is one of benefit; when is the quantity of liquid removed per unit volume by a flush no longer of any significant meaning? RPP-21753 estimates the final technetium-99 concentrations in the tanks AY-101, AN-101, and AN-106 supernate solutions following completion of C tank farm waste retrieval to be in the nominal range of 2×10^{-5} to 2×10^{-4} Ci/L (2×10^{-2} to 2×10^{-1} µCi/ml). A 2,700-gal. supernate initial heel in one of the SSTs would thus be reduced to an estimated technetium-99 concentration range of 1×10^{-5} to 1×10^{-4} µCi/ml following three successive 30,000 to 35,000 gal. flushes. The technetium-99 concentrations in the tank C-103 and C-109 wastes are estimated to be in the 3×10^{-2} to 2×10^{-1} µCi/ml range before retrieval. Thus, any heel flushing is expected to reduce the technetium-99 concentration in the liquid heel to below the average tank technetium-99 concentration prior to retrieval, and three 30,000 to 35,000 gal. flushes are expected to remove about 99.95% or more of the soluble constituents.

The timing for transfers out of tanks C-103 and C-109 is dependent upon personnel resource availability, equipment availability, and DST conditions. Once waste retrieval is started, it should follow the general pattern described, but no liquid additions or removals to/from tanks C-103 or C-109 can be predicted for more than a day or two in advance; therefore, no detailed timeline can be developed showing all liquid additions and removals. The water or supernate addition/removal may be intermittent or continuous. Based upon experience with tanks S-112 and C-203 waste retrieval, it will likely last for an 8- to 16-hour period, then be followed by at least a few days wait, then continue. Work continuity will be dependent upon resource availability and external influences. Ideally the retrievals will be completed within a few months, but delays with tank farm work and lack of available resources could stretch retrieval times out to 12 months per tank.

3.2.1 Basis for Using Supernate

By using DST AN-106 supernate as the waste retrieval liquid, the waste from tanks C-103 and C-109 may be able to be retrieved and transferred into AN-106 without the need for a specific evaporator campaign or transfer of waste to other DSTs.

If water were to be used for retrieving the waste from tanks C-103 and C-109, the total volume of liquid required would be approximately 4.6 million gal. (2.3 million + 2.1 million + 2 × 105,000 gal.). If water were used for retrieving waste from tanks C-103 and C-109, the retrieved waste volume would exceed the capacity of the receiving DST and would require multiple waste transfers to other DSTs and evaporation of the liquid to reduce the volume. If water were used for retrieval and the waste volume were managed within the constraints of DST AN-106, about 10 waste transfers out of AN-106 would be required to complete the waste retrieval from tanks C-103 and C-109. To evaporate all of the water to retain DST operating space, approximately seven evaporator campaigns lasting for between five and seven months would be required. This number of transfers and evaporator campaigns would induce significant delays to waste retrieval operations.

Because the supernate is recycled, the net liquid addition to double-shelled receiver tanks will be the nominal 90,000 to 105,000 gal. of flush water per tank plus the volume of interstitial liquid in the retrieved tanks. Following completion of C tank farm waste retrievals, the DST receipt tanks will be at or near their storage capacity.

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

- Currently an evaporator campaign may be 400,000 to 800,000 gal. Evaporation is done on a feed tank basis. If a DST were freed to hold only retrieval water-waste slurry, up to 1 million gal. could be evaporated per batch. If it were necessary to mix the dilute slurry with a number of other tanks, a batch size may be reduced to only approximately 300,000 gal.

- The dilute sluicing fluid would require two passes through the evaporator to achieve full concentration

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

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

The number of campaigns is determined by starting with the initial volume of waste to be processed, 4.6 million gal. To this is added the volume of waste left after the first pass through the evaporator (i.e., 0.5×4.6 million gal. = 2.3 million gal.). Summing these volumes gives 6.9 million gal. Dividing by the 1-million-gal. campaign volume gives 6.9 or 7 campaigns.

The duration of the campaigns is equal to the sum of duration of its elements (i.e., transfers [7 days] + evaporator campaign [12 days] + shutdown [2 days] = 21 days).

The duration of 7 consecutive campaigns is 147 days. Adjusting this value for the operating efficiencies of between 70 and 90% gives a total duration for 7 consecutive 1-million-gal. campaigns of between 5 and 7 months. This is a theoretical time only. To this must be added downtime for maintenance and other issues, and the additional problems associated with transferring 4.6 million gal. of waste within tank farms. The 25 DSTs in the 200 East Area contain approximately 23.3 million gal. as of November 30, 2004. At a nominal 1.1 million gal. per tank, there is no room for the volumes associated with all water sluicing, nor will there be sufficient space cleared up until a number of years following Waste Treatment Plant (WTP) startup. Therefore, evaporation time for water sluicing only will take longer than five to seven months.

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

This use of supernate recycle instead of water for retrieval of the insoluble solids in tanks C-103 and C-109 results in the following benefits:

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

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

3.3 TECHNOLOGIES CONSIDERED AND RATIONALE FOR SELECTION

Candidate waste retrieval technologies currently available for deployment at tanks C-103 and C-109 are (1) modified sluicing and (2) the mobile retrieval system. Modified sluicing uses water or DST supernate to mobilize waste to a pump where it can be removed from a tank. The mobile retrieval system consists of an articulated mast system, 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.

Although modified sluicing could introduce more liquids to the tank than the mobile retrieval system, the modified sluicing system provides a relatively high waste retrieval rate and should not be eliminated from consideration for sound tanks. Addition of liquid to sound tanks as identified in HNF-EP-0182 using the modified sluicing system is considered acceptable. The mobile retrieval system uses vacuum to remove waste to the tank farm surface where liquid is added to enable the waste to be transferred as a slurry. Because of this difference, the mobile retrieval system is currently the preferred waste retrieval technology for tanks that are known or suspected leaking tanks. When modified sluicing is performed using DST supernate, the overall volume of waste requiring management (storage and/or volume reduction) in the DST system is reduced.

After considering both candidate waste retrieval technologies and designation of the tanks as being sound, modified sluicing using recycled DST supernate was selected as the preferred technology for deployment in tanks C-103 and C-109.

3.4 ANTICIPATED PERFORMANCE GOALS

The WRSs for tanks C-103 and C-109 will be designed to retrieve as much waste from the tanks as technically practical with waste residues not to exceed 360 ft^3 or the limit of technology, whichever is less in accordance with the requirements of HFFACO Milestone M-45-00 (see Table 3-3).

3.5 WASTE RETRIEVAL SYSTEM DIAGRAM

A preliminary diagram of the WRS in-tank components is provided in Figures 3-2 and 3-3. As noted in Section 3.1.1 the elevation in the AN tank farm is approximately 22 ft higher than the elevation in the C tank farm.

3.6 WASTE RETRIEVAL SYSTEM FUNCTIONS AND REQUIREMENTS

This section defines the upper-level functions and corresponding requirements to which the tanks C-103 and C-109 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 tanks C-103 and C-109 WRS will be consistent with this work plan. The functions and requirements are provided in Table 3-3 and are focused on defining the upper-level requirements for the tanks.

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

The existing buried waste transfer lines routed to tanks C-103 and C-109 have been isolated to prevent the inadvertent transfer of waste or intrusion of water into the tanks. Following waste retrieval activities for these tanks, the new transfer lines and auxiliary equipment will be flushed as needed and the equipment reused or disposed of as discussed in Section 3.9.

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

Flushing of any valve boxes should not be necessary following retrieval since any such flushing, which is expected to be transferred back to the SST being retrieved, would be expected to be performed before completion of retrieval. Should the situation arise where a valve box needs to be flushed following retrieval, it is estimated that the flush volume would be in the 100- to 200-gal. range. This solution would go to the tank just retrieved, unless a valve change could be made to direct the solution to another SST covered by this tank waste retrieval work plan which had not yet completed retrieval.

Table 3-3. Tanks C-103 and C-109 Waste Retrieval System Functions and Requirements. (2 Sheets)

Function	Requirement	Basis*	Key Elements
Control gaseous and particulate discharges	The ventilation system exhaust shall be filtered to restrict emissions to the environment.	WAC 173-303 WAC 173-400 WAC 173-460 WAC 246-247 TFC-ESHQ-ENV-STD-03 TFC-ESHQ-ENV-STD-04	Mitigate potential release to the public and the environment.
Mitigate potential for leaks to occur during waste retrieval	Prevent inadvertent release from tank C-103 or tank C-109 to the environment.	RPP-13033, Section 3.3.2.3.4	Do not raise waste level above benchmark level. Benchmark level to be provided in process control plan.
Control waste level in tanks C-103 and C-109	The WRS shall be operated to prevent waste level from exceeding 185 in.	OSD-T-151-00013	Minimize liquid level to the extent practical.
Control waste level in DST receiver tank	The WRS shall be operated to maintain waste level within specified allowable maximum and minimum values.	OSD-T-151-00007	Provide for safe waste storage in DSTs.
Remove waste from tanks C-103 and C-109	The WRS shall be capable of removing as much waste as technically possible, with tank waste residues not to exceed 360 ft^3, or the limit of the waste retrieval technology, whichever is less.	WAC 173-303 HFFACO Milestone M-45-00	The WRS shall provide the ability to retrieve as much waste as technically possible.
Control and monitor the waste removal process in tanks C-103 and C-109	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 3-3. Tanks C-103 and C-109 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.	WAC 173-303-283(3)(i) 29 CFR 1910 10 CFR 835 29 CFR 1926	OSHA standards. Occupational Radiation Protection.
WRS secondary containment and leak detection	For ex-tank equipment and piping, the WRS shall incorporate secondary containment and leak-detection design features.	40 CFR 265 WAC 173-303 DOE O 435.1 RPP-13033 HNF-SD-WM-TSR-006	Provide for safe and compliant transfer of waste to the receiver DST.

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

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

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

It is currently planned to leave all in-tank equipment (e.g., the transfer pump) in the tank following retrieval. However, in the unlikely event it is necessary to remove such equipment, it may have to be washed down upon removal to remove excess contamination or to reduce exposure for personnel protection. The volume of water expected for such purposes would likely be in the 50- to 200-gal. range.

Existing risers, pits, and/or caissons associated with the tanks will be isolated following the retrieval activities. These isolation methods are designed to minimize water intrusion to the tank. However, by the general design and nature of the equipment intrusion of rainwater or snowmelt cannot be precluded.

The old process lines and pits used for previous waste transfers should have limited potential for containing residual liquid. The 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. The pits also contained drains to a collection tank. In accordance with RPP-13774, disposition of the ex-tank ancillary equipment, including pipelines, will be performed in accordance with a separate component closure activity plan. Flushing of old lines or pits would not be done unless required or permitted by the component closure activity plan. Should such flushing be required or necessary, it would not take place until closure activities were underway, so the impact of any line flush volumes would be accounted for in the closure plan approved tank fill process.

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

3.8 INFORMATION FOR NEW ABOVEGROUND TANK SYSTEMS

While there are no new aboveground waste tanks or waste treatment systems, the ancillary and containment equipment are considered part of a tank system per WAC-173-303-040, "Definitions." The new aboveground waste tank system equipment is described in Section 3.1.1. The WRS components that contact the waste are the equipment installed in the SST risers that introduce the retrieval sluicing liquid and retrieve the waste, temporary aboveground HIHTLs, and a portable valve box. Aboveground pits, leak detectors, etc. may also come in contact with the waste should there be transfer line leakage.

3.9 DISPOSITION OF WASTE RETRIEVAL SYSTEM FOLLOWING WASTE RETRIEVAL

3.9.1 Disposition of New Waste Retrieval System Components

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

3.9.2 Disposition of Existing Ancillary Equipment

Ancillary equipment associated with tanks C-103 and C-109 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-103 and C-109 is described in Section 2.6. Any contaminated equipment located within risers that needs to be removed following waste retrieval will be packaged and disposed of onsite in accordance with the approved waste acceptance criteria for the Hanford Site burial grounds and TFC-OPS-WM-C-10.

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

3.10 AIR MONITORING PLAN

ORP and CH2M HILL, pursuant to federal requirements for protection of their workers, will develop and implement IH monitoring plans for exhauster stack emissions for the retrieval of tanks C-103 and C-109. The plans will be developed and implemented pursuant to the requirements of TFC-PLN-43, *Tank Farm Contractor Health And Safety Plan*. The constituents of potential concern (COPCs) for which exhauster stack sampling and analysis will be conducted will be identified in the IH monitoring plans for each tank-retrieval. The COPC identified in the IH monitoring plans will be all or a subset, as determined to be appropriate by CH2M HILL IH, of those constituents listed in RPP-20949, *Data Quality Objectives For The Evaluation Of Tank Chemical Emissions For Industrial Hygiene Technical Basis*, Table 4-1, developed with input from Ecology. Once the initial subset of COPC is identified and listed in the IH monitoring plans, no COPC shall be dropped from that list without 90 days prior notification to and approval from Ecology. If ORP notifies Ecology of its desire to cease exhauster stack sampling for a COPC initially identified and listed in an IH monitoring plan and no response is received from Ecology within 90 days, the COPC will be deleted from the IH monitoring plan and sample and analysis activities for that COPC will cease. New COPCs may be added to an IH monitoring plan without notification to or approval from Ecology and without modifying or revising this tank waste retrieval work plan.

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

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

4.0 LEAK DETECTION, MONITORING, AND MITIGATION

The integrated leak detection, monitoring, and mitigation strategy for tanks C-103 and C-109 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 C-103 and C-109 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-103 and C-109
- Minimizes waste releases to the environment should a leak occur
- Provides for detecting a leak in a timely manner
- Provides for determining leak volume in a timely manner
- Provides technically defensible data to support the appropriate response action
- Minimizes the potential risks to human health and the environment.

4.1 EXISTING TANK LEAK MONITORING

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

4.1.1 Drywell Monitoring

There are 70 drywells surrounding the 100-series tanks in the C tank farm. Under the current waste storage mode, drywell logging is performed in accordance with GJO-HGLP 1.8.1, *Hanford Tank Farms Vadose Zone Monitoring Project Baseline Monitoring Plan*. The selections of boreholes and the logging intervals are based on a priority scoring methodology defined in GJO-HGLP-1.8.1. Recent borehole logging results performed as a part of the baseline characterization of the C tank farm, including information describing the background contamination levels present around the drywells surrounding tanks C-103 and

C-109, are presented in GJPO-HAN-18, *Vadose Zone Characterization Project at the Hanford Tank Farms, C Tank Farm Report* and in DOE-EM/GJ641-2004, *Hanford Tank Farms Vadose Zone Monitoring Project: Quarterly Summary Report for Second Quarter Fiscal Year 2004*. Evaluation of historical drywell monitoring data is provided in RPP-14430.

Six drywells are in relatively close proximity to tank C-103 (Figure 4-1). Five of the drywells (30-03-01, 30-03-03, 30-03-05, 30-03-07, 30-03-09) are within 10 ft of tank C-103 and are spaced approximately equidistant from each other around the perimeter of the tank in a 240° arc from north to west. Four of the drywells are 100 ft deep and two are 125 to 130 ft deep. The remaining drywell (30-06-04) is located adjacent to SST 241-C-106 to the northwest (GJPO-HAN-18).

Eight drywells are in relatively close proximity to tank C-109 (Figure 4-1). Five of the drywells (30-09-01, 30-09-02, 30-09-06, 30-09-07, and 30-09-11) are within 10 ft of tank C-109 and are spaced around the perimeter of the tank. The three remaining drywells (30-06-10, 30-08-02, and 30-09-10) are between 11 and 14 ft from the edge of the tank (GJPO-HAN-18). Six of the drywells are 100 ft deep and 2 are 125 to 130 ft deep.

4.1.2 Groundwater Monitoring

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

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

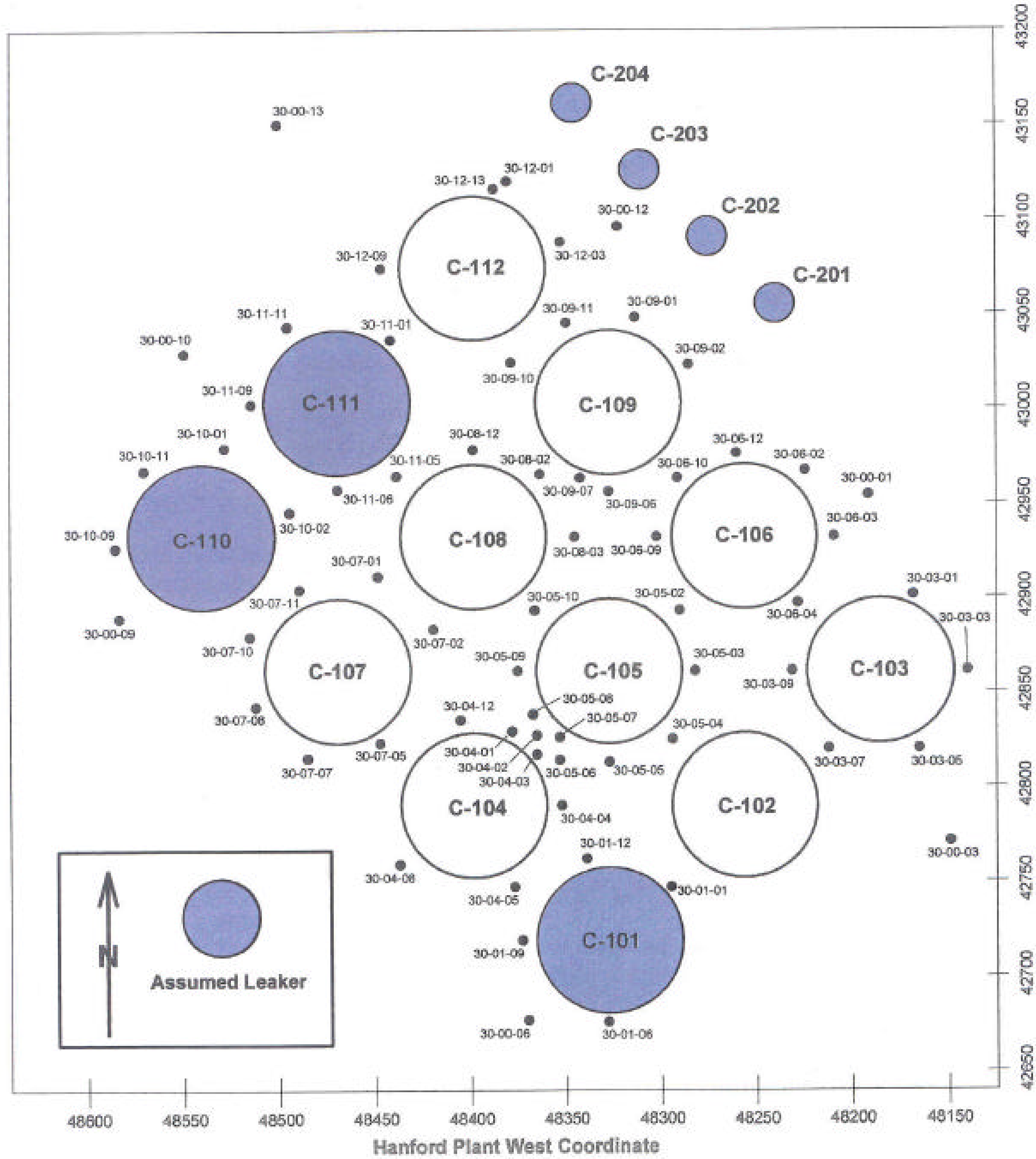
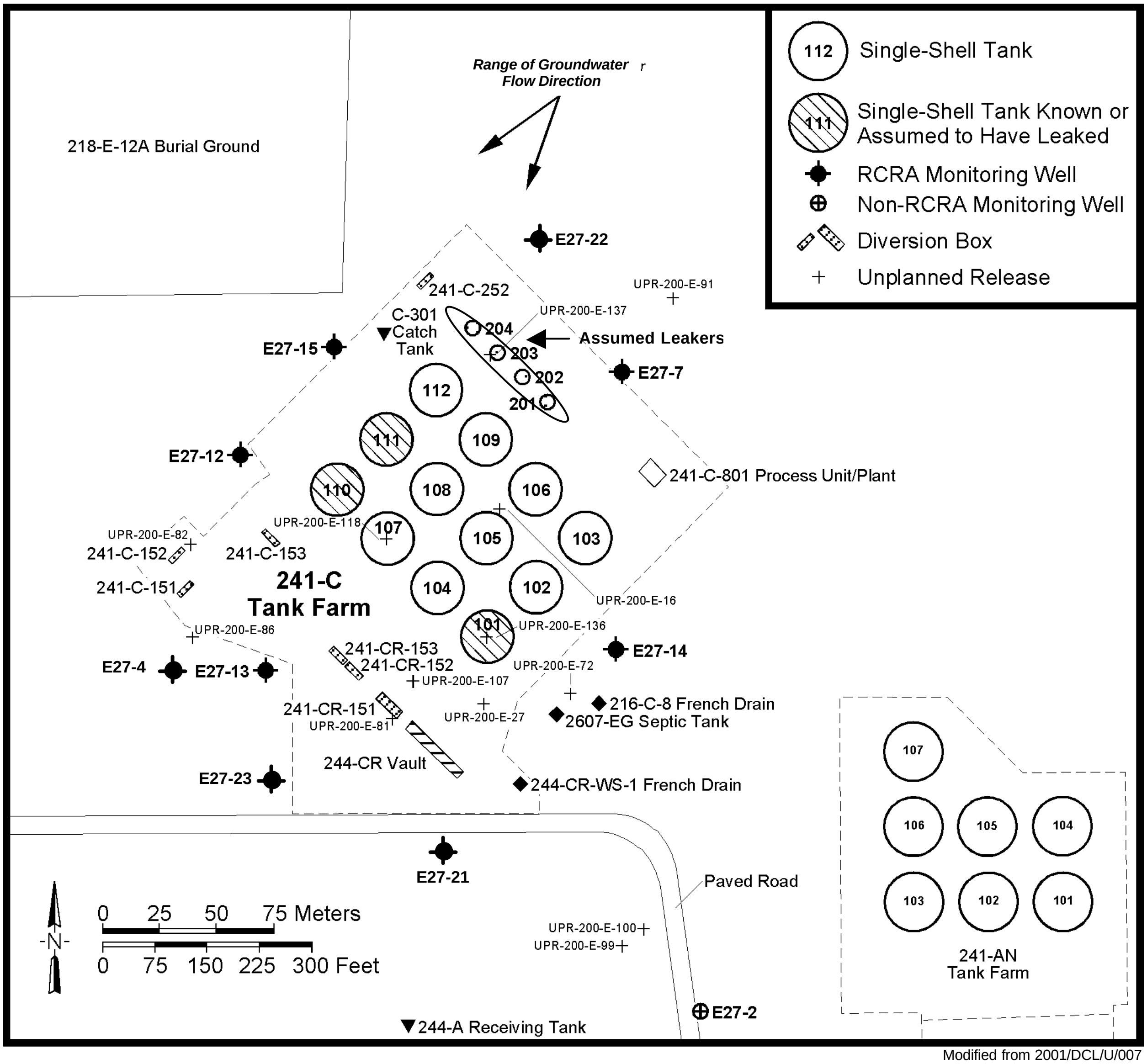


Figure 4-2. Waste Management Area C and Regulated Structures.*



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

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

4.1.3 In-Tank Monitoring

The waste levels in tanks C-103 and C-109 while in storage mode are monitored for intrusion on a quarterly basis using an ENRAF level gauge (OSD-T-151-00031, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection*).

Because all of the interim stabilization criteria have been met for tanks C-103 and C-109, no in-tank leak detection monitoring is currently being performed for them. The basis for in-tank leak detection and intrusion monitoring is provided in RPP-9937, *Single-Shell Tank System Leak Detection and Monitoring Functions and Requirements Document*.

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

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-103 and C-109 during waste retrieval along with a description of how it will be operated.

4.2.1 Leak Detection and Monitoring for Single-Shell Tanks

The primary method for leak detection and leak monitoring for tanks C-103 and C-109 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.

For tanks C-103 and C-109, the high-resolution resistivity (HRR) system will be deployed in a demonstration mode. Although HRR will not be used for process control, Ecology will be informed if an anomaly, indicating a potential leak, is detected during retrieval. 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.

The overall strategy for leak detection during waste retrieval at tanks C-103 and C-109 is to deploy best available technologies for leak detection and leak monitoring. The HRR LDM system will be deployed as a part of a technology demonstration for tanks C-103 and C-109. The HRR LDM system has not been proven on an SST at this time. HRR leak detection has been deployed in a demonstration mode on SST 241-S-102. Following completion of waste retrieval at SST 241-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. This test is described in RPP-17191, *SST Deployment Demonstration and Injection Leak Testing of the HRR Long Electrode LDM System*. These first 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. During the HRR demonstration deployment, the existing drywells surrounding the tanks will be monitored as the primary leak detection method and mass balance calculations will be performed as a backup. The HRR demonstration deployment will provide valuable operating experience and will be used for data collection and evaluation. HRR will only be used in a demonstration mode on a tank during waste retrieval until a decision is made on whether or not it will be used as a baseline leak detection system during retrieval. Should HRR be validated before completion of waste retrieval, HRR, will at that time, become the primary leak detection system for these tanks and drywell monitoring will be stopped for the retrieval LDM where HRR is the primary LDM system.

Additional detail on the SST leak detection approach is provided in the following sections. Leak detection in the waste transfer system and in the receiver DST will be performed using standard leak detection methods in the transfer pits and DST annulus.

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

4.2.1.1. Ex-Tank Leak Detection for Single-Shell Tanks. 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). Weekly logging will be performed during waste retrieval operations. Due to operational constraints, this weekly reading may be missed occasionally. Ecology will be informed of missed drywell monitoring. The drywells will be rebaselined within 6 months after retrieval operations have been completed and will be monitored quarterly for a year 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 handheld moisture gauge will be deployed to monitor specific regions of interest in selected drywells for increases in soil moisture content. The handheld moisture gauge will be deployed by qualified personnel in accordance with TO-320-022, *Operate Model 503DR Hydroprobe Neutron Moisture Detection*. 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 that is 35 to 50 ft below grade and any layers with fine sediments. The base of the tank farm excavation represents a zone of material compacted by tank farm construction activity that may affect lateral movement of water in the vadose zone. Likewise, any fine sediment layers would be expected to control accumulation of any moisture associated with a new leak plume. In the event of an unexplained increase in soil moisture content, additional monitoring with 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.

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-103:** 30-03-01, 30-03-03, 30-03-05, 30-03-07, 30-03-09, and 30-06-04-18.
- **Tank C-109:** 30-09-01, 30-09-02, 30-09-06, 30-09-07, and 30-09-11, 30-06-10, 30-08-02, and 30-09-10.

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

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

The spectral gamma logging system is the logging system used to establish baseline conditions in 1995 - 2000. This logging system is based on a liquid nitrogen cooled high purity germanium 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 spectral gamma logging system truck is also used to operate the neutron moisture logging system, which measures insitu vadose zone moisture over the range of 0 to about 25 vol% moisture content. The neutron moisture logging system uses the same source-detector relationship as the handheld moisture gauge.

The radionuclide assessment system was specifically designed for routine monitoring against the baseline established from the spectral gamma logging system 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 spectral gamma logging system, it is mounted on a smaller truck and collects data at a faster rate.

The handheld moisture gauge is a commercially available system (model 503DR Hydroprobe manufactured by CPN International, Inc.) designed for manual measurement of insitu 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 vol% moisture content.

4.2.1.2. In-Tank Volume (Material) Balance (During Operation). Material balances will be performed for all transfers between tanks in accordance with the process control plan. Primary inputs to the material balance include water additions, volume of waste transferred from tank C-103 or C-109; volume of supernate transferred from the DST receiver tank to tank C-103 or C-109; and the volume of waste within the DST receiver tank. The accuracy of the material balance will be limited because waste volume data for the tank from which waste is being retrieved can only be estimated. Given the operational strategy to minimize liquids in tank C-103 or C-109 during waste retrieval operations, there will not be a liquid level measurement available. Given the dished bottoms of the tanks and the location of the level instrumentation near the side, waste levels cannot be measured below approximately 12,000 gal. In the absence of a means to collect real-time volume measurements for the tank, estimates will be developed using the in-tank camera combined with material balance data.

Transfer line leaks may also be detected by radiation monitoring of the HIHTL in accordance with RPP-12711.

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.

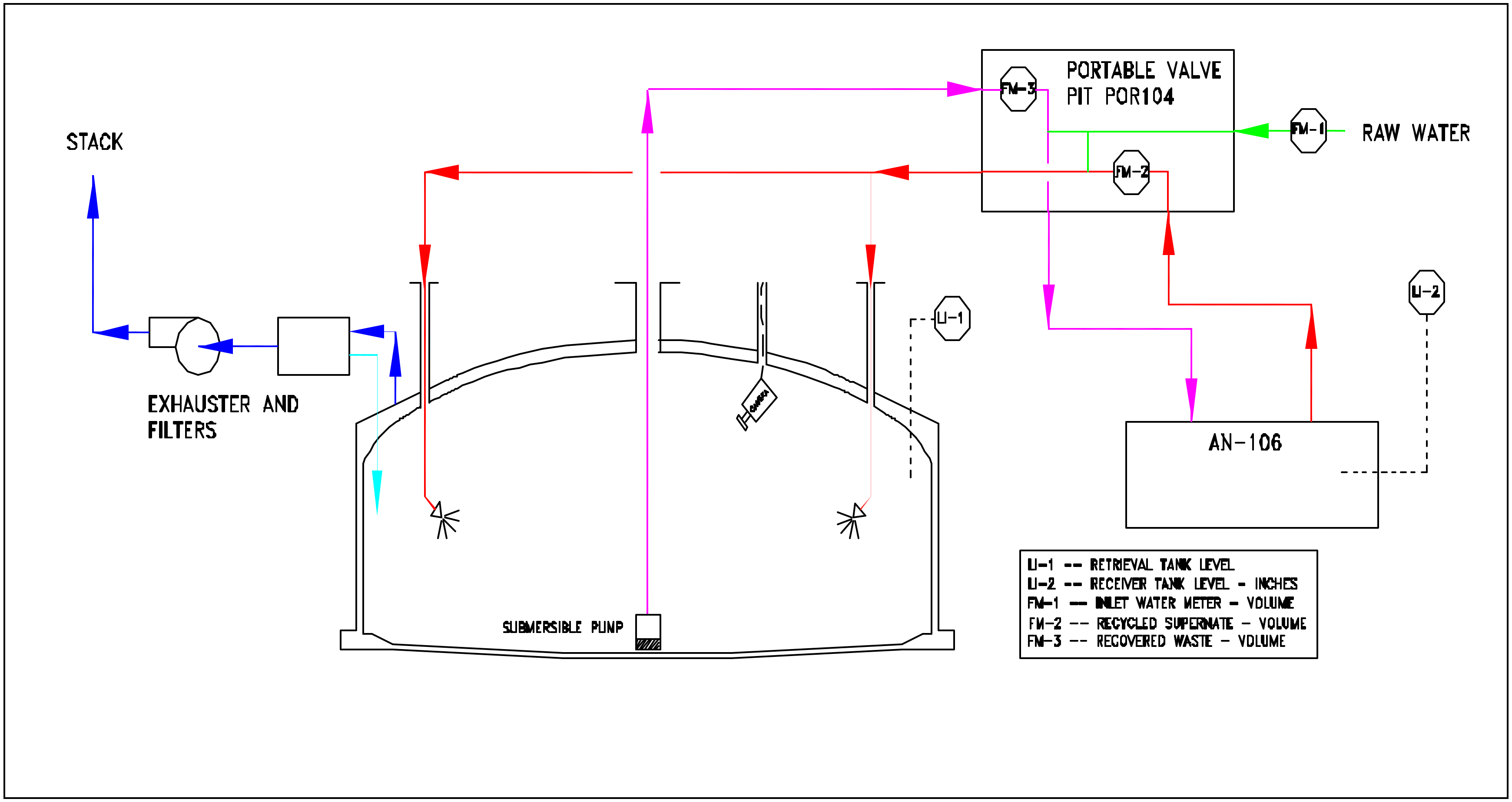
4.2.1.3. High-Resolution Resistivity. The HRR long electrode LDM system is currently planned as a demonstration deployment at tanks C-103 and C-109. The demonstration deployments will serve to gather data and gain working knowledge and experience with the system. The HRR method uses baseline geophysical 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 a leak 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 data will be evaluated on a periodic basis as described in RPP-24576, *HRR LDM Data Processing, Assessment, and Reporting Procedure for C-Farm*. RPP-24576 provides the details as to how the data are reviewed and on what frequency. Following is a summary of some of the information provided in this document. This summary is for information purposes only, and where a difference exists between RPP-24576 and this summary, the wording in RPP-24576 takes precedence.

Figure 4-3. Tanks C-103 and C-109 Simplified Flowsheet Schematic Showing Measurement Locations.



The resistivity data will be analyzed for the presence of large signal changes that are indicative of leaks having a low false alarm potential. This will be a subjective evaluation wherein the trace lines are observed and if no changes are evident it is assumed that there is no leak discernable with HRR. If significant anomalies are observed, these will be statistically evaluated against 95% confidence intervals for a shift in the baseline mean data. Ecology will be informed if an anomaly indicating a potential leak is detected during retrieval.

Deployment of the HRR system for leak detection in the tank farms is new. It is expected that there will be lessons learned during the demonstration deployments. Lessons learned from the demonstration deployments of the HRR system will be incorporated to the extent possible in the design and operation of subsequent HRR system deployments.

4.2.2 Leak Detection in Transfer Lines and Pits

Supernate will be transferred from the receiver DST and liquid waste and slurries will be transferred from tanks C-103 and C-109 back to the receiver DST 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 HIHTL in accordance with the requirements of RPP-13033, *Tank Farms Documented Safety Analysis*, and RPP-12711. Pits associated with the receiver tank will also be monitored.

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

4.2.3 Leak Detection in the Receiver Double-Shell Tank

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

4.3 RATIONALE FOR SELECTION OF LEAK DETECTION AND MONITORING TECHNOLOGY

The LDM technology selected for deployment at tanks C-103 and C-109 represents the best available technology that is consistent with the planned approach for waste retrieval.
The primary leak detection method uses available drywells and established technologies to monitor for liquid losses in the soils surrounding the tanks. Additionally, mass balance will be

used as a backup to the primary method. The HRR system is being deployed as a demonstration technology that may provide improved leak detection monitoring by interrogating the area beneath the tanks.

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-103 and C-109 must be designed and operated. The system specification for the C farm 100-series tanks that defines design criteria will be consistent with this work plan. The functions and requirements for LDM are detailed in Table 4-1.

4.5 ANTICIPATED TECHNOLOGY PERFORMANCE

There is no single value that can be stated as the maximum leak that could go undetected by drywell monitoring for either tank C-103 or tank C-109. There are a wide range of variables that influence the effectiveness of drywell monitoring. A Monte Carlo-type analysis of drywell monitoring performance for SST leak detection was prepared that considered the impact of all significant variables (RPP-10413, *Tank S-112 Saltcake Waste Retrieval Demonstration Project Leak Detection, Monitoring, and Mitigation Strategy,* Appendix B). The calculations indicated that, assuming an optimum 10-ft distance between the tank leak location and the drywell, the 95^{th} percentile leak size is 300 gal. This means if the leak is 10 ft from the drywell, 95% of the calculated leak volumes at detection are 300 gal. or less. When the leak to drywell spacing is set at 45 ft, the 95^{th} percentile leak volume size is 18,000 gal. When it is assumed that there are 3 drywells around the tank and the leak to drywell distance is varied randomly for the analysis, the 95^{th} percentile leak size is 7,980 gal. The variation between the low and high end of the 300- to 18,000-gal. range illustrates the impact of the variables which include, but are not limited to, the distance between leak location and the drywell, leak rate, monitoring equipment capabilities, soil properties, and soil moisture content. Many additional factors can influence the leak rate. The selected monitoring frequency can also impact the leak size at discovery.

Tanks C-103 and C-109 both contain 5 drywells within 10 ft of the edge of the tanks. Tank C-103 contains an additional drywell located between it and tank C-106, which can be used and tank C-109 has 3 additional drywells located between 11 and 14 ft away. Therefore, drywell monitoring for tanks C-103 or C-109 should be comparable to, or more effective than, that estimated in RPP-10413.

As noted in Section 4.2.1.1, the process control plan will define the frequency 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 nominal daily basis when waste retrieval and transfers are being performed.

Table 4-1. Tanks C-103 and C-109 Leak Detection and Monitoring Functions and Requirements.

Function	Requirement	Basis	Key Elements
Detect leaks during waste removal from tanks C-103 and C-109	The LDM system shall be capable of detecting liquid waste releases during all waste removal operations.	WAC 173-303	Utilize both in-tank and ex-tank LDM technologies to detect loss of liquid from a tank; see Section 4.0.
Monitor leaks from tanks C-103 and C-109 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	Utilize both in-tank and ex-tank LDM technologies and operating strategies that will allow estimates of leak volumes and migration rates to be developed in the event of a leak.
Mitigate leaks during tanks C-103 and C-109 waste retrieval	The integrated retrieval and LDM system shall be designed and operated to mitigate leaks as the primary means of minimizing environmental impacts from leaks during waste retrieval if they occur.	WAC 173-303	Leak mitigation strategy described in Section 4.6.
WRS secondary containment and leak detection	For ex-tank equipment and piping, the WRS shall incorporate secondary containment and leak-detection design features in accordance with 40 CFR 265.193 and DOE O 435.1.	40 CFR 265 WAC 173-303 DOE O 435.1 RPP-13033 HNF-SD-WM-TSR-006	Provide for safe and compliant transfer of waste to the receiver DST.

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

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

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

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

RPP-13033, 2005, *Tank Farms Documented Safety Analysis*, Rev. 1H, CH2M HILL Hanford Group, Inc., Richland, Washington.

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

The size of a leak that could be noted using only material balance data has not been formally evaluated for sludge removal from these two C farm tanks. RPP-10413 evaluated a mass balance uncertainty analysis for tank S-112. This tank was estimated to contain approximately 615,000 gal. of waste before retrieval. The vast majority of this waste was saltcake. The two C farm tanks that are the subject of this tank waste retrieval work plan are estimated to contain 63,000 to 72,000 gal. of waste that is predominantly sludge. At least 34 variables were evaluated in RPP-10413 for tank S-112, and the conclusion of that document was that the leak volume uncertainty for tank S-112 had a greater than 80,000 gal. 95% confidence interval uncertainty range at the point where 80% of the original waste was retrieved. RPP-10413 also states that mass balances can detect leaks on the order of 10,000 gal. if both the sending and receiving tanks have a liquid surface.

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

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

The transfer lines and DSTs are RCRA compliant.

4.6 MITIGATION STRATEGY

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

- The in-tank liquid inventory during waste retrieval will be less than liquid levels present in the tanks before interim stabilization activities were undertaken.
- Waste will be retrieved from the center region of the tank first
- Liquid inventories will be removed between waste retrieval campaigns.
- Leak assessment protocols will be per the procedures related to tank leak assessments and resolution of material balance issues.

- Leak assessment protocols are specified in TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process* and include:

  i. **Review available information and identify additional information needs.** Available information includes in-tank and ex-tank measured data (e.g., surface level, flow rate, barometric pressure); tank process history; historical drywell logs; photographs, etc.

  ii. **Develop specific leak and non-leak hypotheses.** Analysts and subject matter experts develop leak and non-leak hypotheses through a concurrence approach.

  iii. **Assess leak probability.** The probability for each leak and non-leak hypothesis is calculated. The probability assessment is reviewed and concurred with by the analysts.

  iv. **Prepare leak assessment report.** The leak assessment report includes the information reviewed, discussion of hypotheses considered, summary of analysts' assessments, summary of mathematical probabilities, and final determination.

- Resolution of transfer material balance issues is per TFC-ENG-CHEM-D-44, *Resolution of Waste Transfer Material Balance Discrepancies*. This procedure lists six potential sources of a positive transfer material balance discrepancy, nine potential sources of a negative transfer material balance discrepancy, 11 potential sources which might cause either a positive or negative transfer material balance discrepancy, and seven other factors which might be considered as part of the evaluation.

- Periodically evaluating HRR system data collected from the demonstration deployment. Data anomalies will be established as leak evaluation indicators and reported once the HRR system is determined as a viable leak detection system.

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

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

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

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

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

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

Should a belowgrade leak from the tank be indicated during waste retrieval, liquid additions to the tank will be suspended and the liquid inventory within the tank will be removed as soon as practical to the extent possible. Ecology will be informed within 72 hours that a leak assessment was initiated and that retrieval operations have been suspended to validate if a leak has occurred. The response to a potential leak will be the same regardless of the leak rate. If the leak assessment concludes that no leak is indicated, waste retrieval operations will resume under normal operating procedures. Should a leak be validated, the operating contractor will notify the appropriate regulatory agencies in accordance with TFC-ESHQ-ENV_FS-C-01, *Environmental Notification*. This includes notification to Ecology pursuant to the requirements of WAC 173-303.

If a belowgrade leak from the tank is indicated during waste retrieval, liquid additions to the tank will be suspended and actions described above will be implemented.

Should a leak be detected in the aboveground containment structures, the waste transfer pumps would be shut down and the leakage would be transferred to the SST being retrieved using the sump pump. Leaked waste will be returned to the SST being retrieved instead of the DST receiver tank because the elevation of the receiver DST farms is higher than that at the C tank farm and wastes leaked to the secondary containment of the transfer lines would drain to the containments at the C tank farm, and leaked wastes would not be transferred to the DST through a transfer system with unknown or questionable integrity. The leaks would be repaired or the leak location bypassed before resuming waste retrieval operations.

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

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

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

- 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 4 hours of annunciation must be reported
- Operating annulus continuous air monitor readings that equal or exceed the continuous air monitor alarm setpoint, 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 liquid 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.
- Equipment handling controls are used to minimize the potential for dropping equipment into the tank, which could penetrate the tank bottom during installation.
- Maintaining a benchmark level in each tank. The waste level shall not exceed this benchmark. The benchmark levels shall be defined in the process control plan.

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

4.6.2 Leak Mitigation for Receiving Tank Leak

The following is a summary of leak mitigation actions for a DST. A more detailed discussion can be found in HNF-3484, *Double-Shell Tank Emergency Pumping Guide*, and RPP-5842, *Time Deployment Study for Annulus Pumping*.

Actions taken in the event of a leak of waste from primary tank piping into the secondary containment system of the DST system, or other receiver tank, during a waste transfer from an SST to a DST include (1) stopping the flow of waste into the tank system (stopping the transfer), (2) pumping waste in the primary tank to another DST until the liquid level in the secondary containment is no longer increasing, and (3) removing the waste from the secondary containment system as soon as practicable. Tanks that develop leaks at or near the tank bottom may also require salt well jet pumping to remove trapped liquids from between solid layers in the tank.

The only receiver tank for the tank C-103 and C-109 wastes is a DST.

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

4.6.3 Leak Mitigation for Transfer Line Leak

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

5.0 REGULATORY REQUIREMENTS IN SUPPORT OF RETRIEVAL OPERATIONS

Retrieval of waste from the SSTs will be performed under the requirements of HFFACO, *Atomic Energy Act of 1954*, RCRA, "Hazardous Waste Management Act" and its implementing regulations, and WAC-173-303, "Dangerous Waste Regulations." The SSTs do not provide secondary containment and are not compliant with RCRA and "Hazardous Waste Management Act" interim facility standards of Subpart J of 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, "Closure and Post-Closure," under the authority of HFFACO Milestone M-45-00, "Complete Closure of all Single Shell Tanks Farms." Except as otherwise modified by HFFACO Milestone M-45-00, DOE conducts day-to-day operations of the SSTs in accordance with the interim facility standards established in WAC-173-303-400(3), "Interim Status Facility Standards." WAC 173-303-400(3) incorporates by reference the interim status performance standards set forth by the EPA in 40 CFR 265. Additionally, the SSTs are governed by federal regulations promulgated under the authority of the *Atomic Energy Act of 1954* and various DOE directives incorporated into the contract between the ORP 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 EPA in 40 CFR 265 Subpart J for tank systems. Elements of the interim status standards relevant to the WRS along with the WRS features and/or operating plans and procedures are summarized in Table 5-1.

If required, approval to retrieve waste that could contain polychlorinated biphenyls (PCBs) from tanks C-103 and C-109 using supernate from the receiver DST and transfer the resulting slurry to the receiver DST will be obtained from EPA before initiating waste retrieval operations. DST supernate is classified as PCB remediation waste in accordance with Ecology et al. (2000), *Framework Agreement for Management of Polychlorinated Biphenyls (PCBs) in Hanford Tank Waste*. Because the DST supernate is PCB remediation waste, the retrieval of waste from SSTs, when using DST supernate, requires a Risk-Based Disposal Approval, approved by EPA, pursuant to 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 health hazard. (d) The owner or operator must record inspections in an inspection log or summary.	RPP-16922, Section 10, contains the Interim Status inspection schedule for both the SST and DST systems. The inspection requirements are implemented through Operator Rounds and Shift Office tickle files. Deficiencies discovered by operators are entered into the Problem Evaluation Request system and resolved through the Tank Farm Contractor work control process contained in TFC-OPS-MAINT-C-01.
265.16 [WAC 173-303-330], Personnel Training	(a) Facility personnel must successfully complete a program of classroom instruction or on-the-job training that teaches them to perform their duties in a way that ensures the facility's compliance with the requirements of this part. (b) Facility personnel must successfully complete the program required in paragraph (a) of this section within six months after the date of their employment or assignment to a facility, or to a new position at a facility, whichever is later. Employees hired after the effective date of these regulations must not work in unsupervised positions until they have completed the training requirements of paragraph (a) of this section. (c) Facility personnel must take part in an annual review of the initial training required in paragraph (a) of this section (d) The owner or operator must maintain records at the facility (e) Training records must be kept until closure of the facility	TFC-PLN-07 contains the training requirements for tank farm workers. Completion of the requirements is recorded in the ITEM. ITEM records are also used to support regulatory agency inquiry during compliance inspections. Tank farm employees who enter the TSD portion of the facility also complete, at a minimum, 24-hour hazardous waste worker training. Employees who may come in contact with tank waste complete the 40-hour hazardous waste worker training. Both groups complete annual 8-hour hazardous waste worker refresher training.
Subpart D [WAC 173-303-350] [WAC 173-303-360], Contingency Plan and Emergency Procedures	265.51 [WAC 173-303-350 (1)]: Each owner or operator must have a contingency plan. 265.52 [WAC 173-303-350 (2) and (3)]: (a) The contingency plan must describe the actions facility personnel must take in response to fires, explosions, or any unplanned sudden or non-sudden release of hazardous waste or hazardous waste constituents to air, soil, or surface water	The Tank Farm Contingency Plan, which supports both the SST and DST systems, is contained in HNF-IP-0263-TF. Supporting the contingency plan are the abnormal operating procedures and the emergency response procedures. Required notifications are contained in TFC-ESHQ-ENV_FS-C-01.

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

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

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

Regulation	Requirement	Compliance Method
	the environment (d) If the emergency coordinator determines that the facility has had a release, fire, or explosion which could threaten human health, or the environment, outside the facility, he must report his findings. (e) The emergency coordinator must take all reasonable 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, Assessment of existing tank systems integrity	(a) For each existing tank system that does not have secondary containment meeting the requirements of 265.193, the owner or operator must determine that the tank system is not leaking or is unfit for use. (b) This assessment must determine that the tank system is adequately designed and has sufficient structural strength and compatibility with the waste(s) to be stored or treated to ensure that it will not collapse, rupture, or fail. (d) If, as a result of the assessment conducted a tank system is found to be leaking or unfit for use, the owner or operator must comply with the requirement of 265.196.	(a) and (b): RPP-10435 prepared and submitted under HFFACO Milestone M-23-24. (d) HFFACO M-45 series milestones
265-192, Design and Installation of New Tank Systems or Components	(a) Owners or operators of new tank systems or components must ensure that the foundation, structural support, seams, connections, and pressure control (if applicable) are adequately designed and that the tank system has sufficient structural strength, compatibility with the waste to be stored or treated, and corrosion protection so that it will not collapse, rupture, or fail. The owner or operator must obtain a written assessment, reviewed and certified by an independent, qualified, registered professional engineer attesting that the system has sufficient structural integrity and is acceptable for the storing and treating of hazardous waste. (b) The owner or operator of a new tank systems must ensure that proper handling procedures are adhered to in order to prevent damage to the system during installation. Prior to covering, enclosing, or placing a new tank system or component in use, an independent, qualified installation inspector or an independent, qualified, registered professional engineer, either of whom is trained and experienced in the proper installation of tank systems, must inspect the system or component. (c) New tank systems or components and piping that are placed underground	The HIHTL design and installation is verified and certified by an IQRPE. Aboveground retrieval systems are verified and certified by an IQRPE (e.g., RPP-16666). System design and IQRPE certification ensure that parts (a), (b), (c), (d), and (e) are met. Cathodic protection is not installed on the HIHTL.

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

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

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

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

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

Regulation	Requirement	Compliance Method
	visually inspected for leaks on a daily basis (4) Pressurized aboveground piping systems with automatic shutoff devices that are visually inspected for leaks on a daily basis.	
265.194, General Operating Requirements	(a) Hazardous wastes or treatment reagents must not be placed in a tank system if they could cause the tank, its ancillary equipment, or the containment system to rupture, leak, corrode, or otherwise fail. (b) The owner or operator must use appropriate controls and practices to prevent spills and overflows from tank or containment systems. They include at a minimum: (1) Spill prevention controls (2) Overfill prevention controls (3) Maintenance of sufficient freeboard in uncovered tanks to prevent overtopping by wave or wind action or by precipitation	Control of the waste retrieval process is defined in the process control plan for each retrieval: (1) System design. (2) The receiving DST has primary tank level instrumentation which is monitored during transfers. (3) Not applicable.
265.195, Inspections	(a) The owner or operator must inspect, where present, at least once each operating day: (1) Overfill/spill control equipment (2) The aboveground portions of the tank system, if any, to detect corrosion or release of waste (3) Data gathered from monitoring equipment and leak-detection equipment (e.g., pressure and temperature gauges, monitoring wells) to ensure that the tank system is being operated according to its design (4) The construction materials and the area immediately surrounding the externally accessible portion of the tank system including secondary containment structures to detect erosion or signs of release of hazardous waste (b) The owner or operator must inspect cathodic protection systems, if present, according to, at a minimum, the following schedule to ensure that they are functioning properly (1) the proper operation of the cathodic protection system must be confirmed within six months after initial installation and annually thereafter (2) All sources of impressed current must be inspected and/or tested, as	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
	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 (3)(c)(vii)], Response to leaks or spills and disposition of leaking or unfit-for-use tank systems	A tank system or secondary containment system from which there has been a leak or spill, or which is unfit for use, must be removed from service immediately, and the owner or operator must satisfy the following requirements; (a) Cessation of use; prevent flow or addition of wastes (b) Removal of waste from tank system or secondary containment system (c) Containment of visible releases to the environment (d) Notifications, reports	Response to leak or spills is defined in Section 4.0
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	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
	recover waste material to the extent economically feasible; and (i) Endangerment of the health of employees, or the public near the facility.	and recover waste to the limits of technology in accordance with HFFACO milestone M-45-00 (see Section 3.4). (i) The public is protected by the NOC per WAC 173-303-400 & 460. Workers are protected per TFC-PLN-43.
WAC 173-303-400, Interim Status Facility Standards	Incorporates by reference 40 CFR 265 with the exception of 265.1 (c)(4), 265.149-150 and 265.430. Replaces federal terms in 40 CFR 265 (i.e., regional administrator, hazardous) with state terms (i.e., department, dangerous)	

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

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

6.0 PRELIMINARY ISOLATION EVALUATION

This section provides a preliminary isolation evaluation for tanks C-103 and C-109. Tank C-103 is designated as partially interim isolated and intrusion prevention measures have been completed for tank C-109. Intrusion prevention measures were completed in the 1980s for tank C-109. Intrusion prevention measures were not completed for tank C-103 because of ongoing saltwell pumping until 2003 and then direct transition into retrieval operations.
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 tank C-109 and that were originally planned for tank C-103 are provided on the following drawings:

- *Piping Waste Tank Isolation C-Tank Farm Plot Plan* (H-2-73338, Sheet 1)
- *Piping Waste Tank Isolation TK 241-C-103* (H-2-73343, Sheet 1)
- *Piping Waste Tank Isolation TK 241-C-109* (H-2-73349, Sheet 1).

Installation of waste retrieval equipment in tanks C-103 and C-109 will involve placement of equipment through new or existing tank risers. Following completion of waste retrieval, the in-tank equipment may be removed or may be left in place for disposition during tank closure activity actions. New isolation drawings or modifications to existing drawings will be prepared to define methods for isolating potential intrusion pathways following completion of waste retrieval. The current planning baseline for component closure of tanks C-103 and C-109 includes closure of tank C-103 in 2006 and tank C-109 in 2007.

Intrusion monitoring will be conducted per OSD-T-151-00031 until specific post-retrieval monitoring requirements are defined. Pre-retrieval isolation is discussed in Section 3.7.

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-103 and C-109. The need to consider long-term human health impacts in developing tank waste retrieval work plans was established in the HFFACO M-45 milestone series through Change Request M-45-04-01.

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

> *A pre-retrieval risk assessment of potential residuals, consideration of past leaks, and potential leaks during retrieval, based on available data and the most sophisticated analysis available at the time. The purpose of this risk assessment is to aid operational decisions during retrieval activities. This risk assessment will not be used to make final retrieval or closure decisions. Minimally it will contain the following:*

- *Long-term human health risk associated with potential leaks during retrieval and potential residual waste after completion of retrieval.*
  - *Potential impacts to groundwater, including a waste management area (WMA)-level risk assessment.*
  - *Potential impacts based on an intruder scenario.*
- *Process management responses to a leak during retrieval and estimated potential leak volume.*
- *The pre-retrieval risk analysis will be based on the following criteria:*
  - *Using the WMA fenceline for point of compliance.*
  - *Identify the primary indicator contaminants (accounting for at least 95% of impact to groundwater risk) and provide the incremental lifetime cancer risk (ILCR) and hazard index (HI).*
  - *Using ILCR and HI for the industrial and residential human scenarios as the risk metric.*
  - *Calculated concentration(s) of primary indicator contaminant(s) in groundwater (mg/L and pCi/L).*

The risk information provided in this section was developed to meet the requirements identified in the HFFACO Appendix I. Information is provided for two main categories of impacts: (1) long-term human health risk associated with use of groundwater and (2) long-term human health risk associated with inadvertent post-closure human intrusion. Uncertainty or sensitivity evaluations of the impact of constituent concentration variability will be provided in the closure plan risk assessment and the retrieval data report.

Groundwater pathway impacts are discussed in Section 7.1. Inadvertent intruder impacts are discussed in Section 7.2. Calculation detail is provided in RPP-22000, *Tanks C-103 and C-109 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*.

7.1 GROUNDWATER PATHWAY IMPACTS

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

The methodology used to develop the retrieval leak impact graphs is described in Section 7.1.1. Tank-specific retrieval leak impact results are discussed in Section 7.1.2. Retrieval leak impact graphs for tanks C-103 and C-109 are provided in Appendix A and Appendix B, respectively. A WMA-level perspective on groundwater pathway impacts is provided in Section 7.1.3 to help place the potential retrieval leak impacts from the individual tanks into the context of the potential impacts for the C tank farm as a whole.

7.1.1 Retrieval Leak Evaluation Methodology

The retrieval leak graphs were developed using the following methodology:

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

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

$$R_i = I_i \times C_i \times H_i \tag{7-1}$$

Where:

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

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

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

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

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

The HNF-SD-WM-TI-707 evaluation provides unit dose factors, unit risk factors, and unit HI factors for a comprehensive set of contaminants of potential concern for Hanford Site risk assessment. A total of 93 radionuclides and 161 chemicals are evaluated. The unit factors were derived from standard formulas using data considered to be the most current or technically sound. For radionuclides, the cancer morbidity risk coefficients in EPA-402-R-99-001, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, were used. For chemicals, the non-cancer toxicity reference doses and cancer induction slope factors adopted by EPA and listed in the Integrated Risk Information System (IRIS) (http://www.epa.gov/iris) were used. Where toxicity parameters were not available in IRIS, values from EPA-540/R-97/036, *Health Effects Assessment Summary Tables (HEAST) FY 1997 Update* and the Risk Assessment Information System (RAIS) (http://risk.lsd.ornl.gov) maintained by the Oak Ridge National Laboratory were used. To provide an indication of the importance of missing toxicity parameters, the evaluation also includes estimates of the missing parameters for chemicals that have a reference dose or slope factor for ingestion, but none for inhalation, or vice versa.

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

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

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

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

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

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

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

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

[a] Source = RPP-13774, 2004, *Single-Shell Tank System Closure Plan*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington, Addendum C1, Tables 33 and 34, and additional model output data (includes contributions from one tank leak [C-105] and three unplanned releases [UPR-200-E-81, UPR-200-E-82, UPR-200-E-86]).

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

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

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 were driven by contributions from the highly mobile (K_d = 0 mL/g) contaminants. Uranium had not yet broken through to the water table at the time of peak for any source term and therefore made no contribution to the peaks. Uranium exhibited increasing concentrations at the end of the 10,000-year simulation and was a primary contributor to the impacts calculated at the end of the simulation. The impacts at the end of the simulation were lower than the peak impacts by an order of magnitude or more.

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

Nonradiological ILCR was assessed in the RPP-13774 analysis based solely on hexavalent chromium exposure. The nonradiological ILCR results from RPP-13774 are shown in Table 7-1 for information purposes to provide an indication of the potential magnitude of nonradiological ILCR. The results indicate that nonradiological ILCR peaks would be on the order of 10^{-7} for the past leak and retrieval leak source terms and 10^{-8} for the residual waste source term. However, because it is based on only one contaminant, nonradiological ILCR was not carried forward as a separate evaluation metric (i.e., was not used to generate a separate set of retrieval leak impact graphs). The degree to which hexavalent chromium ILCR provides an indication of total ILCR is uncertain due to the limited number of chemical analytes reported in the BBI. There is additional uncertainty regarding chromium speciation and the degree of conservatism introduced by assuming that all chromium is hexavalent chromium.

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

7.1.1.2. Potential Retrieval Leak Inventories. This document presents much of the risk data assuming an 8,000-gal. retrieval leak volume. This quantity is used only as a point of reference, and for consistency and comparison with the volume assumed in the WMA C closure plan (RPP-13774, Appendix C) risk assessment. The choice of the reference volume is arbitrary and does not affect how the risk values would be used in the event of a retrieval leak. The 8,000 gal.

is a hypothetical volume that represents neither an anticipated leak volume nor a leak detection limit. Tanks C-103 and C-109 are classified sound and are not anticipated to leak during waste retrieval. If a leak is detected, however, the risk graphs provided in Appendices A and B will allow the leak impacts to be estimated regardless of leak volume.

The retrieval leak impact graphs provided in the appendices were generated by applying Equation 7-1 over a range of hypothetical retrieval leak inventories for each indicator contaminant (RPP-22000). Because potential retrieval leak volumes are uncertain, the inventory range was selected to encompass a small leak on the low end and a large leak on the high end. Points of reference were added to the graphs to show the estimated current tank inventory and the estimated inventory associated with a hypothetical 8,000-gal. retrieval supernate leak. The 8,000-gal. volume is used only for information purposes to provide a point of reference on the graphs.

Development of the tank-specific inventories shown as points of reference on the graphs for tanks C-103 and C-109 is discussed in the appendices. Current inventory values were taken from the BBI by downloading from the Tank Waste Information Network System (TWINS) database. Hypothetical retrieval leak inventory values were calculated from the best available published data source.

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

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

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

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

A total of 14 individual simulation cases were included in the analysis. Each case described the behavior of seven surrogate contaminants of varying distribution coefficients under variable waste release modes for the selected sources. The simulations were all performed using a unit source inventory (i.e., one 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 one curie of radionuclide or one 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 7-1).

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

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

WMA = waste management area.

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

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

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

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

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

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

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

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

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

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

7.1.2 Retrieval Leak Impacts Analysis Results

Tank-specific retrieval leak impact graphs generated using the methodology described above are provided in Appendix A and Appendix B for tanks C-103 and C-109, respectively.

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

7.1.3 Waste Management Area C Risk Assessment

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

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

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

7.1.3.1. Potential Retrieval Leaks. Potential WMA C retrieval leak impacts are summarized in Table 7-4 from the results of the base case analysis presented in RPP-13774. 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 retrieval leak source term.

The retrieval leak source term was simulated in the RPP-13774 analysis based on a hypothetical 8,000-gal. retrieval leak from each of the 12 C-100-series tanks. The four C-200-series tanks were assumed not to leak during waste retrieval. A sensitivity case with a larger retrieval leak volume was also included.

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

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

MCL = maximum contaminant level.
NA = not applicable.

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

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

The retrieval leak inventories used for the RPP-13774 analysis were generated with the Hanford Tank Waste Operations Simulator (HTWOS) model assuming a raw water sluicing scenario. Retrieval leak inventories for a DST supernate sluicing scenario were not assessed in the RPP-13774 analysis. For this retrieval work plan, retrieval leak inventories for a DST supernate sluicing scenario were estimated using data from the waste retrieval flowsheet calculation presented in RPP-21753. These inventories are shown as reference points on the retrieval leak impact graphs presented in the appendices. Comparison tables showing the DST supernate inventories and the RPP-13774 raw water inventories are also presented in the appendices. Because human health impacts are proportional to source inventory, the tables provide an indication of potential differences in impacts between the two sluicing scenarios. Generally, the estimated DST supernate inventories were two to eight times higher than the corresponding raw water inventories.

The RPP-13774 base case simulation results indicate the peak groundwater concentrations from retrieval leaks would arrive at the WMA C downgradient fenceline in the year 2082. Groundwater concentrations were calculated as cumulative fenceline average concentrations over the entire downgradient length of the WMA C fenceline. The peak groundwater concentrations from retrieval leaks were projected to overlap in time and be additive with the peak groundwater concentrations from past leaks but were not projected to be additive with the peaks from residual waste.

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

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.

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

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

MCL = maximum contaminant level.
NA = not applicable.

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

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

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

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 four lower than the corresponding impacts calculated in the RPP-13774 analysis.

7.1.3.3. Past Leaks. WMA C past leak impacts are summarized in Table 7-6 from the results of the base case analysis presented in RPP-13774. The table shows the predicted peak groundwater concentration, radiological ILCR, nonradiological ILCR, and noncarcinogenic chemical 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-E-82, UPR-200-E-86). Other reported unplanned ancillary equipment releases in WMA C were considered but disregarded in the RPP-13774 analysis because they were determined not to represent significant sources of contamination compared to the sources analyzed.

Although the peak from past tank leaks was projected to arrive ahead of the peak from unplanned pipeline releases by approximately 26 years, the contributions from these sources were summed and reported as a single peak arriving in the year 2117. Groundwater concentrations were calculated as cumulative fenceline average concentrations over the entire downgradient length of the WMA C fenceline. The peak groundwater concentrations from past leaks were projected to overlap in time and be additive with the peak groundwater concentrations from retrieval leaks but were not projected to be additive with the peaks from residual waste. The peak from retrieval leaks was projected to arrive in 2082 compared with 2092 for the past tank leak. This occurred because the retrieval leak volume used in the RPP-13774 analysis was 8,000 gal. whereas the past leak (C-105) volume was 1,000 gal. An 8,000 gal. volume has greater driving force and lower tendency to spread laterally in the vadose zone than a 1,000 gal. volume.

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

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

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 Non-Radiological	2117	1.1E-07	2.4E-07	3.3E-02	2.0E-01	NA	NA

MCL = maximum contaminant level.
NA = not applicable.

[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.

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

Spectral gamma logging data reported in RPP-14430 shows little evidence of vadose zone contamination consistent with a tank leak in the vicinity of the tanks classified as leakers in HNF-EP-0182. Although no leaks have been reported from tank C-105, there is contamination reported in the vadose zone from routine geophysical monitoring between this tank and tank C-104. The measured vadose zone contamination in the vicinity of tank C-105 was therefore included in the RPP-13774 risk assessment, along with the measured vadose zone contamination associated with three verified leaks from ancillary equipment associated with WMA C. Additional information on WMA C vadose zone contamination can be found in RPP-14430; RPP-15317, *241-C Waste Management Area Inventory Data Package*; GJPO-HAN-18; and GJO-98-39-TARA GJO-HAN-18, *Vadose Zone Characterization Project at the Hanford Tank Farms, Addendum to the C Tank Farm Report*. Additional perspective on the integrity of tanks in WMA C can be found in RPP-10435.

7.2 INTRUDER RISK

Inadvertent waste site intrusion risk is an assessment of the health impacts from unknowingly intruding into a waste site at some point in the future following closure. Intruder impact estimates are included in this work plan to provide perspective on potential post-closure risks associated with closing tanks C-103 and C-109 assuming waste is retrieved to the HFFACO interim retrieval goal of 360 ft^3 of residual waste and the residuals are closed in place (Ecology et al. 1989).

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

7.2.1 Intruder Scenarios And Performance Objectives

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

- An intruder who inadvertently drills into the closed site and brings some of the waste to the surface, receiving an acute dose (driller scenario).

- A post-drilling resident who lives where waste has been exhumed and scattered over the surface, receiving a chronic dose (post-intrusion residential scenarios). Three such residential scenarios were included:
  - Suburban resident with a garden
  - Rural farmer with a dairy cow
  - Commercial farmer.

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

The performance objective identified in DOE/ORP-2003-11 for the driller scenario was 500 mrem effective dose equivalent 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 over the period from 0 to 1,000 years after closure. The time of compliance (or soonest time when the intrusion was assumed to occur) for the DOE/ORP-2003-11 analysis was 500 years after closure 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 in. for well driller and suburban resident with a garden and 10.5 in. for rural farmer with a dairy cow
- Assume the tanks each contain a volume of 360 ft^3 of residual waste at closure
- Assume the residual tank waste is embedded in a grout matrix that renders a fraction of the exhumed waste unavailable for inhalation and ingestion

- Assume intrusion occurs before contaminants have migrated from the closed facility in any significant quantity.

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

Sections 7.2.2.1 and 7.2.2.2 discuss the calculation methodology for the two primary components of intruder calculation, inventory and dose. Tank-specific results for tanks C-103 and C-109 are provided in Appendix A and Appendix B, respectively. Calculation detail is provided in RPP-22000.

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

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

$$I_{EX} / V_{EX} = I_T / V_T \quad (7\text{-}2)$$

$$I_{EX} / (p\ r^2\ h) = I_T / (p\ R^2\ h) \quad (7\text{-}3)$$

$$I_{EX} = I_T\ (p\ r^2\ h) / (p\ R^2\ h) \quad (7\text{-}4)$$

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

Where:

I_{EX} = exhumed inventory (undecayed) (Ci)
I_T = tank residual inventory (Ci)

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

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

$$I_{EX}(t) = I_{EX}\ Exp(-?t) \quad (7\text{-}6)$$

Where:

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

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

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

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

t = elapsed time since closure in years.

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

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

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

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

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

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

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

The driller scenario unit dose factors are given in terms of the dose per unit contaminant concentration in the drill cuttings (mrem per Ci/kg) (Table 7-7). The radiation dose to this individual is the dose (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 Equation 7-7.

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

Where:

M_{EX} = exhumed mass (kg)
r = borehole radius (m)
h = borehole height (depth to water table) (m)
? = 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 the individual appendices. Intruder impacts are provided for tanks C-103 and C-109 in Appendix A and Appendix B, respectively.

8.0 LESSONS LEARNED

A comprehensive lessons-learned effort was completed to meet the requirements of RPP-10901, *S-102 Initial Waste Retrieval Functions and Requirements*. RPP-10901 summarizes lessons learned from the Hanford Site, DOE, and general industries applicable to waste retrieval from underground storage tanks. Additionally, lessons learned from RPP-18629, *Performance Evaluation for C-106, S-102/112 and C-200 Series Tank Retrieval Activities*, were reviewed. The lessons learned identified in RPP-10901 and RPP-18629 were reviewed and the following have been incorporated into the tanks C-103 and C-109 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 resistance sealants and gaskets.
- Cold test all fluid connections and components before deployment to ensure leak tightness.
- Incorporate features to flush components that transport slurries to prevent/correct blockages. Design the features to operate with minimal changes to the system and operator intervention.
- Design systems to facilitate maintenance and support functions while incorporating safety and ALARA features.
- Provide access to instrumentation and other components requiring servicing and maintenance that does not require breaching the confinement system.
- Simplify system control screens to maximize operator efficiency and recognition of key operational parameters/data.
- Incorporate features to unplug piping systems in the event of a line blockage.
- Conduct comprehensive field 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.

9.0 REFERENCES

10 CFR 830, "Nuclear Safety Management," *Code of Federal Regulations*, as amended.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*, as amended.

29 CFR 1910, "Occupational Safety and Health Standards," *Code of Federal Regulations*, as amended.

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

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

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

40 CFR 268, "Land Disposal Restrictions," *Code of Federal Regulations*, as amended.

40 CFR 302, "Designation, Reportable Quantities, and Notification," *Code of Federal Regulations*, as amended.

40 CFR 761, "Polychlorinated Biphenyls (PCBs). Manufacturing, Processing, Distribution, Commerce, and Use Prohibitions," *Code of Federal Regulations*, as amended.

AIR 05-407, 2005, *Categorical Tank Farm Facility Waste Retrieval and Closure: Phase II Waste Retrieval Operations*, NOC ID 587, letter dated 4/26/2005, Washington State Department of Health, Olympia, Washington.

Aromi, E. S., 2002, "Contract Number DE-AC27-99RL14047; Recommendation to Proceed with Interim Stabilization of Tank 241-C-103," (letter CHG-0200473 to H.L. Boston, ORP, February 7), CH2M HILL Hanford Group, Inc., Richland, Washington.

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APPENDIX A

TANK C-103 LONG-TERM HUMAN HEALTH RISK

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LIST OF TERMS

Terms

None required; terms are defined within the document text.

Abbreviations, Acronyms, and Initialisms

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

Units

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

A1.0 TANK C-103 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

This appendix provides tank-specific human health risk information for 241-C-103 (tank C-103). 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-103. The methodology used to generate the graphs is described in Section 7.1.1. Calculation detail for the graphs is provided in RPP-22000, *Tanks C-103 and C-109 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*.

A2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures A-1 through A-3 provide the tank C-103 waste retrieval leak impact graphs for the three indicator contaminants (technetium-99, hexavalent chromium, and nitrite) identified in Section 7.1.1.1.

Figure A-1. Tank C-103 Technetium-99 Risk Plot.

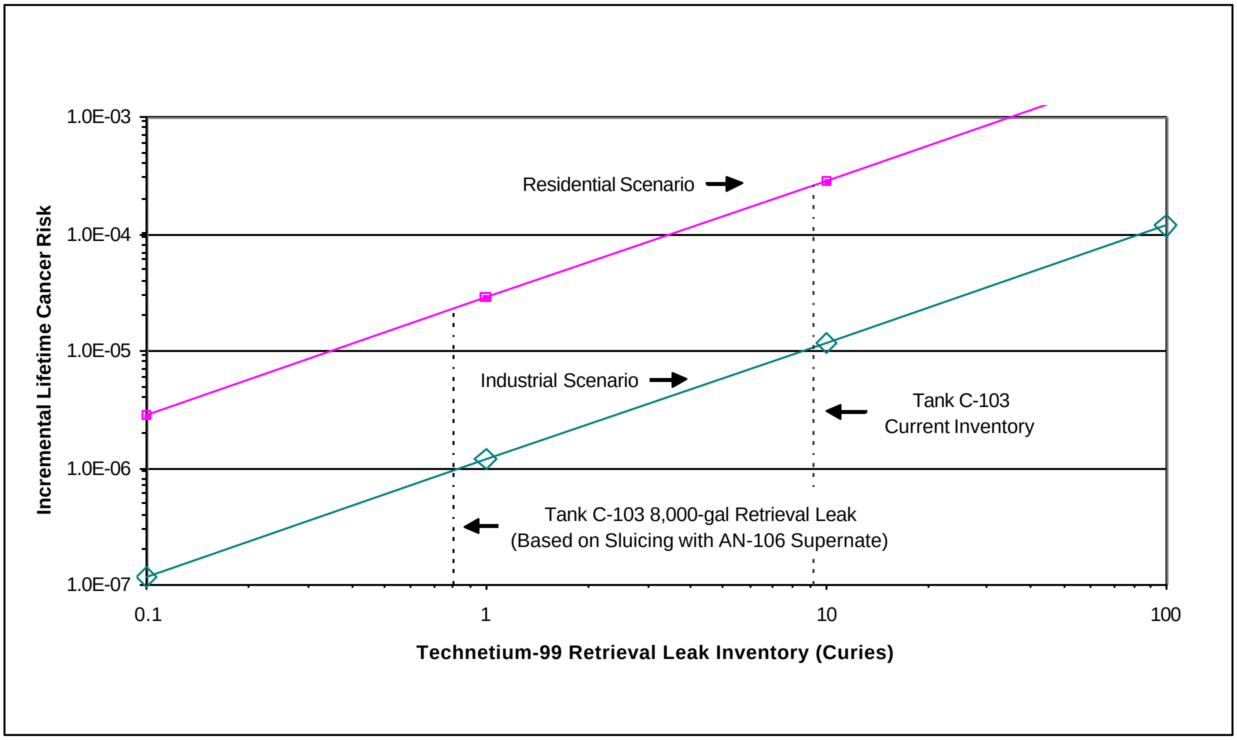

Figure A-2. Tank C-103 Hexavalent Chromium Hazard Quotient Plot.

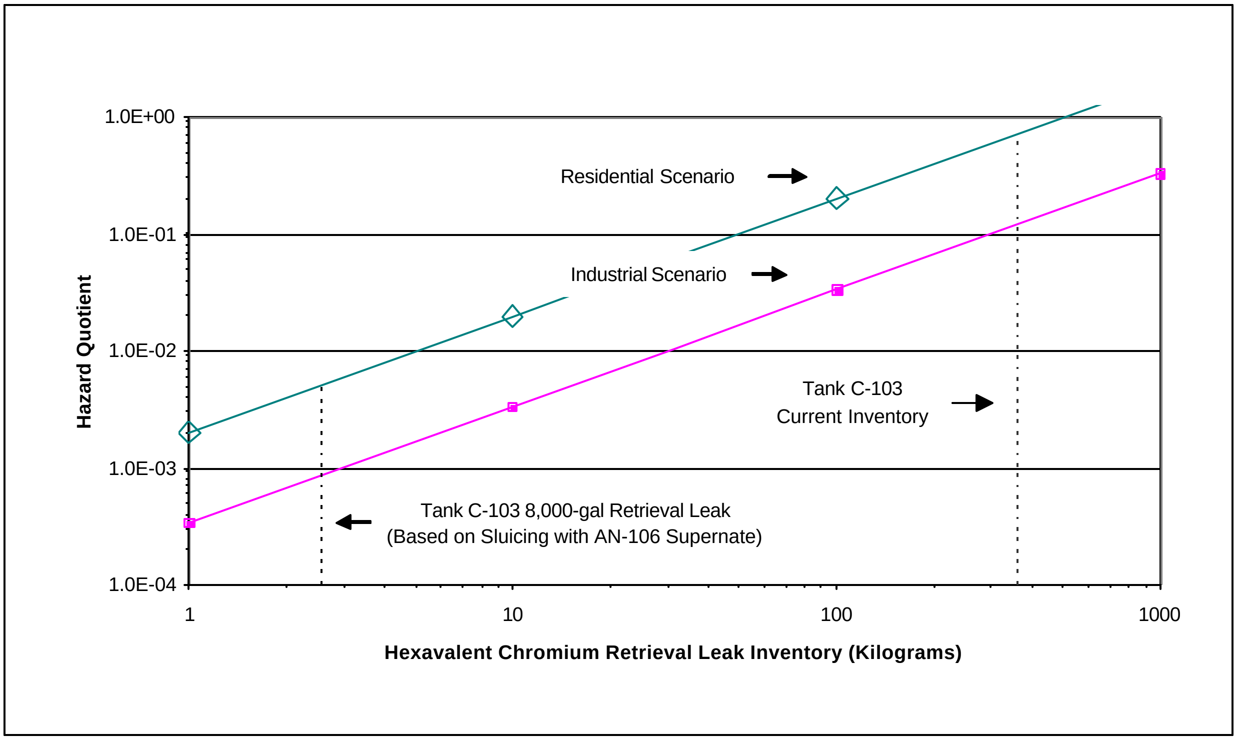

Figure A-3. Tank C-103 Nitrite Hazard Quotient Plot.

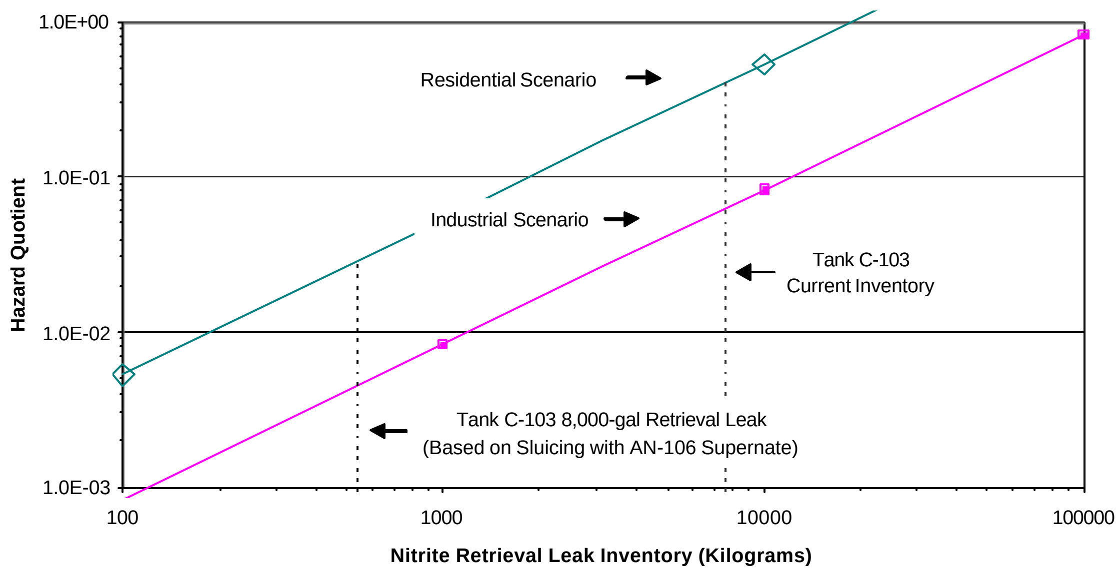

Figure A-1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-103 during retrieval. Figures A-2 and A-3 show the peak groundwater pathway hazard quotient from hexavalent chromium and nitrite, respectively, as a function of the amount of hexavalent chromium and nitrite leaked from tank C-103 during waste retrieval.

The ILCR and hazard quotient values shown on the graphs were based on the predicted peak groundwater concentrations at the waste management area (WMA) C downgradient fenceline. As discussed in Section 7.1.1.3, the projected arrival time of the peaks is approximately the year 2082 based on the supporting contaminant transport analysis in RPP-13774, *Single-Shell Tank System Closure Plan*. The graphs provide a retrieval leak risk picture for tank C-103 but do not include contributions from other WMA C sources. Projected impacts from other WMA C sources are discussed in Section 7.1.3.

Two sloped lines representing the industrial and residential scenarios were plotted on each graph. The datapoints for these lines were calculated as described in Section 7.1.1 over a range of technetium-99, hexavalent chromium, and nitrite values. Because potential retrieval leak volumes are uncertain, the inventory range was selected to encompass a small leak on the low end and a large leak on the high end. Selection of the inventory range was arbitrary and independent of any assumption on the type of retrieval fluid used (raw water or supernate).

Vertical dashed lines were added to each graph as points of reference to show the estimated current tank C-103 inventory and the inventory associated with a potential 8,000-gal. retrieval leak. The 8,000-gal. volume was a hypothetical volume used only as a point of reference and for consistency with previous analyses. It was not intended to represent anticipated retrieval leak volumes or leak detection limits for tank C-103.

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

A2.2 INVENTORY

The reference lines shown in Figures A-1 through A-3 to indicate current inventory and retrieval leak inventory were developed from the best available data and information. Current inventories were taken from the best-basis inventory by downloading from the Tank Waste Information Network System (TWINS) database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gal.) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C_103 by sluicing with recycled supernate from double-shell tank (DST) 241-AN-106. The retrieval leak fluid concentrations for this retrieval scenario were developed using data from RPP-21753, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*.

The RPP-21753 flowsheet description provides calculated time-phased contaminant concentrations in both the recycled supernate and the retrieved slurry. The flowsheet assumes a retrieval sequence and includes DST-to-DST transfers necessary to maintain waste volume within overall DST space limits. The flowsheet also includes planned near-term waste retrieval actions that would affect the tank inventory (e.g., C-200-series tanks waste retrieval).

The retrieval leak fluid concentrations used to develop the estimated leak inventories shown on the graphs were taken from the predicted liquid phase concentrations given in RPP-21753. The predicted liquid phase concentrations and resulting tank C-103 leak inventories for the DST 241-AN-106 recycled supernate retrieval scenario are shown in Table A-1. The table also shows leak inventories for a raw water retrieval scenario.

RPP-21753 provides an estimated flowsheet for the C tank farm waste retrieval process. Although the flowsheet includes an assumed retrieval sequence, there are numerous possible combinations of which single-shell tanks can go to which tanks and in which order. It is impractical to provide a single flowsheet that looks at all possible combinations of tanks and tank retrieval order, and the end result is not expected to cause any significant change in the risk associated with the overall waste retrieval process.

Regardless of the retrieval sequence and receiver DST, when all of the C farm tanks are retrieved the wastes currently in the C farm tanks will (excluding the remaining heels) be in the receiver DSTs and the final DST system volume increase will be approximately the same. The volume of water required for line flushing and final tank flushing will be approximately the same regardless of sequence. The relative risk associated with retrieving the two single-shell tanks as a whole should not be significantly impacted by changing the order or receiver tank, and in any event the variance involved is within the variance associated with the estimated supernate concentrations. There may be potential technical issues with switching tanks, but these are addressed by the waste compatibility program.

Raw water retrieval leak inventories are given in Table A-1 to provide a perspective on the potential effects on retrieval leak impacts caused by sluicing with recirculated DST supernate. The raw water inventories shown are the inventories used for the RPP-13774 base case risk analysis. Those inventories were based on a hypothetical 8,000-gal. retrieval leak volume and retrieval leak fluid concentrations estimated using the Hanford Tank Waste Operations Simulator model. Because retrieval leak human health impacts are proportional to inventory, comparing the inventory differences provides an indication of the differences in impacts between the two sluicing fluids. Table A-1 indicates raw water leak inventories would be moderately lower than the supernate leak inventories for technetium-99 and nitrite and slightly higher for hexavalent chromium.

Table A-1. Tank C-103 Retrieval Leak Inventory Comparison for Different Sluicing Fluids.

Contaminant	Leak Fluid Concentration			Inventory in 8,000-gal. Retrieval Leak		
	AN-106 Supernate [a]	Raw Water [b]	Units	AN-106 Supernate	Raw Water	Units
Technetium-99	2.67E-05	5.12E-06	Ci/L	8.10E-01	1.55E-01	Ci
Hexavalent Chromium	8.58E-05	1.29E-04	kg/L	2.60E+00	3.91E+00	kg
Nitrite	1.80E-02	2.13E-03	kg/L	5.44E+02	6.45E+01	kg

[a] Appendix D, Table D-3 from RPP-21753, 2005, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

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

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

The estimated technetium-99 inventory associated with a hypothetical 8,000-gal. retrieval leak from tank C-103 was estimated to be approximately 0.8095 Ci (RPP-22000). As shown in Figure A-1, this corresponds to an ILCR of approximately 9.38×10^{-7} for the industrial scenario and 2.28×10^{-5} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 68 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000-gal. retrieval leak from tank C-103 was estimated to be approximately 2.6 kg (RPP-22000). As shown in Figure A-2, this corresponds to a hazard quotient of approximately 8.97×10^{-4} for the industrial scenario and

5.11×10^{-3} for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 2.18×10^{-4} mg/L.

The nitrite inventory associated with an 8,000-gal. retrieval leak from tank C-103 was estimated to be approximately 544 kg (RPP-22000). As shown in Figure A-3, this corresponds to a hazard quotient of approximately 4.52×10^{-3} for the industrial scenario and 2.91×10^{-2} for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 4.57×10^{-2} mg/L.

A2.4 EXAMPLE CALCULATION

To illustrate the calculation method used for the retrieval leak impact graphs, the following example is provided. The example uses the industrial scenario ILCR result of 9.38×10^{-7}. Using Equation 7-1 from Section 7.1.1, the industrial scenario ILCR was calculated as the product of the technetium-99 inventory (Table 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:

$$\text{ILCR} = (0.8095\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 9.38 \times 10^{-7}.$$

Complete calculation details are provided in RPP-22000.

A3.0 INADVERTENT INTRUDER IMPACTS

The starting inventories for the tank C-103 intruder calculation were the estimated radionuclide inventories remaining in the tank following retrieval to Ecology et al. 1989, *Hanford Federal Facility and Consent Order* interim retrieval goal of 360 ft^3 (2,700 gal.) of residual waste. These inventories were taken from RPP-15317, *241-C Waste Management Area Inventory Data Package* and are based on the selective phase removal inventory estimation method. Inventories for all 46 radionuclides reported in the best-basis inventory are provided in RPP-15317 and were used in the calculation (RPP-22000). Inventories for the subset of best-basis inventory radionuclides that were shown in DOE/ORP-2003-11, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* to dominate intruder doses at 500 years after closure are shown in Table A-2.

Table A-2. Tank C-103 Inventory of Dose-Driving Contaminants in 360 ft^3 of Residual Waste.*

Radionuclide	Units	Tank C-103
Strontium-90	Ci	6.47E+04
Technetium-99	Ci	5.83E-01
Tin-126	Ci	2.43E-01
Cesium-137	Ci	1.79E+03
Plutonium-239	Ci	9.03E+01
Plutonium-240	Ci	1.39E+01
Americium-241	Ci	6.73E+01

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

Table A-3 summarizes the intruder analysis results for tank C-103. These results were generated using the methodology described in Section 7.2. Complete calculation detail is provided in RPP-22000. 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.

Table A-3. Tank C-103 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	0.052	0.004
Technetium-99	0.000	0.015	0.000
Tin-126	0.126	0.122	0.013
Cesium-137	0.002	0.003	0.000
Plutonium-239	0.579	3.260	0.147
Plutonium-240	0.086	0.483	0.022
Americium-241	0.296	1.194	0.058
Other Radionuclides	0.001	0.003	0.000
TOTAL	1.090	5.132	0.244

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

EDE = effective dose equivalent.

The dose values in Table A-3 are for intrusion at 500 years after closure assuming a grout-stabilized residual waste volume of 360 ft^3. Table A-3 indicates that tank C-103 would not exceed the performance objectives of 500 mrem effective dose equivalent for acute exposure and 100 mrem/yr effective dose equivalent for chronic exposure at 500 years after closure. The total doses at 500 years after closure would be dominated by plutonium-239 and americium-241.

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.

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

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

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

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

RPP-22000, 2005, *Tanks C-103 and C-109 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX B

TANK C-109 LONG-TERM HUMAN HEALTH RISK

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LIST OF TERMS

Terms

None required; terms are defined within the document text.

Abbreviations, Acronyms, and Initialisms

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

Units

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

B1.0 TANK C-109 PRE-RETRIEVAL RISK ASSESSMENT RESULTS

This appendix provides tank-specific human health risk information for 241-C-109 (tank C-109). 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-109. The methodology used to generate the graphs is described in Section 7.1.1. Calculation detail for the graphs is provided in RPP-22000, *Tanks C-103 and C-109 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*.

B2.1 RETRIEVAL LEAK IMPACT GRAPHS

Figures B-1 through B-3 provide the tank C-109 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-109 Technetium-99 Risk Plot.

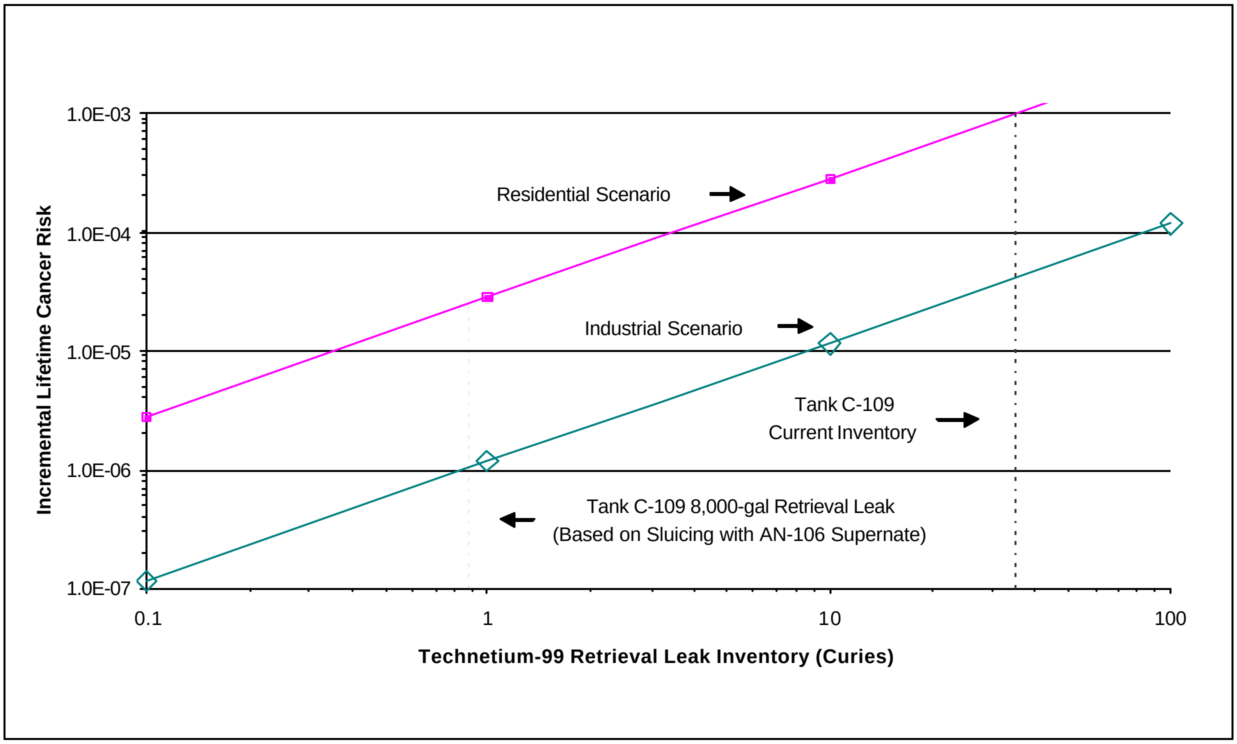

Figure B-2. Tank C-109 Hexavalent Chromium Hazard Quotient Plot.

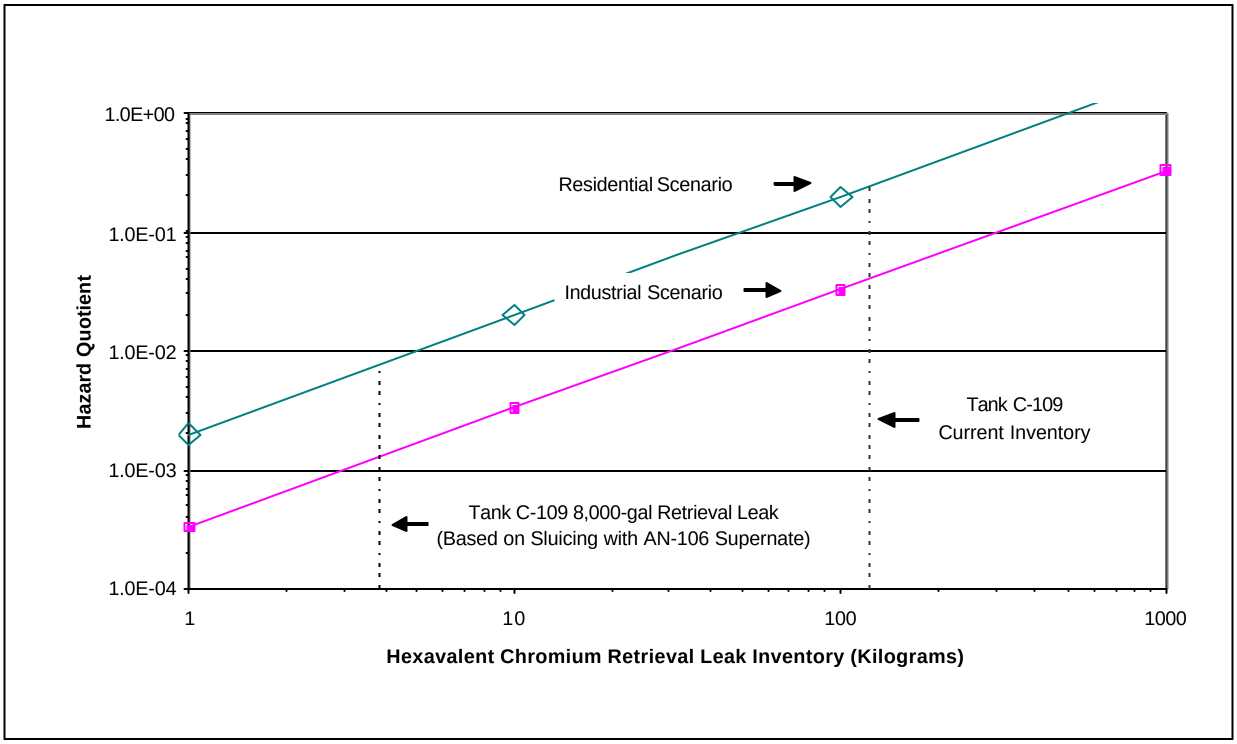

Figure B-3. Tank C-109 Nitrite Hazard Quotient Plot.

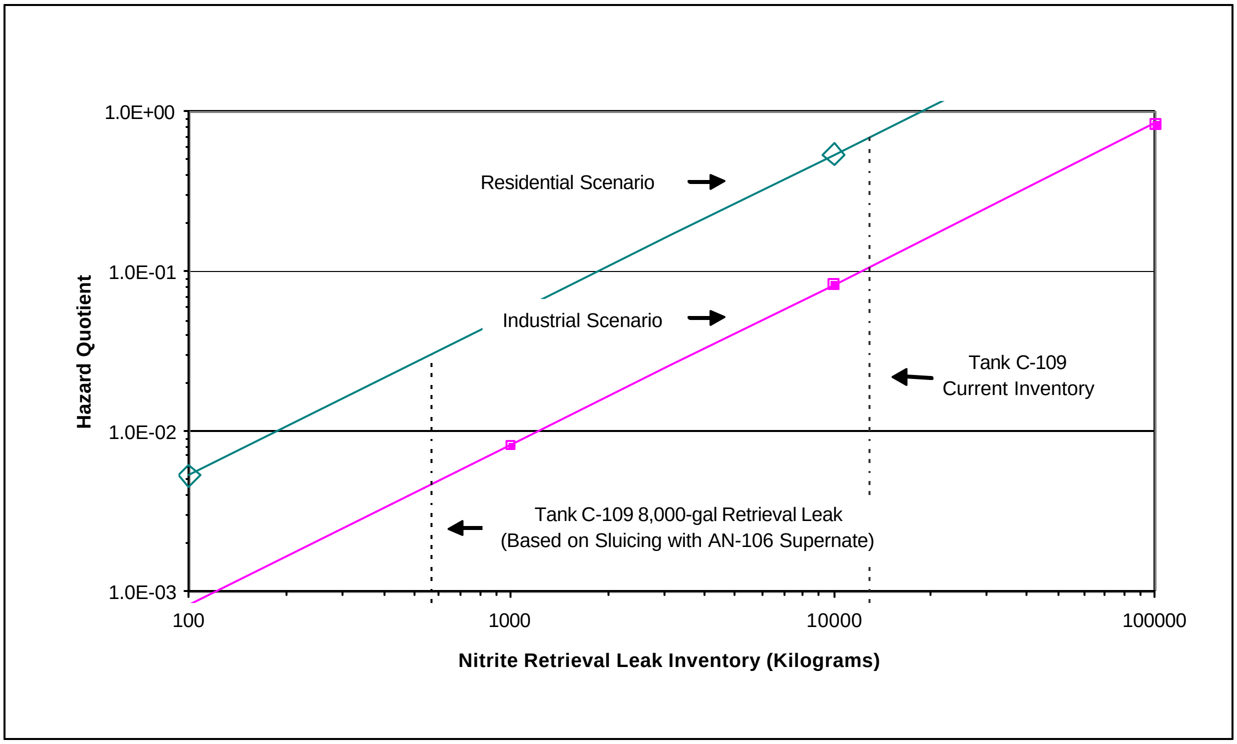

Figure B-1 shows the peak groundwater pathway incremental lifetime cancer risk (ILCR) from technetium-99 as a function of the amount of technetium-99 leaked from tank C-109 during retrieval. Figures B-2 and B-3 show the peak groundwater pathway hazard quotient from hexavalent chromium and nitrite, respectively, as a function of the amount of hexavalent chromium and nitrite leaked from tank C-109 during waste retrieval.

The ILCR and hazard quotient values shown on the graphs were based on the predicted peak groundwater concentrations at waste management area (WMA) C downgradient fenceline. As discussed in Section 7.1.1.3, the projected arrival time of the peaks is approximately the year 2082 based on the supporting contaminant transport analysis in RPP-13774, *Single-Shell Tank System Closure Plan*. The graphs provide a retrieval leak risk picture for tank C-109 but do not include contributions from other WMA C sources. Projected impacts from other WMA C sources are discussed in Section 7.1.3.

Two sloped lines representing the industrial and residential scenarios were plotted on each graph. The datapoints for these lines were calculated as described in Section 7.1.1 over a range of technetium-99, hexavalent chromium, and nitrite values. Because potential retrieval leak volumes are uncertain, the inventory range was selected to encompass a small leak on the low end and a large leak on the high end. Selection of the inventory range was arbitrary and independent of any assumption on the type of retrieval fluid used (raw water or supernate).

Vertical dashed lines were added to each graph as points of reference to show the estimated current tank C-109 inventory and the inventory associated with a potential 8,000-gal. retrieval leak. The 8,000-gal. volume was a hypothetical volume used only as a point of reference and for consistency with previous analyses. It was not intended to represent anticipated retrieval leak volumes or leak detection limits for tank C-109.

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

B2.2 INVENTORY

The reference lines shown in Figures B-1 through B-3 to indicate current inventory and retrieval leak inventory were developed from the best available data and information. Current inventories were taken from the best-basis inventory by downloading from the Tank Waste Information Network System (TWINS) database (http://twinsweb.pnl.gov/twins.htm). Retrieval leak inventories were calculated by multiplying the hypothetical retrieval leak volume (8,000 gal.) by the estimated retrieval leak fluid concentration. Waste was assumed to be retrieved from tank C-109 by sluicing with recycled supernate from double-shell tank (DST) 241-AN-106. The retrieval leak fluid concentrations for this retrieval scenario were developed using data from RPP-21753, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*.

The RPP-21753 flowsheet description provides calculated time-phased contaminant concentrations in both the recycled supernate and the retrieved slurry. The flowsheet assumes a retrieval sequence and includes DST-to-DST transfers necessary to maintain waste volume within overall DST space limits. The flowsheet also includes planned near-term waste retrieval actions that would affect the tank inventory (e.g., C-200-series tanks waste retrieval).

The retrieval leak fluid concentrations used to develop the estimated leak inventories shown on the graphs were taken from the predicted liquid phase concentrations given in RPP-21753. The predicted liquid phase concentrations and resulting tank C-109 leak inventories for the DST 241-AN-106 recycled supernate retrieval scenario are shown in Table B.1. The table also shows leak inventories for a raw water retrieval scenario.

RPP-21753 provides an estimated flowsheet for the C tank farm waste retrieval process. Although the flowsheet includes an assumed retrieval sequence, there are numerous possible combinations of which single-shell tanks can go to which tanks and in which order. It is impractical to provide a single flowsheet that looks at all possible combinations of tanks and tank retrieval order, and the end result is not expected to cause any significant change in the risk associated with the overall waste retrieval process.

Regardless of the retrieval sequence and receiver DST, when all of the C farm tanks are retrieved the wastes currently in the C farm tanks will (excluding the remaining heels) be in the receiver DSTs and the final DST system volume increase will be approximately the same. The volume of water required for line flushing and final tank flushing will be approximately the same regardless of sequence. The relative risk associated with retrieving the two single-shell tanks as a whole should not be significantly impacted by changing the order or receiver tank, and in any event the variance involved is within the variance associated with the estimated supernate concentrations. There may be potential technical issues with switching tanks, but these are addressed by the waste compatibility program.

Raw water retrieval leak inventories are given in Table B-1 to provide a perspective on the potential effects on retrieval leak impacts caused by sluicing with recirculated DST supernate. The raw water inventories shown are the inventories used for the RPP-13774 base case risk analysis. Those inventories were based on a hypothetical 8,000-gal. retrieval leak volume and retrieval leak fluid concentrations estimated using the Hanford Tank Waste Operations Simulator model. Because retrieval leak human health impacts are proportional to inventory, comparing the inventory differences provides an indication of the differences in impacts between the two sluicing fluids. Table B-1 indicates raw water leak inventories would be slightly lower than the supernate leak inventories for the three indicator contaminants.

Table B-1. Tank C-109 Retrieval Leak Inventory Comparison for Different Sluicing Fluids.

Contaminant	Leak Fluid Concentration			Inventory in 8,000-gal. Retrieval Leak		
	AN-106 Supernate [a]	Raw Water [b]	Units	AN-106 Supernate	Raw Water	Units
Technetium-99	2.93E-05	2.70E-05	Ci/L	8.86E-01	8.18E-01	Ci
Hexavalent Chromium	1.28E-04	9.83E-05	kg/L	3.88E+00	2.98E+00	kg
Nitrite	1.88E-02	1.02E-02	kg/L	5.69E+02	3.09E+02	kg

[a] Appendix D, Table D-3 from RPP-21753, 2005, *C-Farm 100 Series Tanks, Retrieval Process Flowsheet Description*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

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

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

The estimated technetium-99 inventory associated with a hypothetical 8,000-gal. retrieval leak from tank C-109 was estimated to be approximately 0.886 Ci (RPP-22000). As shown in Figure B-1, this corresponds to an ILCR of approximately 1.03×10^{-6} for the industrial scenario and 2.50×10^{-5} for the residential scenario. The peak technetium-99 groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 74.4 pCi/L.

The hexavalent chromium inventory associated with a hypothetical 8,000-gal. retrieval leak from tank C-109 was estimated to be approximately 3.88 kg (RPP-22000). As shown in Figure B-2, this corresponds to a hazard quotient of approximately 1.26×10^{-3} for the industrial scenario and 7.63×10^{-3} for the residential scenario. The peak hexavalent chromium groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 3.26×10^{-4} mg/L.

The nitrite inventory associated with an 8,000-gal. retrieval leak from tank C-109 was estimated to be approximately 569 kg (RPP-22000). As shown in Figure B-3, this corresponds to a hazard quotient of approximately 4.73×10^{-3} for the industrial scenario and 3.04×10^{-2} for the residential scenario. The peak nitrite groundwater concentration at the WMA C fenceline from this retrieval leak would be approximately 4.78×10^{-2} mg/L.

B2.4 EXAMPLE CALCULATION

To illustrate the calculation method used for the retrieval leak impact graphs, the following example is provided. The example uses the industrial scenario ILCR result of 1.03×10^{-6}. Using Equation 7-1 from Section 7.1.1, the industrial scenario ILCR was calculated as the product of the technetium-99 inventory (Table B-1), the technetium-99 retrieval leak unit groundwater concentration factor (Table 7-2), and the technetium-99 industrial scenario unit risk factor (Table 7-3), as follows:

$$\text{ILCR} = (0.886\ \text{Ci}) \cdot (8.4 \times 10^{1}\ \text{pCi/L per Ci}) \cdot (1.38 \times 10^{-8}\ \text{ILCR per pCi/L}) = 1.03 \times 10^{-6}$$

Complete calculation details are provided in RPP-22000.

B3.0 INADVERTENT INTRUDER IMPACTS

The starting inventories for the tank C-109 intruder calculation were the estimated radionuclide inventories remaining in the tank following retrieval to Ecology et al. (1989), *Hanford Federal Facility and Consent Order* interim retrieval goal of 360 ft^3 (2,700 gal.) of residual waste. These inventories were taken from RPP-15317, *241-C Waste Management Area Inventory Data Package* and are based on the selective phase removal inventory estimation method. Inventories for all 46 radionuclides reported in the best-basis inventory are provided in RPP-15317 and were used in the calculation (RPP-22000). Inventories for the subset of best-basis inventory radionuclides that were shown in DOE/ORP-2003-11, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* to dominate intruder doses at 500 years after closure are shown in Table B-2.

Table B-2. Tank C-109 Inventory of Dose-Driving Contaminants in 360 ft^3 of Residual Waste.*

Radionuclide	Units	Tank C-109
Strontium-90	Ci	1.07E+04
Technetium-99	Ci	1.37E+00
Tin-126	Ci	1.82E-03
Cesium-137	Ci	7.26E+03
Plutonium-239	Ci	2.58E+00
Plutonium-240	Ci	4.38E-01
Americium-241	Ci	1.98E+00

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

Table B-3 summarizes the intruder analysis results for tank C-109. These results were generated using the methodology described in Section 7.2. Complete calculation detail is provided in RPP-22000. 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.

Table B-3. Tank C-109 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	0.009	0.001
Technetium-99	0.000	0.036	0.000
Tin-126	0.001	0.001	0.000
Cesium-137	0.010	0.011	0.001
Plutonium-239	0.017	0.093	0.004
Plutonium-240	0.003	0.015	0.001
Americium-241	0.009	0.035	0.002
Other Radionuclides	0.000	0.002	0.000
TOTAL	0.040	0.202	0.009

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

EDE = effective dose equivalent.

The dose values in Table B-3 are for intrusion at 500 years after closure assuming a grout-stabilized residual waste volume of 360 ft^3. Table B-3 indicates that tank C-109 would not exceed the performance objectives of 500 mrem effective dose equivalent for acute exposure and 100 mrem/yr effective dose equivalent for chronic exposure at 500 years after closure. The total doses at 500 years after closure would be dominated by plutonium-239.

B4.0 REFERENCES

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

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

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RPP-22000, 2005, *Tanks C-103 and C-109 Long-Term Human Health Risk Calculations to Support Tank Waste Retrieval Work Plan*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX C

AVAILABLE INVENTORY AND INVENTORY UNCERTAINTY DATA

LIST OF TABLES

Table C-1. Tank C-103 Inventory. C-1
Table C-2. Tank C-109 Inventory. C-9

Table C-1. Tank C-103 Inventory.[a] (8 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{106}Ru	Sludge	AR (Solid)	5.07E-06	not reported	Ci
	Sludge	CWP1 (Solid)	8.05E-11	not reported	Ci
	Supernate	SRR (Liquid)	9.65E-09	not reported	Ci
	Total		5.08E-06	--	Ci
^{113m}Cd	Sludge	AR (Solid)	1.53E+00	not reported	Ci
	Sludge	CWP1 (Solid)	2.89E-01	not reported	Ci
	Supernate	SRR (Liquid)	1.36E-02	not reported	Ci
	Total		1.83E+00	--	Ci
^{125}Sb	Sludge	AR (Solid)	2.52E-01	not reported	Ci
	Sludge	CWP1 (Solid)	3.44E-04	not reported	Ci
	Supernate	SRR (Liquid)	5.96E-03	not reported	Ci
	Total		2.58E-01	--	Ci
^{126}Sn	Sludge	AR (Solid)	1.21E-01	not reported	Ci
	Sludge	CWP1 (Solid)	4.30E-04	not reported	Ci
	Supernate	SRR (Liquid)	8.29E-04	not reported	Ci
	Total		1.22E-01	--	Ci
^{129}I	Sludge	AR (Solid)	4.86E-03	not reported	Ci
	Sludge	CWP1 (Solid)	5.47E-02	not reported	Ci
	Supernate	SRR (Liquid)	3.65E-06	not reported	Ci
	Total		5.96E-02	--	Ci
^{134}Cs	Sludge	AR (Solid)	1.12E-02	not reported	Ci
	Sludge	CWP1 (Solid)	7.20E-06	not reported	Ci
	Supernate	SRR (Liquid)	6.20E-04	not reported	Ci
	Total		1.18E-02	--	Ci
^{137}Cs	Sludge	AR (Solid)	1.66E+04	5.12E+03	Ci
	Sludge	CWP1 (Solid)	2.65E+04	8.18E+03	Ci
	Supernate	SRR (Liquid)	6.96E+01	2.35E+03	Ci
	Total		4.32E+04	--	Ci
^{137m}Ba	Sludge	AR (Solid)	1.57E+04	not reported	Ci
	Sludge	CWP1 (Solid)	2.50E+04	not reported	Ci
	Supernate	SRR (Liquid)	6.57E+01	not reported	Ci
	Total		4.07E+04	--	Ci
^{14}C	Sludge	AR (Solid)	2.43E-01	not reported	Ci
	Sludge	CWP1 (Solid)	2.53E-01	not reported	Ci
	Supernate	SRR (Liquid)	1.01E-03	not reported	Ci
	Total		4.97E-01	--	Ci
^{151}Sm	Sludge	AR (Solid)	2.76E+04	not reported	Ci
	Sludge	CWP1 (Solid)	4.31E+00	not reported	Ci
	Supernate	SRR (Liquid)	6.09E+00	not reported	Ci
	Total		2.76E+04	--	Ci

Table C-1. Tank C-103 Inventory.[a] (8 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{152}Eu	Sludge	AR (Solid)	4.54E+00	not reported	Ci
	Sludge	CWP1 (Solid)	5.17E-04	not reported	Ci
	Supernate	SRR (Liquid)	1.32E-03	not reported	Ci
	Total		4.54E+00	--	Ci
^{154}Eu	Sludge	AR (Solid)	8.60E+02	3.20E+02	Ci
	Sludge	CWP1 (Solid)	1.37E+03	5.09E+02	Ci
	Supernate	SRR (Liquid)	3.45E-03	1.17E-01	Ci
	Total		2.23E+03	--	Ci
^{155}Eu	Sludge	AR (Solid)	5.92E+02	2.40E+02	Ci
	Sludge	CWP1 (Solid)	9.46E+02	3.83E+02	Ci
	Supernate	SRR (Liquid)	6.46E-03	2.19E-01	Ci
	Total		1.54E+03	--	Ci
^{226}Ra	Sludge	AR (Solid)	1.26E-06	not reported	Ci
	Sludge	CWP1 (Solid)	1.37E-07	not reported	Ci
	Supernate	SRR (Liquid)	1.05E-08	not reported	Ci
	Total		1.40E-06	--	Ci
^{227}Ac	Sludge	AR (Solid)	9.13E-06	not reported	Ci
	Sludge	CWP1 (Solid)	7.42E-07	not reported	Ci
	Supernate	SRR (Liquid)	5.29E-08	not reported	Ci
	Total		9.93E-06	--	Ci
^{228}Ra	Sludge	AR (Solid)	5.21E-05	not reported	Ci
	Sludge	CWP1 (Solid)	1.58E-12	not reported	Ci
	Supernate	SRR (Liquid)	1.34E-13	not reported	Ci
	Total		5.21E-05	--	Ci
^{229}Th	Sludge	AR (Solid)	4.92E-07	not reported	Ci
	Sludge	CWP1 (Solid)	2.31E-10	not reported	Ci
	Supernate	SRR (Liquid)	6.25E-11	not reported	Ci
	Total		4.92E-07	--	Ci
^{231}Pa	Sludge	AR (Solid)	1.74E-05	not reported	Ci
	Sludge	CWP1 (Solid)	1.47E-06	not reported	Ci
	Supernate	SRR (Liquid)	8.05E-08	not reported	Ci
	Total		1.90E-05	--	Ci
^{232}Th	Sludge	AR (Solid)	1.25E-06	not reported	Ci
	Sludge	CWP1 (Solid)	1.82E-12	not reported	Ci
	Supernate	SRR (Liquid)	1.39E-13	not reported	Ci
	Total		1.25E-06	--	Ci
^{232}U	Sludge	AR (Solid)	1.18E-03	not reported	Ci
	Sludge	CWP1 (Solid)	4.25E-05	not reported	Ci
	Supernate	SRR (Liquid)	2.43E-07	not reported	Ci
	Total		1.22E-03	--	Ci

Table C-1. Tank C-103 Inventory.[a] (8 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{233}U	Sludge	AR (Solid)	7.41E-02	not reported	Ci
	Sludge	CWP1 (Solid)	2.07E-06	not reported	Ci
	Supernate	SRR (Liquid)	7.65E-07	not reported	Ci
	Total		7.41E-02	--	Ci
^{234}U	Sludge	AR (Solid)	1.93E-01	not reported	Ci
	Sludge	CWP1 (Solid)	9.32E-01	not reported	Ci
	Supernate	SRR (Liquid)	2.65E-03	not reported	Ci
	Total		1.13E+00	--	Ci
^{235}U	Sludge	AR (Solid)	8.12E-03	not reported	Ci
	Sludge	CWP1 (Solid)	3.98E-02	not reported	Ci
	Supernate	SRR (Liquid)	1.12E-04	not reported	Ci
	Total		4.80E-02	--	Ci
^{236}U	Sludge	AR (Solid)	4.63E-03	not reported	Ci
	Sludge	CWP1 (Solid)	2.12E-02	not reported	Ci
	Supernate	SRR (Liquid)	7.00E-05	not reported	Ci
	Total		2.59E-02	--	Ci
^{237}Np	Sludge	AR (Solid)	3.77E-02	not reported	Ci
	Sludge	CWP1 (Solid)	3.05E-04	not reported	Ci
	Supernate	SRR (Liquid)	1.94E-04	not reported	Ci
	Total		3.82E-02	--	Ci
^{238}Pu	Sludge	AR (Solid)	1.32E+01	not reported	Ci
	Sludge	CWP1 (Solid)	3.62E+01	not reported	Ci
	Supernate	SRR (Liquid)	1.62E-03	not reported	Ci
	Total		4.94E+01	--	Ci
^{238}U	Sludge	AR (Solid)	1.92E-01	not reported	Ci
	Sludge	CWP1 (Solid)	9.55E-01	not reported	Ci
	Supernate	SRR (Liquid)	2.58E-03	not reported	Ci
	Total		1.15E+00	--	Ci
^{239}Pu	Sludge	AR (Solid)	4.06E+02	not reported	Ci
	Sludge	CWP1 (Solid)	2.10E+03	not reported	Ci
	Supernate	SRR (Liquid)	3.92E-02	not reported	Ci
	Total		2.50E+03	--	Ci
^{240}Pu	Sludge	AR (Solid)	8.83E+01	not reported	Ci
	Sludge	CWP1 (Solid)	4.37E+02	not reported	Ci
	Supernate	SRR (Liquid)	9.09E-03	not reported	Ci
	Total		5.25E+02	--	Ci
^{241}Am	Sludge	AR (Solid)	1.10E+03	not reported	Ci
	Sludge	CWP1 (Solid)	3.97E+01	not reported	Ci
	Supernate	SRR (Liquid)	2.90E-03	9.81E-02	Ci
	Total		1.14E+03	--	Ci

Table C-1. Tank C-103 Inventory.[a] (8 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{241}Pu	Sludge	AR (Solid)	4.85E+02	not reported	Ci
	Sludge	CWP1 (Solid)	1.64E+03	not reported	Ci
	Supernate	SRR (Liquid)	6.67E-02	not reported	Ci
	Total		2.12E+03	--	Ci
^{242}Cm	Sludge	AR (Solid)	6.85E-01	not reported	Ci
	Sludge	CWP1 (Solid)	5.83E-04	not reported	Ci
	Supernate	SRR (Liquid)	3.87E-06	not reported	Ci
	Total		6.85E-01	--	Ci
^{242}Pu	Sludge	AR (Solid)	4.32E-03	not reported	Ci
	Sludge	CWP1 (Solid)	1.36E-02	not reported	Ci
	Supernate	SRR (Liquid)	6.34E-07	not reported	Ci
	Total		1.79E-02	--	Ci
^{243}Am	Sludge	AR (Solid)	5.50E-01	not reported	Ci
	Sludge	CWP1 (Solid)	3.48E-04	not reported	Ci
	Supernate	SRR (Liquid)	1.62E-06	not reported	Ci
	Total		5.50E-01	--	Ci
^{243}Cm	Sludge	AR (Solid)	2.97E-02	not reported	Ci
	Sludge	CWP1 (Solid)	1.03E-05	not reported	Ci
	Supernate	SRR (Liquid)	2.90E-07	not reported	Ci
	Total		2.98E-02	--	Ci
^{244}Cm	Sludge	AR (Solid)	6.80E-01	not reported	Ci
	Sludge	CWP1 (Solid)	2.58E-04	not reported	Ci
	Supernate	SRR (Liquid)	6.72E-06	not reported	Ci
	Total		6.80E-01	--	Ci
^{3}H	Sludge	AR (Solid)	1.13E+00	not reported	Ci
	Sludge	CWP1 (Solid)	2.26E+01	not reported	Ci
	Supernate	SRR (Liquid)	9.36E-03	not reported	Ci
	Total		2.38E+01	--	Ci
^{59}Ni	Sludge	AR (Solid)	6.45E+00	not reported	Ci
	Sludge	CWP1 (Solid)	9.92E-01	not reported	Ci
	Supernate	SRR (Liquid)	8.28E-03	not reported	Ci
	Total		7.45E+00	--	Ci
^{60}Co	Sludge	AR (Solid)	9.82E+01	3.51E+01	Ci
	Sludge	CWP1 (Solid)	1.57E+02	5.62E+01	Ci
	Supernate	SRR (Liquid)	2.50E-02	8.46E-01	Ci
	Total		2.55E+02	--	Ci
^{63}Ni	Sludge	AR (Solid)	5.99E+02	not reported	Ci
	Sludge	CWP1 (Solid)	9.09E+01	not reported	Ci
	Supernate	SRR (Liquid)	7.65E-01	not reported	Ci
	Total		6.91E+02	--	Ci

Table C-1. Tank C-103 Inventory.[a] (8 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{79}Se	Sludge	AR (Solid)	2.92E-02	not reported	Ci
	Sludge	CWP1 (Solid)	1.04E-04	not reported	Ci
	Supernate	SRR (Liquid)	1.94E-04	not reported	Ci
	Total		2.95E-02	--	Ci
^{90}Sr	Sludge	AR (Solid)	5.63E+05	2.03E+05	Ci
	Sludge	CWP1 (Solid)	8.99E+05	3.24E+05	Ci
	Supernate	SRR (Liquid)	6.54E+00	2.21E+02	Ci
	Total		1.46E+06	--	Ci
^{90}Y	Sludge	AR (Solid)	5.63E+05	not reported	Ci
	Sludge	CWP1 (Solid)	8.99E+05	not reported	Ci
	Supernate	SRR (Liquid)	6.54E+00	not reported	Ci
	Total		1.46E+06	--	Ci
^{93m}Nb	Sludge	AR (Solid)	1.45E+00	not reported	Ci
	Sludge	CWP1 (Solid)	5.34E-03	not reported	Ci
	Supernate	SRR (Liquid)	9.16E-03	not reported	Ci
	Total		1.46E+00	--	Ci
^{93}Zr	Sludge	AR (Solid)	1.74E+00	not reported	Ci
	Sludge	CWP1 (Solid)	6.23E-03	not reported	Ci
	Supernate	SRR (Liquid)	1.16E-02	not reported	Ci
	Total		1.75E+00	--	Ci
^{99}Tc [b]	Sludge	AR (Solid)	9.12E+00	not reported	Ci
	Sludge	CWP1 (Solid)	4.55E-02	not reported	Ci
	Supernate	SRR (Liquid)	5.99E-02	not reported	Ci
	Total		9.23E+00	--	Ci
Al	Sludge	AR (Solid)	2.41E+03	not reported	kg
	Sludge	CWP1 (Solid)	5.13E+04	1.34E+04	kg
	Supernate	SRR (Liquid)	0.00E+00	not reported	kg
	Total		5.37E+04	--	kg
Bi	Sludge	AR (Solid)	5.40E-02	not reported	kg
	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Supernate	SRR (Liquid)	0.00E+00	not reported	kg
	Total		5.40E-02	--	kg
Ca	Sludge	AR (Solid)	1.85E+03	not reported	kg
	Sludge	CWP1 (Solid)	4.56E+02	4.71E+02	kg
	Supernate	SRR (Liquid)	5.30E-03	not reported	kg
	Total		2.30E+03	--	kg
Cl	Sludge	AR (Solid)	1.05E+02	3.32E+01	kg
	Sludge	CWP1 (Solid)	1.68E+02	5.32E+01	kg
	Supernate	SRR (Liquid)	8.70E-01	2.94E+01	kg
	Total		2.74E+02	--	kg

Table C-1. Tank C-103 Inventory.[a] (8 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
CN	Sludge	AR (Solid)	1.64E+01	4.38E+00	kg
	Sludge	CWP1 (Solid)	2.61E+01	6.97E+00	kg
	Supernate	SRR (Liquid)	4.48E-02	1.52E+00	kg
	Total		4.26E+01	--	kg
Cr [b]	Sludge	AR (Solid)	1.03E+02	not reported	kg
	Sludge	CWP1 (Solid)	2.57E+02	6.87E+01	kg
	Supernate	SRR (Liquid)	3.58E-02	1.21E+00	kg
	Total		3.60E+02	--	kg
F	Sludge	AR (Solid)	1.78E+02	5.31E+01	kg
	Sludge	CWP1 (Solid)	2.84E+02	8.47E+01	kg
	Supernate	SRR (Liquid)	2.71E+00	9.17E+01	kg
	Total		4.65E+02	--	kg
Fe	Sludge	AR (Solid)	1.44E+04	not reported	kg
	Sludge	CWP1 (Solid)	4.18E+03	1.16E+03	kg
	Supernate	SRR (Liquid)	7.06E-03	not reported	kg
	Total		1.86E+04	--	kg
Hg	Sludge	AR (Solid)	2.41E+01	not reported	kg
	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Supernate	SRR (Liquid)	4.70E-04	not reported	kg
	Total		2.41E+01	--	kg
K	Sludge	AR (Solid)	2.34E+02	not reported	kg
	Sludge	CWP1 (Solid)	9.48E+00	not reported	kg
	Supernate	SRR (Liquid)	6.01E-01	2.03E+01	kg
	Total		2.44E+02	--	kg
La	Sludge	AR (Solid)	0.00E+00	not reported	kg
	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Supernate	SRR (Liquid)	0.00E+00	not reported	kg
	Total		0.00E+00	--	kg
Mn	Sludge	AR (Solid)	4.12E+02	not reported	kg
	Sludge	CWP1 (Solid)	5.12E+01	4.89E+01	kg
	Supernate	SRR (Liquid)	0.00E+00	not reported	kg
	Total		4.64E+02	--	kg
Na	Sludge	AR (Solid)	8.40E+03	not reported	kg
	Sludge	CWP1 (Solid)	7.01E+03	1.83E+03	kg
	Supernate	SRR (Liquid)	6.42E+01	2.17E+03	kg
	Total		1.55E+04	--	kg
Ni	Sludge	AR (Solid)	4.74E+02	not reported	kg
	Sludge	CWP1 (Solid)	1.45E+01	not reported	kg
	Supernate	SRR (Liquid)	1.06E-01	3.59E+00	kg
	Total		4.89E+02	--	kg

Table C-1. Tank C-103 Inventory.[a] (8 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
NO_2 [b]	Sludge	AR (Solid)	2.93E+03	1.52E+03	kg
	Sludge	CWP1 (Solid)	4.68E+03	2.43E+03	kg
	Supernate	SRR (Liquid)	2.94E+01	9.95E+02	kg
	Total		7.65E+03	--	kg
NO_3	Sludge	AR (Solid)	2.87E+02	1.56E+02	kg
	Sludge	CWP1 (Solid)	4.59E+02	2.49E+02	kg
	Supernate	SRR (Liquid)	1.64E+00	5.55E+01	kg
	Total		7.48E+02	--	kg
Oxalate	Sludge	AR (Solid)	4.51E+02	1.70E+02	kg
	Sludge	CWP1 (Solid)	7.20E+02	2.71E+02	kg
	Supernate	SRR (Liquid)	5.98E+00	2.02E+02	kg
	Total		1.18E+03	--	kg
Pb	Sludge	AR (Solid)	5.92E+02	not reported	kg
	Sludge	CWP1 (Solid)	6.42E+02	1.90E+03	kg
	Supernate	SRR (Liquid)	0.00E+00	not reported	kg
	Total		1.23E+03	--	kg
PO_4	Sludge	AR (Solid)	5.39E+02	1.56E+02	kg
	Sludge	CWP1 (Solid)	8.60E+02	2.49E+02	kg
	Supernate	SRR (Liquid)	8.49E+00	2.87E+02	kg
	Total		1.41E+03	--	kg
Si	Sludge	AR (Solid)	1.17E+04	not reported	kg
	Sludge	CWP1 (Solid)	1.41E+03	1.07E+03	kg
	Supernate	SRR (Liquid)	1.98E-02	6.70E-01	kg
	Total		1.32E+04	--	kg
SO_4	Sludge	AR (Solid)	4.65E+02	1.74E+02	kg
	Sludge	CWP1 (Solid)	7.42E+02	2.77E+02	kg
	Supernate	SRR (Liquid)	5.65E+00	1.91E+02	kg
	Total		1.21E+03	--	kg
Sr	Sludge	AR (Solid)	1.95E+01	not reported	kg
	Sludge	CWP1 (Solid)	3.45E+01	3.66E+01	kg
	Supernate	SRR (Liquid)	6.60E-05	not reported	kg
	Total		5.41E+01	--	kg
TIC as CO_3	Sludge	AR (Solid)	4.13E+03	1.14E+03	kg
	Sludge	CWP1 (Solid)	6.59E+03	1.82E+03	kg
	Supernate	SRR (Liquid)	5.76E+01	1.95E+03	kg
	Total		1.08E+04	--	kg
TOC	Sludge	AR (Solid)	2.48E+03	not reported	kg
	Sludge	CWP1 (Solid)	3.75E+03	not reported	kg
	Supernate	SRR (Liquid)	1.12E+01	3.79E+02	kg
	Total		6.24E+03	--	kg

Table C-1. Tank C-103 Inventory.[a] (8 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
U_{TOTAL}	Sludge	AR (Solid)	5.75E+02	not reported	kg
	Sludge	CWP1 (Solid)	2.86E+03	4.97E+04	kg
	Supernate	SRR (Liquid)	7.75E+00	2.62E+02	kg
	Total		3.45E+03	--	kg
Zr	Sludge	AR (Solid)	2.05E+03	not reported	kg
	Sludge	CWP1 (Solid)	3.03E+03	8.42E+02	kg
	Supernate	SRR (Liquid)	8.18E-01	2.77E+01	kg
	Total		5.08E+03	--	kg

AR = PUREX high-level sludge waste.
CWP1 = aluminum cladding waste.
PUREX = plutonium-uranium extraction.
SRR = strontium recovery supernate waste.
TIC = total inorganic carbon.
TOC = total organic carbon.
[a] Reference download from http://twinsweb.pnl.gov/data dated 4/13/05.
[b] Indicator constituents as identified in Section 7.1.1.1.

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{106}Ru	Sludge	1C (Solid)	2.69E-12	not reported	Ci
	Sludge	CWP1 (Solid)	3.96E-11	not reported	Ci
	Sludge	HS (Solid)	5.44E-05	not reported	Ci
	Sludge	TFeCN (Solid)	8.44E-12	not reported	Ci
	Total		5.44E-05	--	Ci
^{113m}Cd	Sludge	1C (Solid)	3.16E-03	not reported	Ci
	Sludge	CWP1 (Solid)	1.42E-01	not reported	Ci
	Sludge	HS (Solid)	4.64E-02	not reported	Ci
	Sludge	TFeCN (Solid)	6.97E-02	not reported	Ci
	Total		2.62E-01	--	Ci
^{125}Sb	Sludge	1C (Solid)	4.22E-05	not reported	Ci
	Sludge	CWP1 (Solid)	1.69E-04	not reported	Ci
	Sludge	HS (Solid)	1.10E-01	not reported	Ci
	Sludge	TFeCN (Solid)	1.03E-03	not reported	Ci
	Total		1.12E-01	--	Ci
^{126}Sn	Sludge	1C (Solid)	2.62E-04	not reported	Ci
	Sludge	CWP1 (Solid)	2.11E-04	not reported	Ci
	Sludge	HS (Solid)	3.73E-03	not reported	Ci
	Sludge	TFeCN (Solid)	9.11E-03	not reported	Ci
	Total		1.33E-02	--	Ci
^{129}I	Sludge	1C (Solid)	2.79E-05	not reported	Ci
	Sludge	CWP1 (Solid)	2.69E-02	not reported	Ci
	Sludge	HS (Solid)	1.68E-05	not reported	Ci
	Sludge	TFeCN (Solid)	1.76E-03	not reported	Ci
	Total		2.87E-02	--	Ci
^{134}Cs	Sludge	1C (Solid)	3.22E-08	not reported	Ci
	Sludge	CWP1 (Solid)	3.54E-06	not reported	Ci
	Sludge	HS (Solid)	3.26E-04	not reported	Ci
	Sludge	TFeCN (Solid)	2.29E-04	not reported	Ci
	Total		5.59E-04	--	Ci
^{137}Cs	Sludge	1C (Solid)	8.62E+02	7.78E+02	Ci
	Sludge	CWP1 (Solid)	4.67E+04	1.20E+04	Ci
	Sludge	HS (Solid)	2.21E+04	5.66E+03	Ci
	Sludge	TFeCN (Solid)	1.03E+05	2.64E+04	Ci
	Total		1.73E+05	--	Ci

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{137m}Ba	Sludge	1C (Solid)	8.14E+02	not reported	Ci
	Sludge	CWP1 (Solid)	4.41E+04	not reported	Ci
	Sludge	HS (Solid)	2.09E+04	not reported	Ci
	Sludge	TFeCN (Solid)	9.71E+04	not reported	Ci
	Total		1.63E+05	--	Ci
^{14}C	Sludge	1C (Solid)	1.25E-02	1.29E-02	Ci
	Sludge	CWP1 (Solid)	1.08E-03	5.22E-04	Ci
	Sludge	HS (Solid)	5.12E-04	2.48E-04	Ci
	Sludge	TFeCN (Solid)	2.38E-03	1.15E-03	Ci
	Total		1.65E-02	--	Ci
^{151}Sm	Sludge	1C (Solid)	5.52E+00	not reported	Ci
	Sludge	CWP1 (Solid)	2.12E+00	not reported	Ci
	Sludge	HS (Solid)	9.90E+02	not reported	Ci
	Sludge	TFeCN (Solid)	9.57E+01	not reported	Ci
	Total		1.09E+03	--	Ci
^{152}Eu	Sludge	1C (Solid)	1.77E-04	not reported	Ci
	Sludge	CWP1 (Solid)	2.54E-04	not reported	Ci
	Sludge	HS (Solid)	1.75E-01	not reported	Ci
	Sludge	TFeCN (Solid)	2.98E-03	not reported	Ci
	Total		1.78E-01	--	Ci
^{154}Eu	Sludge	1C (Solid)	1.19E-02	not reported	Ci
	Sludge	CWP1 (Solid)	1.69E-02	not reported	Ci
	Sludge	HS (Solid)	3.81E+00	3.89E+00	Ci
	Sludge	TFeCN (Solid)	2.08E-01	not reported	Ci
	Total		4.05E+00	--	Ci
^{155}Eu	Sludge	1C (Solid)	5.16E-03	not reported	Ci
	Sludge	CWP1 (Solid)	6.04E-03	not reported	Ci
	Sludge	HS (Solid)	5.49E+00	not reported	Ci
	Sludge	TFeCN (Solid)	9.99E-02	not reported	Ci
	Total		5.60E+00	--	Ci
^{226}Ra	Sludge	1C (Solid)	3.46E-07	not reported	Ci
	Sludge	CWP1 (Solid)	6.75E-08	not reported	Ci
	Sludge	HS (Solid)	3.72E-08	not reported	Ci
	Sludge	TFeCN (Solid)	1.16E-05	not reported	Ci
	Total		1.21E-05	--	Ci

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{227}Ac	Sludge	1C (Solid)	2.95E-06	not reported	Ci
	Sludge	CWP1 (Solid)	3.65E-07	not reported	Ci
	Sludge	HS (Solid)	1.77E-07	not reported	Ci
	Sludge	TFeCN (Solid)	5.55E-05	not reported	Ci
	Total		5.90E-05	--	Ci
^{228}Ra	Sludge	1C (Solid)	3.88E-12	not reported	Ci
	Sludge	CWP1 (Solid)	7.75E-13	not reported	Ci
	Sludge	HS (Solid)	2.69E-13	not reported	Ci
	Sludge	TFeCN (Solid)	5.07E-11	not reported	Ci
	Total		5.56E-11	--	Ci
^{229}Th	Sludge	1C (Solid)	1.09E-09	not reported	Ci
	Sludge	CWP1 (Solid)	1.13E-10	not reported	Ci
	Sludge	HS (Solid)	4.32E-10	not reported	Ci
	Sludge	TFeCN (Solid)	5.18E-09	not reported	Ci
	Total		6.82E-09	--	Ci
^{231}Pa	Sludge	1C (Solid)	2.21E-05	not reported	Ci
	Sludge	CWP1 (Solid)	7.24E-07	not reported	Ci
	Sludge	HS (Solid)	2.49E-07	not reported	Ci
	Sludge	TFeCN (Solid)	6.03E-05	not reported	Ci
	Total		8.33E-05	--	Ci
^{232}Th	Sludge	1C (Solid)	9.18E-12	not reported	Ci
	Sludge	CWP1 (Solid)	8.95E-13	not reported	Ci
	Sludge	HS (Solid)	2.75E-13	not reported	Ci
	Sludge	TFeCN (Solid)	4.38E-11	not reported	Ci
	Total		5.42E-11	--	Ci
^{232}U	Sludge	1C (Solid)	4.12E-07	not reported	Ci
	Sludge	CWP1 (Solid)	2.26E-05	not reported	Ci
	Sludge	HS (Solid)	3.26E-05	not reported	Ci
	Sludge	TFeCN (Solid)	1.23E-05	not reported	Ci
	Total		6.80E-05	--	Ci
^{233}U	Sludge	1C (Solid)	3.43E-08	not reported	Ci
	Sludge	CWP1 (Solid)	1.10E-06	not reported	Ci
	Sludge	HS (Solid)	1.42E-04	not reported	Ci
	Sludge	TFeCN (Solid)	1.02E-06	not reported	Ci
	Total		1.44E-04	--	Ci

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{234}U	Sludge	1C (Solid)	3.31E-02	not reported	Ci
	Sludge	CWP1 (Solid)	4.13E-01	9.25E-02	Ci
	Sludge	HS (Solid)	1.95E-01	4.37E-02	Ci
	Sludge	TFeCN (Solid)	9.08E-01	2.03E-01	Ci
	Total		1.55E+00	--	Ci
^{235}U	Sludge	1C (Solid)	1.48E-03	not reported	Ci
	Sludge	CWP1 (Solid)	1.65E-02	3.70E-03	Ci
	Sludge	HS (Solid)	7.80E-03	1.75E-03	Ci
	Sludge	TFeCN (Solid)	3.63E-02	8.13E-03	Ci
	Total		6.21E-02	--	Ci
^{236}U	Sludge	1C (Solid)	3.70E-04	not reported	Ci
	Sludge	CWP1 (Solid)	6.07E-03	1.36E-03	Ci
	Sludge	HS (Solid)	2.87E-03	6.43E-04	Ci
	Sludge	TFeCN (Solid)	1.34E-02	3.00E-03	Ci
	Total		2.27E-02	--	Ci
^{237}Np	Sludge	1C (Solid)	1.20E-04	not reported	Ci
	Sludge	CWP1 (Solid)	2.88E-02	6.26E-03	Ci
	Sludge	HS (Solid)	1.36E-02	2.96E-03	Ci
	Sludge	TFeCN (Solid)	6.33E-02	1.38E-02	Ci
	Total		1.06E-01	--	Ci
^{238}Pu	Sludge	1C (Solid)	3.18E-02	not reported	Ci
	Sludge	CWP1 (Solid)	4.40E-01	3.57E-01	Ci
	Sludge	HS (Solid)	2.08E-01	1.69E-01	Ci
	Sludge	TFeCN (Solid)	9.68E-01	7.85E-01	Ci
	Total		1.65E+00	--	Ci
^{238}U	Sludge	1C (Solid)	3.37E-02	not reported	Ci
	Sludge	CWP1 (Solid)	3.89E-01	8.72E-02	Ci
	Sludge	HS (Solid)	1.84E-01	4.12E-02	Ci
	Sludge	TFeCN (Solid)	8.57E-01	1.92E-01	Ci
	Total		1.46E+00	--	Ci
^{239}Pu	Sludge	1C (Solid)	4.53E+00	not reported	Ci
	Sludge	CWP1 (Solid)	1.66E+01	1.35E+01	Ci
	Sludge	HS (Solid)	7.83E+00	6.35E+00	Ci
	Sludge	TFeCN (Solid)	3.65E+01	2.96E+01	Ci
	Total		6.54E+01	--	Ci

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{240}Pu	Sludge	1C (Solid)	4.93E-01	not reported	Ci
	Sludge	CWP1 (Solid)	2.92E+00	2.37E+00	Ci
	Sludge	HS (Solid)	1.38E+00	1.12E+00	Ci
	Sludge	TFeCN (Solid)	6.43E+00	5.21E+00	Ci
	Total		1.12E+01	--	Ci
^{241}Am	Sludge	1C (Solid)	7.51E-01	not reported	Ci
	Sludge	CWP1 (Solid)	1.34E+01	8.28E+00	Ci
	Sludge	HS (Solid)	6.36E+00	3.93E+00	Ci
	Sludge	TFeCN (Solid)	2.96E+01	1.83E+01	Ci
	Total		5.01E+01	--	Ci
^{241}Pu	Sludge	1C (Solid)	8.28E-01	not reported	Ci
	Sludge	CWP1 (Solid)	1.53E+01	1.24E+01	Ci
	Sludge	HS (Solid)	7.22E+00	5.85E+00	Ci
	Sludge	TFeCN (Solid)	3.36E+01	2.72E+01	Ci
	Total		5.69E+01	--	Ci
^{242}Cm	Sludge	1C (Solid)	1.30E-04	not reported	Ci
	Sludge	CWP1 (Solid)	2.92E-04	not reported	Ci
	Sludge	HS (Solid)	2.91E-01	not reported	Ci
	Sludge	TFeCN (Solid)	6.51E-03	not reported	Ci
	Total		2.98E-01	--	Ci
^{242}Pu	Sludge	1C (Solid)	6.85E-06	not reported	Ci
	Sludge	CWP1 (Solid)	2.74E-04	2.22E-04	Ci
	Sludge	HS (Solid)	1.29E-04	1.05E-04	Ci
	Sludge	TFeCN (Solid)	6.02E-04	4.88E-04	Ci
	Total		1.01E-03	--	Ci
^{243}Am	Sludge	1C (Solid)	7.61E-05	not reported	Ci
	Sludge	CWP1 (Solid)	1.74E-04	not reported	Ci
	Sludge	HS (Solid)	3.17E-03	not reported	Ci
	Sludge	TFeCN (Solid)	3.84E-03	not reported	Ci
	Total		7.26E-03	--	Ci
^{243}Cm	Sludge	1C (Solid)	1.45E-06	not reported	Ci
	Sludge	CWP1 (Solid)	5.15E-06	not reported	Ci
	Sludge	HS (Solid)	1.47E-02	not reported	Ci
	Sludge	TFeCN (Solid)	7.30E-05	not reported	Ci
	Total		1.48E-02	--	Ci

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{244}Cm	Sludge	1C (Solid)	3.26E-05	not reported	Ci
	Sludge	CWP1 (Solid)	1.29E-04	not reported	Ci
	Sludge	HS (Solid)	3.32E-01	not reported	Ci
	Sludge	TFeCN (Solid)	1.64E-03	not reported	Ci
	Total		3.34E-01	--	Ci
^{3}H	Sludge	1C (Solid)	2.05E-02	1.49E-02	Ci
	Sludge	CWP1 (Solid)	3.31E-01	7.45E-02	Ci
	Sludge	HS (Solid)	1.56E-01	3.51E-02	Ci
	Sludge	TFeCN (Solid)	7.27E-01	1.64E-01	Ci
	Total		1.23E+00	--	Ci
^{59}Ni	Sludge	1C (Solid)	6.79E-04	not reported	Ci
	Sludge	CWP1 (Solid)	4.88E-01	not reported	Ci
	Sludge	HS (Solid)	1.50E-01	not reported	Ci
	Sludge	TFeCN (Solid)	3.04E+00	3.10E+00	Ci
	Total		3.67E+00	--	Ci
^{60}Co	Sludge	1C (Solid)	4.32E-03	not reported	Ci
	Sludge	CWP1 (Solid)	6.53E-01	not reported	Ci
	Sludge	HS (Solid)	1.60E-01	1.63E-01	Ci
	Sludge	TFeCN (Solid)	5.63E-02	not reported	Ci
	Total		8.74E-01	--	Ci
^{63}Ni	Sludge	1C (Solid)	9.42E-02	not reported	Ci
	Sludge	CWP1 (Solid)	4.47E+01	not reported	Ci
	Sludge	HS (Solid)	1.38E+01	not reported	Ci
	Sludge	TFeCN (Solid)	2.71E+02	2.76E+02	Ci
	Total		3.29E+02	--	Ci
^{79}Se	Sludge	1C (Solid)	6.96E-05	not reported	Ci
	Sludge	CWP1 (Solid)	5.14E-05	not reported	Ci
	Sludge	HS (Solid)	9.00E-04	not reported	Ci
	Sludge	TFeCN (Solid)	2.42E-03	not reported	Ci
	Total		3.44E-03	--	Ci
^{90}Sr	Sludge	1C (Solid)	2.62E+02	1.89E+02	Ci
	Sludge	CWP1 (Solid)	6.87E+04	3.00E+04	Ci
	Sludge	HS (Solid)	3.25E+04	1.42E+04	Ci
	Sludge	TFeCN (Solid)	1.51E+05	6.59E+04	Ci
	Total		2.53E+05	--	Ci

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
^{90}Y	Sludge	1C (Solid)	2.62E+02	not reported	Ci
	Sludge	CWP1 (Solid)	6.87E+04	not reported	Ci
	Sludge	HS (Solid)	3.25E+04	not reported	Ci
	Sludge	TFeCN (Solid)	1.51E+05	not reported	Ci
	Total		2.53E+05	--	Ci
^{93m}Nb	Sludge	1C (Solid)	8.05E-02	not reported	Ci
	Sludge	CWP1 (Solid)	2.63E-03	not reported	Ci
	Sludge	HS (Solid)	4.47E-02	not reported	Ci
	Sludge	TFeCN (Solid)	7.23E-02	not reported	Ci
	Total		2.00E-01	--	Ci
^{93}Zr	Sludge	1C (Solid)	8.91E-02	not reported	Ci
	Sludge	CWP1 (Solid)	3.06E-03	not reported	Ci
	Sludge	HS (Solid)	5.35E-02	not reported	Ci
	Sludge	TFeCN (Solid)	8.01E-02	not reported	Ci
	Total		2.26E-01	--	Ci
^{99}Tc [b]	Sludge	1C (Solid)	1.32E+00	5.04E+00	Ci
	Sludge	CWP1 (Solid)	9.15E+00	1.92E+00	Ci
	Sludge	HS (Solid)	4.32E+00	9.08E-01	Ci
	Sludge	TFeCN (Solid)	2.01E+01	4.23E+00	Ci
	Total		3.49E+01	--	Ci
Al	Sludge	1C (Solid)	8.10E+02	5.67E+02	kg
	Sludge	CWP1 (Solid)	6.65E+03	2.05E+03	kg
	Sludge	HS (Solid)	3.14E+03	9.70E+02	kg
	Sludge	TFeCN (Solid)	1.46E+04	4.51E+03	kg
	Total		2.52E+04	--	kg
Bi	Sludge	1C (Solid)	1.03E+03	3.02E+02	kg
	Sludge	CWP1 (Solid)	0.00E+00	not reported	kg
	Sludge	HS (Solid)	0.00E+00	not reported	kg
	Sludge	TFeCN (Solid)	1.48E+01	not reported	kg
	Total		1.05E+03	--	kg
Ca	Sludge	1C (Solid)	5.03E+01	3.16E+01	kg
	Sludge	CWP1 (Solid)	1.65E+03	3.91E+02	kg
	Sludge	HS (Solid)	7.82E+02	1.85E+02	kg
	Sludge	TFeCN (Solid)	3.64E+03	8.63E+02	kg
	Total		6.12E+03	--	kg

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
Cl	Sludge	1C (Solid)	6.14E+01	2.71E+01	kg
	Sludge	CWP1 (Solid)	6.53E+01	1.42E+01	kg
	Sludge	HS (Solid)	3.09E+01	6.73E+00	kg
	Sludge	TFeCN (Solid)	1.44E+02	3.14E+01	kg
	Total		3.01E+02	--	kg
CN	Sludge	CWP1 (Solid)	5.43E+02	1.40E+02	kg
	Sludge	HS (Solid)	2.56E+02	6.59E+01	kg
	Sludge	TFeCN (Solid)	1.19E+03	3.06E+02	kg
	Total		1.99E+03	--	kg
Cr [b]	Sludge	1C (Solid)	4.52E+01	1.98E+01	kg
	Sludge	CWP1 (Solid)	2.17E+01	4.73E+00	kg
	Sludge	HS (Solid)	1.03E+01	2.24E+00	kg
	Sludge	TFeCN (Solid)	4.78E+01	1.04E+01	kg
	Total		1.25E+02	--	kg
F	Sludge	1C (Solid)	5.54E+02	4.43E+02	kg
	Sludge	CWP1 (Solid)	3.99E+01	1.12E+01	kg
	Sludge	HS (Solid)	1.89E+01	5.30E+00	kg
	Sludge	TFeCN (Solid)	8.79E+01	2.47E+01	kg
	Total		7.01E+02	--	kg
Fe	Sludge	1C (Solid)	5.49E+02	1.53E+02	kg
	Sludge	CWP1 (Solid)	1.75E+03	5.59E+02	kg
	Sludge	HS (Solid)	8.29E+02	2.65E+02	kg
	Sludge	TFeCN (Solid)	3.86E+03	1.23E+03	kg
	Total		6.99E+03	--	kg
Hg	Sludge	1C (Solid)	2.05E-02	2.74E-02	kg
	Sludge	CWP1 (Solid)	6.35E-01	1.44E-01	kg
	Sludge	HS (Solid)	3.00E-01	6.79E-02	kg
	Sludge	TFeCN (Solid)	1.40E+00	3.17E-01	kg
	Total		2.35E+00	--	kg
K	Sludge	1C (Solid)	1.73E+01	1.35E+01	kg
	Sludge	CWP1 (Solid)	4.64E+01	1.01E+01	kg
	Sludge	HS (Solid)	2.19E+01	4.76E+00	kg
	Sludge	TFeCN (Solid)	1.02E+02	2.22E+01	kg
	Total		1.88E+02	--	kg

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
La	Sludge	1C (Solid)	9.24E-02	9.43E-02	kg
	Sludge	CWP1 (Solid)	6.80E-01	1.51E-01	kg
	Sludge	HS (Solid)	3.21E-01	7.11E-02	kg
	Sludge	TFeCN (Solid)	1.50E+00	3.32E-01	kg
	Total		2.59E+00	--	kg
Mn	Sludge	1C (Solid)	5.10E+00	4.68E+00	kg
	Sludge	CWP1 (Solid)	1.99E+01	4.86E+00	kg
	Sludge	HS (Solid)	9.42E+00	2.30E+00	kg
	Sludge	TFeCN (Solid)	4.38E+01	1.07E+01	kg
	Total		7.83E+01	--	kg
Na	Sludge	1C (Solid)	5.40E+03	2.29E+03	kg
	Sludge	CWP1 (Solid)	8.78E+03	1.87E+03	kg
	Sludge	HS (Solid)	4.15E+03	8.86E+02	kg
	Sludge	TFeCN (Solid)	1.93E+04	4.12E+03	kg
	Total		3.76E+04	--	kg
Ni	Sludge	1C (Solid)	1.14E+00	8.23E-01	kg
	Sludge	CWP1 (Solid)	1.35E+03	2.89E+02	kg
	Sludge	HS (Solid)	6.36E+02	1.36E+02	kg
	Sludge	TFeCN (Solid)	2.96E+03	6.34E+02	kg
	Total		4.94E+03	--	kg
NO_2 [b]	Sludge	1C (Solid)	5.28E+02	8.23E+02	kg
	Sludge	CWP1 (Solid)	3.45E+03	7.51E+02	kg
	Sludge	HS (Solid)	1.63E+03	3.55E+02	kg
	Sludge	TFeCN (Solid)	7.60E+03	1.65E+03	kg
	Total		1.32E+04	--	kg
NO_3	Sludge	1C (Solid)	6.85E+03	5.29E+03	kg
	Sludge	CWP1 (Solid)	3.48E+03	7.77E+02	kg
	Sludge	HS (Solid)	1.64E+03	3.66E+02	kg
	Sludge	TFeCN (Solid)	7.65E+03	1.71E+03	kg
	Total		1.96E+04	--	kg
Oxalate	Sludge	1C (Solid)	5.51E+01	not reported	kg
	Sludge	CWP1 (Solid)	6.67E+01	not reported	kg
	Sludge	HS (Solid)	1.55E+02	not reported	kg
	Sludge	TFeCN (Solid)	2.83E+02	not reported	kg
	Total		5.60E+02	--	kg

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
Pb	Sludge	1C (Solid)	1.07E+01	9.96E+00	kg
	Sludge	CWP1 (Solid)	2.41E+02	1.27E+02	kg
	Sludge	HS (Solid)	1.14E+02	6.02E+01	kg
	Sludge	TFeCN (Solid)	5.30E+02	2.80E+02	kg
	Total		8.95E+02	--	kg
PO_4	Sludge	1C (Solid)	3.77E+03	2.15E+03	kg
	Sludge	CWP1 (Solid)	6.27E+03	1.78E+03	kg
	Sludge	HS (Solid)	2.96E+03	8.41E+02	kg
	Sludge	TFeCN (Solid)	1.38E+04	3.92E+03	kg
	Total		2.68E+04	--	kg
Si	Sludge	1C (Solid)	3.34E+02	3.15E+02	kg
	Sludge	CWP1 (Solid)	5.20E+02	2.38E+02	kg
	Sludge	HS (Solid)	2.46E+02	1.12E+02	kg
	Sludge	TFeCN (Solid)	1.14E+03	5.21E+02	kg
	Total		2.24E+03	--	kg
SO_4	Sludge	1C (Solid)	7.28E+02	5.02E+02	kg
	Sludge	CWP1 (Solid)	6.63E+02	1.50E+02	kg
	Sludge	HS (Solid)	3.13E+02	7.06E+01	kg
	Sludge	TFeCN (Solid)	1.46E+03	3.29E+02	kg
	Total		3.16E+03	--	kg
Sr	Sludge	1C (Solid)	7.82E+00	2.42E+00	kg
	Sludge	CWP1 (Solid)	3.43E+01	7.45E+00	kg
	Sludge	HS (Solid)	1.62E+01	3.52E+00	kg
	Sludge	TFeCN (Solid)	7.54E+01	1.64E+01	kg
	Total		1.34E+02	--	kg
TIC as CO_3	Sludge	1C (Solid)	3.22E+02	3.74E+02	kg
	Sludge	CWP1 (Solid)	2.64E+03	5.77E+02	kg
	Sludge	HS (Solid)	1.25E+03	2.73E+02	kg
	Sludge	TFeCN (Solid)	5.80E+03	1.27E+03	kg
	Total		1.00E+04	--	kg
TOC	Sludge	1C (Solid)	2.86E+01	2.04E+01	kg
	Sludge	CWP1 (Solid)	2.14E+02	4.76E+01	kg
	Sludge	HS (Solid)	1.01E+02	2.25E+01	kg
	Sludge	TFeCN (Solid)	4.71E+02	1.05E+02	kg
	Total		8.15E+02	--	kg

Table C-2. Tank C-109 Inventory.[a] (11 Sheets)

Analyte	Waste Phase	Waste Type	Inventory	Standard Deviation	Units
U_{TOTAL}	Sludge	1C (Solid)	1.01E+02	1.10E+02	kg
	Sludge	CWP1 (Solid)	1.17E+03	2.62E+02	kg
	Sludge	HS (Solid)	5.51E+02	1.23E+02	kg
	Sludge	TFeCN (Solid)	2.56E+03	5.74E+02	kg
	Total		4.38E+03	--	kg
Zr	Sludge	1C (Solid)	7.44E+00	7.31E+00	kg
	Sludge	CWP1 (Solid)	9.82E-01	2.36E-01	kg
	Sludge	HS (Solid)	4.64E-01	1.12E-01	kg
	Sludge	TFeCN (Solid)	2.16E+00	5.20E-01	kg
	Total		1.11E+01	--	kg

1C = first cycle decontamination.
AR = PUREX high-level sludge waste.
CWP1 = aluminum cladding waste.
HS = hot semiworks.
PUREX = plutonium-uranium extraction.
SRR = strontium recovery supernate waste.
TFeCN = ferrocyanide scavenging.
TIC = total inorganic carbon.
TOC = total organic carbon.

[a] Reference download from http://twinsweb.pnl.gov/data dated 4/13/05.
[b] Indicator constituents as identified in Section 7.1.1.1.